INDIAN JOURNAL OF MALARIOLOGY.

PUBLISHED UNDER THE AUTHORITY OF

THE INDIAN RESEARCH FUND ASSOCIATION

Editor :—Lieut.-Colonel JASWANT SINGH, M.B., Ch.B., D.P.H., D.T.M. & H.

Vol. I, 1947.

PUBLISHED FOR

THE INDIAN RESEARCH FUND ASSOCIATION

BY

THACKER'S PRESS & DIRECTORIES, LTD., CALCUTTA

Price per Volume: Twelve Rupees (or Seventeen Shillings Six Pence) including Postage.

Single Copies: Five Rupees (or Seven Shillings Three Pence) excluding Postag

INDIAN JOURNAL OF MALARIOLOGY.

Vol. I, No. 1. (March 1947)	The Malaria Institute of India, 1938–47 ..	COVELL.
	Breeding of *A. fluviatilis* and Distance from Human Dwellings	RAO AND PHILIP.
	Gonotrophic Discordance in Indian Anopheles ..	RAO.
	De-weeding Tanks and Ponds	RAO AND RAMAKRISHNA.
	Dry Leaf Packing : Further Observations ..	NAGENDRA.
	Malaria on the North Madras Coast ..	SENIOR WHITE *et al.*
	A. I. of Some Anopheles of E. Central India ..	SENIOR WHITE.
	Frequency of Distribution of Gametocytes of Malaria Parasites	BASU.
	Malaria Oöcysts in *A. stephensi*	BASU.
	Insecticides against Anopheles. Part I ..	PURI AND RAJINDAR PAL.
	Insecticides against Anopheles. Part II ..	PURI AND KRISHNASWAMI.
	Insecticides against Anopheles. Part III ..	PURI AND BHATIA.
	Insecticides against Anopheles. Part IV ..	PURI AND KRISHNASWAMI.
	DDT for Malaria Control in Rural and Urban Areas in India	PURI.
	An Enquiry on Certain Aspects of Paludrine ..	AFRIDI *et al.*
Vol. I, No. 2. (June 1947)	History and Development of Antimalarial Drugs	COVELL.
	Bats, Clover, Water Lettuce and Malaria ..	COVELL.
	Report of the Policy regarding the Prevention of Malarial Conditions during Construction.	
	Malaria Control with DDT in Baluchistan ..	AFRIDI AND BHATIA.
	Investigation of Malaria in Bengal-Orissa Border	GANGULI.
	Measurements of Malaria	DAKSHINAMURTY.
	Experiments with Paludrine	VISWANATHAN AND BAILY.
	Malaria in the Malabar Squirrel	MULLIGAN AND SOMMERVILLE.
	Suppressive Mepacrine Treatment to the B. A. Railway Staff	ADHIKARI.
Vol. I, No. 3. (September 1947)	Therapeutic Trials on Paludrine in India in 1947	AFRIDI.
	Field Trials of 'Paludrine' in Naini Tal Tarai ..	SRIVASTAVA.
	Report on the Use of Paludrine in the Field ..	JAFAR.
	Treatment of Malaria with Paludrine ..	GHOSH.
	Study of 58 Malaria Cases treated with Paludrine	DE AND DATTA.
	Report on the Use of Paludrine Tablets ..	PAREKH AND BOGHANI.
	Paludrine Treatment Enquiry in Assam ..	LOMAX.

Available on application to

Messrs. THACKER, SPINK & CO. (1933), LTD.

P. O. Box 54, CALCUTTA.

RECORDS OF THE MALARIA SURVEY OF INDIA.

Vol. I, No. 1. (October 1929)	A Bibliography of Malaria in India ..	SINTON.
Vol. I, No. 2. (March 1930)	Collected Memoranda on Malaria, 1847–1924.	
Vol. I, No. 3. (October 1930)	Malaria in Peshawar	RICHMOND AND MENDIS.
	Malaria in Delhi	SENIOR WHITE.
	Note on Malaria in Delhi	SINTON.
	Malaria in Sind	YOUNG AND MAJID.
	Notes on Malaria in Sind	SINTON.
	Canal Irrigation and Malaria	GILL.
	Rice Cultivation and Malaria	GILL.
Vol. I, No. 4. (December 1930)	Experiments on the Value of Cinchona Alkaloids	SINTON.
	Relative Values of Cinchona Alkaloids ..	SINTON.
	Malaria in Madras Presidency	RAO.
	Spleen Rates in the Garo Hills	SHORTT.
	Paris Green as a Larvicide	CHALAM.
	Malaria in Sind. Parts I to III	COVELL AND BAILY.
Vol. II, No. 1. (March 1931)	Transmission of Malaria by Anophelines ..	COVELL.
	Malaria during the Sarda Canal Construction ..	CLYDE.
	Malaria in Tea Gardens, Mariani, Assam ..	MACDONALD AND CHOWDHURY.
	Notes on Entomological Technique ..	BARRAUD.
	The Eggs of Indian Anopheles	CHRISTOPHERS AND BARRAUD.
Vol. II, No. 2. (June 1931)	Mosquito Survey at Birnagar	BOSE.
	Distribution of Anopheline Mosquitoes in India	COVELL.
	Anopheline and Culicine Mosquitoes of Siam ..	BARRAUD AND CHRISTOPHERS.
	The Blood Sugar in Malaria	SINTON AND KEHAR.
	The Anopheline Fauna of India. Parts I to IV	CHRISTOPHERS.
	A Portable Screener for Paris Green Diluents ..	BUTT.
Vol. II, No. 3. (September 1931)	Tour of Malaria Commission, L. of Nations ..	SCHÜFFNER.
	Malaria Surveys in Kathiawar	SINTON.
	Hibernation of Anophelines in the Punjab ..	CHOWDHURY.
	Malaria in the Karnal District . ..	MACDONALD AND MAJID.
	The *funestus* Series of Anopheles	CHRISTOPHERS AND PURI.
	Studies on the Reticulo-Endothelial System. III	MULLIGAN.
Vol. II, No. 4. (December 1931)	Malaria in Sind. Parts IV to VII	COVELL AND BAILY.
	Splenomegaly in Malarious Communities ..	MACDONALD.
	Malaria in Bikaner	MACDONALD.
	Malaria in Peshawar	RICHMOND.
	A. gambiæ in Seychelles	HERMITTE.
	Dissections of Anophelines in Mysore ..	SWEET AND RAO.
Vol. III, No. 1. (June 1932)	Malaria in Calcutta	COVELL.
	Malaria in Patiala State	COVELL.
	Malaria in Sind. Part VIII	COVELL AND BAILY.
	Anti-Malarial Measures in Sylhet, Assam ..	STRICKLAND AND MURPHY.
	Malaria in Tea Estates in Sibsagar District, Assam	MANSON AND RAMSAY.
	A. philippinensis as a Carrier in Bengal ..	BOSE.
	Wire Gauze Screens	MULLIGAN AND MAJID.
	Spectra Studies in Malarial Sera	KEHAR.

(Continued on the next page.)

Vol. III, No. 2. (December 1932)	Anophelines of Hyderabad, Deccan ..	ABRAHAM.
	Malarial Immunity in Jalpaiguri Duars ..	SARKAR.
	Petroleum Oils for Malaria Control ..	RAMSAY AND CARPENTER.
	Malaria Survey of Tea Estates in Assam ..	RICE AND SAVAGE.
	Malaria Survey of Kachugaon, Assam ..	GUPTA *et al.*
	Principles *re* Preparation of Canal Projects ..	PUNJAB WATERLOGGING BD.
	Malaria in Patiala State (Further Note) ..	COVELL.
	Malarial Epidemic in Northern Sind ..	COVELL AND BAILY.
	Studies in Malarial Immunity. Part I ..	SINTON AND MULLIGAN.
	Helminthic Infections in Anophelines ..	SINTON.
	A. aitkeni James var. n. *pinjaurensis* ..	BARRAUD.
	Identification of Monkey Malarial Parasites. Pt. I	SINTON AND MULLIGAN.
Vol. III, No. 3. (June 1933)	Identification of Monkey Malarial Parasites. Pt. II	SINTON AND MULLIGAN.
	Parenteral *v.* Oral Administration of Quinine ..	KARAMCHANDANI.
	Injection of Human Sporozoites into Monkeys ..	MAJID.
	Malaria in Jorhat, Assam	MANSON AND RAMSAY.
	Rice Cultivation in Spain	SINTON.
	Distribution of Anophelines in India ..	BARRAUD.
	Mosquito with Pollinia on Proboscis ..	BARRAUD.
	Studies in Malarial Immunity. Part II ..	MULLIGAN AND SINTON.
	Malaria in Kalimpong and Sikkim	SUR, BHATTACHARJI & KHAN.
	Malaria Survey in Patna	BASU.
	Mosquitoes and Sandflies in Rajputana ..	JASWANT SINGH.
Vol. III, No. 4. (December 1933)	Malaria and Waterlogging	LAL AND SHAH.
	Malaria in Mysore State. Parts I to III ..	SWEET.
	Malaria in Mysore State. Part IV	SWEET AND RAO.
	Mixed Infections in Monkey Malaria. Pts. I & II	SINTON AND MULLIGAN.
	Studies in Malarial Immunity. Part III ..	MULLIGAN AND SINTON.
	An Improvised Dissecting Microscope ..	NEAL AND SAVAGE.
	Malaria in Kachugaon, Assam. (Further Note)	GUPTA *et al.*
Vol. IV, No. 1. (March 1934)	Standardization of Cinchona Alkaloids ..	SINTON.
	Studies of Malarial Pigment (Hæmozoin). Part I	SINTON AND GHOSH.
	Studies of Malarial Pigment (Hæmozoin). Part II	GHOSH AND SINTON.
	Infected Anophelines in Travancore ..	IYENGAR.
	Anopheles Hatching under Controlled Conditions	MEHTA.
Vol. IV, No. 2. (June 1934)	Anti-Gametocyte and Anti-Larval Measures ..	SENIOR WHITE AND ADHIKARI.
	Notes on Malaria in Mysore State. Part V ..	SWEET AND RAO.
	Notes on Malaria in Mysore State. Part VI ..	SWEET.
	Malaria in Sind. Parts IX, X and XI ..	COVELL AND BAILY.
	A Mosquito-flight Experiment	SATYANARAYANA.
	Macroscopical Identification of Anopheline Larvæ	MANSON.
	Studies of Malarial Pigment. Part III ..	SINTON AND GHOSH.
Vol. IV, No. 3. (September 1934)	Studies in Untreated Malaria	LOWE.
	Notes on Malaria in Mysore State. Part VII ..	NURSING, RAO AND SWEET.
	Larval Survey of Land around Birnagar ..	BOSE.
	Longevity of Some Indian Anophelines. Part I	MEHTA.
	Malaria and Mosquito Control in Delhi ..	COVELL.
	Mosquito Prevalence in Calcutta City ..	KNOWLES AND BASU.
	Chemical Composition of Malaria Pigment ..	GHOSH AND NATH.
	Malaria in Sind. Part XII	COVELL AND BAILY.

(Continued on the next page.)

Vol. IV, No. 4. (December 1934)	Malaria Control in Vizagapatam Harbour	SATYANARAYANA.
	Anophelines of the Anaimallai Hills	MEASHAM AND CHOWDHURY.
	Methods for Detection of Atebrin in Urine	WATS AND GHOSH.
	Infected Anophelines in Travancore	IYENGAR.
	Unsuccessful Attempts to Transmit Monkey Malarial Parasites to other Animals.	KHAZAN CHAND AND HARBHAGWAN.
	Quartan Malaria Parasite of Monkeys	SINTON.
	Ammonia and the Oviposition of Anophelines	MEHTA.
Vol. V, No. 1. (March 1935)	A Method for Cleaning the Capillary Tubes	SINTON.
	Dispersion of Anopheline Larvæ	SINTON AND MAJID.
	Taxonomy of *A. maculipennis*	KARAMCHANDANI.
	Effect of Atmospheric Humidity on *C. fatigans*	KARAMCHANDANI.
	Clinical Efficacy of Totaquina	HICKS AND DIWAN CHAND.
	Malaria on the Barsi Light Railway (Deccan)	LINDBERG.
	Anopheles Breeding and Rice Cultivation	SEN.
Vol. V, No. 2. (June 1935)	Malaria in Sind. Parts XIII and XIV	COVELL AND BAILY.
	Experiment with Paris Green in Sind	COVELL, BAILY AND PRASAD.
	Paris Green Dusting on Rice Crops	COVELL.
	The Emergence of Anophelines	SEN.
	Changes in the Proteins of the Blood Sera	GHOSH AND SINTON.
	Atebrin Musonate	HICKS.
Vol. V, No. 3. (September 1935)	Species Anomaly amongst Anophelines	SEN.
	Breeding Habits of *Aëdes* of Calcutta	SEN.
	Malaria-carrying Mosquitoes of Calcutta	GANGULI.
	What Malaria Costs India	SINTON.
	Identification of Anopheline Adults and Larvæ	PURI.
	Efficacy of Insecticidal Sprays	SINTON AND WATS.
	Studies in Malarial Immunity. Part IV	SINTON AND HARBHAGWAN.
	Malaria at Nijpat Jaintiapur, Assam	GUPTA *et al.*
	Malaria at Sylhet Town, Assam	GUPTA *et al.*
	Malaria in Baluchistan	MULLIGAN.
Vol. V, No. 4. (December 1935)	Village Malaria in W. Bengal	TIMBRES.
	Anti-Larval Malaria Control in Assam	RICE.
	Morphology of Malarial Parasites	PANDIT.
	Absorption and Excretion of Atebrin	KEHAR.
	What Malaria Costs India (*Contd.*)	SINTON.
	Marsh Poison in India	DEMPSTER.
	Injection of Human Sporozoites into Monkeys	SINGH AND HARBHAGWAN.
	'One Man' Oiling Method	RICE.
	Studies in Malarial Immunity. Part V	SINTON.
Vol. VI, No. 1. (March 1936)	Cholesterol Changes in Malaria	KRISHNAN *et al.*
	Malaria Control by Subsoil Drainage	SENIOR WHITE.
	Tebetren in Malaria	MANSON.
	Larva of *Anopheles gigas* var. *baileyi*	RICE *et al.*
	Bionomics of *Anopheles sundaicus*	NEOGI.
	Androphilic Indices of certain Anophelines	RAMSAY *et al.*
	Malaria, Food Supply and Population in India	SINTON.
	Anopheles habibi from Quetta	MULLIGAN AND PURI.
	Aëdes ægypti in Aeroplanes	HICKS AND DIWAN CHAND.
	What Malaria Costs India (*Concld.*)	SINTON.

(*Concluded on the next page.*)

Vol. VI, No. 2. (June 1936)	Atebrin and Atebrin Musonate in Malaria ..	SEELIG AND WADHAWA SINGH.
	Distribution of Anopheline Mosquitoes in India	PURI.
	Infectivity and Feeding Habits of Anophelines ..	LAMPRELL.
	Salinity of the Breeding Places of *A. sundaicus*	NEOGI.
	Epidemic Malaria in Madras Presidency ..	VISWANATHAN.
	Malaria in Quetta: An Analysis	MOLONY AND GORMAN.
	Malaria in Quetta, Baluchistan	MULLIGAN AND BAILY.
Vol. VI, No. 3. (September 1936)	Malaria in Sind. Part XV	COVELL AND BAILY.
	Malarial Epidemic in N. Sind	COVELL AND BAILY.
	'Herbage Cover' Method of Larval Control ..	SENIOR WHITE.
	Treatment and Prophylaxis with Atebrin ..	RAO AND CHELUVARAYAN.
	Pharmacology of Plasmoquine	DIKSHIT.
	Malaria Control in Calcutta	CHOWDHURY.
	Malaria Survey of Haltugaon, Assam ..	PAUL, DAS AND ROY.
	Vitamin Deficiency and Infection	KEHAR.
	Physico-Chemical Factors in Monkey Malaria ..	KEHAR.
	Dissections of Anophelines in Mysore ..	A CORRECTION.
	Anopheles habibi Mulligan and Puri, 1936 ..	A CORRECTION.
Vol. VI, No. 4. (December 1936)	Mosquito Survey of Karachi Air Port ..	HICKS AND DIWAN CHAND.
	Gambusia affinis under Indian Conditions ..	MULLIGAN AND MAJID.
	'Entoray' Machine Experiments	WATS AND BILDERBECK.
	A. minimus in Assam	RICE AND MOHAN.
	Mosquito-Catching Machine Experiments ..	SENIOR WHITE *et al.*
	Larvivorous Fishes of India	PRASHAD AND HORA.
	Mosquito Control Work in Vizagapatam Port ..	EBDEN AND SATYANARAYANA.
Vol. VII, No. 1. (March 1937)	Epidemiology of Malaria in a Punjab District ..	HICKS AND MAJID.
	Malaria Transmission in Jeypore Hills. Part I	SENIOR WHITE.
	Action of Plasmoquine in Pregnancy ...	DIKSHIT.
	Host-Parasite Relationship in Malarial Infections	SINTON.
	Application of Paris Green from Aircraft ..	COVELL AND AFRIDI.
	Technique for Marking and Catching Mosquitoes	MAJID.
	Mosquitocidal Value of Derris, etc. ..	WATS AND SINGH.
	The Use of *Gambusia affinis* in India ..	A CORRECTION.
Vol. VII, Nos. 2 and 3. (June-September 1937)	Cholesterol and Lecithin in Malaria ..	KEHAR.
	Sedimentation Rate of Erythrocytes in Malaria	KEHAR AND HARBHAGWAN.
	Prevalence of Anophelines in Deltaic Bengal ..	SEN.
	Maxillary Index of Indian Anophelines ..	SENIOR WHITE.
	Hæmoglobinuria in *P. knowlesi* Infections ..	WATS AND HARBHAGWAN.
	Paris Green and Paddy	RAO AND SWEET.
	Study of Village Malaria in Mysore State ..	SWEET.
	Improved Feather-Duster Mosquito Trap ..	GORE.
	Winter Malaria Infection in Bengal Dooars ..	NEOGI AND KHAN.
Vol. VII, No. 4. (December 1937)	Anti-gametocyte and Anti-larval Control ..	SENIOR WHITE AND ADHIKAR
	Quinine Supplies in India	RUSSELL.
	Freshwater Fishes of the Bombay Karnatak ..	GIDEON *et al.*
	Acridine Compound in Treatment of Malaria ..	SHORTT AND MENON.
	Anopheline Mosquitoes of the Arakan Coast ..	GREWAL.

JOURNAL OF THE MALARIA INSTITUTE OF INDIA.

Vol. I, No. 1. (March 1938)	The Malaria Survey of India, 1927—1937	COVELL.
	Measurements of *A. culicifacies* Ova	SWEET AND RAO.
	Malaria in Poona and in its Vicinity	BARBER AND RICE.
	Malaria Survey of Bannu Cantonment	DOGRA.
	A. sundaicus (*ludlowi*) and Malaria in Calcutta	SEN.
	Malaria Resolutions of Java Conference	
	Malaria Control by Insecticidal Sprays	COVELL *et al.*
	Wing Measurements of *A. stephensi*	SUBBA RAO *et al.*
	Clinical Malaria in Troops at Bannu	DOGRA.
Vol. I, No. 2. (June 1938)	Eggs of *A. varuna* and *A. fluviatilis*	MENON.
	Arsenious Oxide Content of Paris Green	RICE AND ROY.
	Malaria in Jeypore Hills. Part II	SENIOR WHITE.
	Apparatus for Mixing Larvicides	BUTT.
	Cross-Breeding of *A. stephensi* Varieties	SWEET *et al.*
	Dispersion of *Culex fatigans*. Part I	AFRIDI AND MAJID.
	Malaria Transmission in Singhbhum Hills	SENIOR WHITE AND DAS.
	Egg of *Ficalbia* (*M.*) *hybrida*	MENON.
	Malaria in Kutch State	AFRIDI *et al.*
	Malaria in Manbhum, 1936	MITRA.
	Cashew-Nut Shell Oil as a Larvicide	WATS AND BHARUCHA.
Vol. I, No. 3. (September 1938)	Epidemiology of Malaria	SCHÜFFNER.
	Breeding Places of *A. sundaicus*	SEN.
	Ova Measurements of *A. stephensi* Varieties	RAO *et al.*
	Rapid Method of Mosquito Dissection	LAZARUS.
	Note on the Larva of *A. varuna*	ROY.
	Malarial Infection in a Paddy Bird	BASU.
	Epidemiology of Malaria in Pattukkottai	RUSSELL *et al.*
	League of Nations 4th Report	
	Shute's Technique of Counting Sporozoites	ROY.
Vol. I, No. 4. (December 1938)	Malaria due to Defective and Untidy Irrigation	RUSSELL.
	Effect of Drugs on Mosquito Infectivity. II	CHOPRA AND BASU.
	Egg of *A. leucosphyrus* Don.	IYENGAR.
	Extra-Abdominal Spleen in Infected Monkey	AFRIDI.
	A Trematode Parasitic in Anopheles Mosquitoes	MENON.
	Swarming and Pairing of Mosquitoes	RAO AND RUSSELL.
	Control of Malaria-Mosquitoes in Bengal	ROY.
	On the Presence of *A. stephensi* in Calcutta	ROY *et al.*
	Malaria in Bahrein Islands	AFRIDI AND MAJID.
	Observations with 'Entoray' Machine	SYDDIQ.
Vol. II, No. 1. (March 1939)	Antimalaria Operations in Delhi. Part I	COVELL.
	Siphon for Control of Mosquito Breeding	MACDONALD.
	Mechanism of Immunity in Malaria	SINTON.
	Action of Certain Plants as Larvicides	MANSON.
	Natural Infection of *subpictus* and *vagus*	RUSSELL *et al.*
	Anopheline Transmitters of Malaria	MATHEW.
	Dissections of Anopheles	IYENGAR.
	Ammonium Sulphate as Fertilizer and Larvicide	BRINK AND CHOWDHURY.
	Aëdes Survey of Hog Island	AFRIDI.

(*Continued on the next page.*)

Vol. II, No. 2. (June 1939)	A Note on the Yellow Fever Position	RUSSELL.
	Note on Anti-Malaria Measures in Quetta	DE BURCA.
	Epidemiology of Malaria in Ennore	RUSSELL AND JACOB.
	Studies on Anti-Malarial Drugs. Part III	CHOPRA AND BASU.
	Studies on the Biology of *P. falciparum*	BASU.
	Egg of *A. philippinensis* Ludl.	ROY AND SIDDONS.
	Malaria in the Darjeeling Terai	GILROY.
	Treatment of Simian Malaria with M & B 693	JASWANT & HARWANT SINGH.
	Studies in Immunity in Malaria. Part VI	SINTON.
Vol. II, No. 3. (September 1939)	Food Preferences of Anopheles Mosquitoes	AFRIDI *et al.*
	Spray-Killing Adult Mosquitoes. Part I	RUSSELL AND KNIPE.
	Importance of *A. varuna* as a Malaria Carrier	ROY.
	Mating and Egg Formation in *C. fatigans*	ROY AND MAJUMDAR.
	Failure of 'M_3' in Malaria	CHOPRA AND BASU.
	The Gumti Weir, Lucknow	BANERJEA.
	Use of Paris Green in Casuarina-Pits	RUSSELL AND JACOB.
	Use of Fish in Casuarina-Pits	RUSSELL AND JACOB.
	Naturalistic Control in Casuarina-Pits	RUSSELL AND JACOB.
Vol. II, No. 4. (December 1939)	Antimalaria Operations in Delhi. Part II	COVELL AND AFRIDI.
	Malaria in the Wynaad, South India	COVELL AND HARBHAGWAN.
	Manufacture of Quinine Tablets in U. P.	BANERJEA.
	Plasmoquine in Pregnancy	DIKSHIT.
	Malaria Around the Chilka Lake	SENIOR WHITE AND ADHIKARI.
	Experimental Malaria Infections in Anopheles	RUSSELL AND MOHAN.
	Insectary Colonies of *A. stephensi* (Type)	RUSSELL AND MOHAN.
	Malaria Parasite Rates in Infants	RUSSELL *et al.*
	Malaria Infection in *A. subpictus* and *A. vagus*	ROY.
Vol. III, No. 1. (June 1940)	Behaviour of Adult *A. culicifacies*. Part I	AFRIDI AND PURI.
	Behaviour of Adult *A. culicifacies*. Part II	AFRIDI *et al.*
	Agglutination Reactions with *P. knowlesi*	JASWANT & HARWANT SINGH.
	Aplocheilus lineatus for Mosquito Control	JOHN.
	Anti-larval Flushing in Ceylon	WORTH AND SUBRAHMANYAM.
	Use of Automatic Siphon Sluices	RAMSAY AND ANDERSON.
	Immunity in Monkey Malaria	JASWANT & HARWANT SINGH.
	Vectors of Malaria in Bengal	IYENGAR.
	Altitude at which Malaria Occurs	CAPON.
	Mechanical Sprayers for Mosquitocides	WATS AND BHARUCHA.
	Passive Immunity in Monkey Malaria	JASWANT & HARWANT SINGH.
	Dispersion of *Culex fatigans*. Part II	AFRIDI *et al.*
	Habitat and Association of Anopheline Larvæ	RUSSELL AND RAO.
	Larvæ of *M. uniformis* and *annulifera*	MENON.
	Insecticidal and Larvicidal Action of *T. vogelii*	CHOPRA *et al.*
	Immunity Experiments on Monkeys	SHORTT AND MENON.
	Experiments with Monkey and Avian Malaria	SHORTT AND MENON.
	Agglutination of Sporozoites of *P. gallinaceum*	MULLIGAN AND RUSSELL.

(*Continued on the next page.*)

Vol. III, Nos. 2 and 3. (September 1940)	Influence of Malaria on Natality	GILL.
	Results of Forcible Feeding of Mosquitoes ..	ROY AND GHOSH.
	Armigeres theobaldi Breeding in *Curcuma* Flowers	CHARI.
	Behaviour of *Anopheles minimus*. Part I ..	THOMSON.
	Behaviour of *Anopheles minimus*. Part II ..	THOMSON.
	Behaviour of *Anopheles minimus*. Part III ..	THOMSON.
	Anopheles stephensi in Calcutta	SENIOR WHITE.
	Behaviour of Adult *A. culicifacies*. Part III ..	SENIOR WHITE.
Vol. III, No. 4. (December 1940)	Malaria Transmission in Eastern Satpuras ..	SENIOR WHITE AND ADHIKARI.
	Malaria in Singhbhum Hills. Part II ..	SENIOR WHITE & NARAYANA.
	Anopheles of Ricefields in S. E. Madras ..	RUSSELL AND RAO.
	Effect of Diet on Malaria in Monkeys ..	PASSMORE AND SOMMERVILLE.
	Action of Pyrethrum on Mosquito Larvæ ..	CHOPRA *et al.*
	Species Control of a Hill-Stream by Training ..	MONDAL.
	Metabolism of Tissues in Presence of Plasmoquine	NANDI.
	Blumea densiflora and *Artemisia vulgaris* ..	CHOPRA *et al.*
	Bionomics of *A. subpictus* and *A. annularis* ..	ROY.
	Larva of *A. varuna* (Iyengar)	RAO AND RAMAKRISHNA.
	Specific Agglutination of Sporozoites ..	MULLIGAN *et al.*
	Sulphathiazole in Monkey Malaria	DIKSHIT AND GANAPATHI.
	Spray-killing Adult Mosquitoes. Part II ..	RUSSELL AND KNIPE.
	Malaria Infections in South Indian Anophelines	RUSSELL AND RAO.
	Cellular and Humoral Agencies against Malaria	MULLIGAN *et al.*
	Monkey Malaria Control with Spleen Extracts ..	MULLIGAN *et al.*
	Acquired Immunity in Monkey Malaria ..	MULLIGAN *et al.*
	Natural Infection with *P. inui* in *S. sinicus* ..	MULLIGAN AND SWAMINATH.
Vol. IV, No. 1. (June 1941)	Antimalaria Operations in Delhi. Part III ..	COVELL.
	Agglutinogenic Properties of Sporozoites ..	RUSSELL *et al.*
	Immunization of Fowls against *P. gallinaceum* ..	MULLIGAN *et al.*
	Experimental Malaria Control in a Tea Garden	VISWANATHAN.
	Adult Habits of *A. fluviatilis* and *A. varuna* ..	SENIOR WHITE.
	Behaviour of *Anopheles minimus*. Part IV ..	THOMSON.
	Observations on *Anopheles leucosphyrus* ..	CLARK AND CHOUDHURY.
	Insecticidal and Larvicidal Action of *Ocimum* Spp.	CHOPRA *et al.*
	Aquatic Plants in the Ecology of Anophelines ..	SEN.
	Utility of Malaria Parasite Indices in Infants ..	VISWANATHAN.
	Malaria in Mawchi Mines Area	JAMES.
Vol. IV, No. 2. (December 1941)	Spleen and Parasite Surveys in Ceylon ..	SIVALINGAM AND RUSTOMJEE.
	The Natural Host of *P. gallinaceum* ..	SHORTT *et al.*
	Stage of *P. gallinaceum* in Incubation Period ..	IYER *et al.*
	Spray-killing Adult Mosquitoes. Part III ..	RUSSELL AND KNIPE.
	Malaria Immunity in the Rhesus Monkey ..	DIKSHIT.
	Abdominal Tergites of Adult Mansonioides ..	MENON.
	Efficacy and Costs of Mosquito Control Methods	JOB.
	Behaviour of *Anopheles minimus*. Part V ..	THOMSON.
	Behaviour of *Anopheles minimus*. Part VI ..	THOMSON.
	Microsporidia infesting Anophelines of India ..	SEN.
	Seasonal Prevalence of Anopheles in S. E. Madras	RUSSELL AND RAO.
	Malaria-carrying Anophelines in Assam ..	VISWANATHAN *et al.*
	Malaria in the Jharia Mining Settlement ..	RAO.

(*Continued on the next page.*)

Vol. IV, No. 3. (June 1942)	Immunization of Fowls against Sporozoites ..	RUSSELL *et al.*
	Intermittent Irrigation of Ricefields ..	RUSSELL *et al.*
	Mosquito Control by Larvivorous Fish ..	RAO AND RAMOO.
	Epidemiology of Malaria in the Nilgiris District	RUSSELL AND JACOB.
	Spray-killing Adult Anophelines	VISWANATHAN.
	Swarming of *sundaicus* and *subpictus* ..	VENKAT RAO *et al.*
	Control of Mosquito-breeding by Shading ..	RAO AND RAMOO.
	A. pallidus as Malaria Carrier in Udaipur State	ROY AND BISWAS.
	Malaria in the Tista Valley	KHAN.
	Malaria in Puri	PANIGRAHI.
Vol. IV, No. 4. (December 1942)	New Variety of *A. turkhudi* from Palestine ..	SALITERNIK AND THEODOR.
	Malaria in the Deltaic Region of Bengal ..	IYENGAR.
	New Variation of *A. gambiæ*	DE BURGA AND YUSAF.
	Mosquitoes of Rot-holes in Trees, etc., in Ceylon	WIJESUNDARA.
	Malaria in the Coastal Belt of Orissa ..	COVELL AND PRITAM SINGH.
	Behaviour of *A. minimus*. Part VII ..	THOMSON.
	Behaviour of *A. minimus*. Part VIII ..	THOMSON.
	Control of Rural Irrigation Malaria ..	RUSSELL AND KNIPE.
	Control of Mosquito Breeding by Fish ..	RAO AND RAMOO.
Vol. V, No. 1. (June 1943)	Studies on Infectivity of *A. stephensi* ..	KNOWLES AND BASU.
	Studies on Infectivity of *A. annularis* ..	BASU.
	Breeding places of *A. fluviatilis*	ADISUBRAMANIAM AND VEDAMANIKKAM.
	Spray-killing Adult Mosquitoes. Part IV ..	RUSSELL *et al.*
	Bionomics of *A. culicifacies*. Part I ..	RAJINDAR PAL.
	Antimalaria Operations in Delhi. Part IV ..	COVELL AND JASWANT SINGH.
	Distribution of *A. sundaicus* in Vizagapatam ..	SUNDARESAN AND RAO.
	Edging of Breeding Places	SUBBARAMAN AND VEDAMANIKKAM.
	A. subpictus as a Malaria Carrier	ROY.
	Breeding of *A. stephensi* in Salt Water ..	BANA.
	Malaria Control at Puttukkottai	RAO.
	Malaria in Ahmedabad	JASWANT SINGH AND JACOB.
Vol. V, No. 2. (December 1943)	Prophylaxis & Treatment of Malaria in War ..	COVELL.
	Malaria Transmission in Orissa	SENIOR WHITE *et al.*
	Malaria Transmission around Vizagapatam ..	SENIOR WHITE AND RAO.
	Malaria Transmission in Hazaribagh Ranges ..	SENIOR WHITE.
	Anopheles from East Africa	DE BURGA.
	Anopheles from Eritrea	DE BURGA AND SHAH.
	Histological Structure of Midgut	RAJINDAR PAL.
	Longevity of *A. fluviatilis*	RAJINDAR PAL.
	Behaviour of *A. fluviatilis*. Part I ..	VISWANATHAN AND RAO.
	Spleen and Parasite Surveys in Ceylon ..	SIVALINGAM.
Vol. V, No. 3. (June 1944)	Malaria in North Kanara	JASWANT SINGH AND JACOB.
	Malaria in Nizamsagar Ayacut Area ..	ABRAHAM AND SAMUELS.
	Forecasting of Malaria Epidemics	YACOB AND SATYA SWAROOP.
	Eggs of Ceylon Anopheles	D'ABRERA.
	Quartan Malaria Transmission by *culicifacies*	SIDDONS.
	Infectivity of *culicifacies*	SIDDONS.
	New Species of *Lophoceratomyia*	MENON.
	Treatment with Atebrin and Plasmoquine ..	BIRD.
	P. tenue in Ceylon	SAMARASINGHE *et al.*

(*Concluded on the next page.*)

Vol. V, No. 4. (December 1944)	Anopheles of India and the Far East ..	COVELL.
	Malaria Control in Deltaic Bengal ..	IYENGAR.
	Behaviour of *A. fluviatilis*. Part II ..	VISWANATHAN *et al.*
	Mineral Oil as Larvicide	JAYEWICKREME.
	Epidemiology of Malaria in Ceylon ..	RUSTOMJEE.
	Malaria in Jharia Mining Settlement ..	RAO.
Vol. VI, No. 1. (June 1945)	Infant Malaria in North Kanara	VISWANATHAN.
	Periodicity of Malaria Epidemics	YACOB AND SWAROOP.
	Bionomics of *A. culicifacies*. Part II ..	RAJINDAR PAL.
	Laboratory Colony of *A. fluviatilis* ..	MOHAN.
	Behaviour of *A. fluviatilis*. Part III ..	RAO.
	Spray-killing with DDT and Pyrethrum ..	SENIOR WHITE.
	Malaria in Vizagapatam	SUBBARAO AND APPARAO.
	Malaria in Salsette Island	VISWANATHAN.
	Malaria in Pandharpur	SOMAN.
Vol. VI, No. 2. (December 1945)	Malaria in Irwin Canal Area. Part I ..	RAO.
	Malaria in Irwin Canal Area. Part II ..	RAO AND NASSIRUDDIN.
	Bionomics of Indian Anophelines	SENIOR WHITE *et al.*
	Bionomics of *A. culicifacies*. Part III ..	RAJINDAR PAL.
	Bionomics of *A. culicifacies*. Part IV ..	RAJINDAR PAL.
	Behaviour of *A. fluviatilis*. Part IV.. ..	VISWANATHAN *et al.*
	False Economy in Antimalaria Campaigns ..	COVELL.
	Dry Leaf Packing for Control of Mosquito Breeding	NAGENDRA.
Vol. VI, No. 3. (June 1946)	Malaria Transmitted by *A. fluviatilis* ..	VISWANATHAN.
	A Net for catching *Gambusia* Fish	MASILLAMANI.
	A Paris Green Distributor	MASILLAMANI.
	Tropical Zone Malaria	DE BURGA.
	Anopheline Fauna of Manipur Area	MORTIMER.
	Malaria and Rainfall in the Punjab	YACOB AND SATYA SWAROOP.
	Pyrethrum, D.D.T. and Gammexane D919 ..	WU *et al.*
	Orissa : From Pleasaunce to Pathological Museum	SENIOR WHITE AND RAO.
	Control of the Breeding of *A. sundaicus* ..	IYENGAR.
	A Controlled Field Trial of SN 7618-5 (Chloroquine)	GOLDSMITH.
	Malaria Course for Engineers	COVELL.
	Investigation of New Plant Larvicides ..	PENDSE *et al.*
Vol. VI, No. 4. (December 1946)	Malaria in Tungabhadra Project, Madras ..	RAO *et al.*
	Malaria in Fort Sandeman (Baluchistan) ..	DE BURGA.
	Rôle of *A. stephensi* in Calcutta	SIDDONS.
	Malaria Control in North Kanara. Part I ..	VISWANATHAN.
	Malaria Control in North Kanara. Part II ..	VISWANATHAN AND PARIKH.
	Culicine Control with D.D.T.	PRINGLE & HARWANT SINGH.
	Malaria and Irrigation in India	COVELL.
	Hand and Spray Catching of Mosquitoes ..	SENIOR WHITE AND RAO.
	Analysis of Night Catches of Anopheles ..	SENIOR WHITE.
	Outdoor Resting of Some Oriental Anopheles ..	SENIOR WHITE.
	Anopheline Breeding in Ricefields	SENIOR WHITE.
	Malaria Transmission in E. Central India ..	SENIOR WHITE.
	House Spraying with D.D.T.	SENIOR WHITE AND GHOSH.

TABLE OF CONTENTS.

Vol. I.

No. 1 (March 1947).

PAGE

COVELL, G. The Malaria Institute of India, 1938–47 1

RAO, V. V., and PHILIP, M. I. The relationship between the breeding of *A. fluviatilis* and distance from human dwellings 37

RAO, V. V. On gonotrophic discordance among certain Indian Anopheles ... 43

RAO, V. V., and RAMAKRISHNA, V. De-weeding tanks and ponds in antimalaria operations 51

NAGENDRA, S. Further observations on dry leaf packing for the control of mosquito breeding 67

SENIOR WHITE, R., RAMAKRISHNA, V., and RAO, V. V. Malaria on the North Madras coast 81

SENIOR WHITE, R. On the anthropophilic indices of some Anopheles found in East Central India 111

BASU, B. C. The frequency of distribution of gametocytes of the Indian strains of malaria parasites 123

BASU, B. C. Abnormal development of malarial oöcysts in *A. stephensi* ... 129

PURI, I. M., and RAJINDAR PAL. Studies on some insecticides against anopheline adults and larvæ. Part I 133

PURI, I. M., and KRISHNASWAMI, A. K. Studies on some insecticides against anopheline adults and larvæ. Part II 159

PURI, I. M., and BHATIA, M. L. Studies on some insecticides against anopheline adults and larvæ. Part III 183

PURI, I. M., and KRISHNASWAMI, A. K. Studies on some insecticides against anopheline adults and larvæ. Part IV 193

PURI, I. M. The practical application of DDT for malaria control in rural and urban areas in India 211

AFRIDI, M. K., RAMAKRISHNAN, S. P., GOSWAMI, A., and MENON, M. K. An enquiry on certain aspects of paludrine 221

PAGE

No. 2 (June 1947).

COVELL, G. A brief review of the history and development of the more important antimalarial drugs 231

COVELL, G. Bats, clover, water lettuce and malaria 243

Report of a committee convened for the co-ordination of policy regarding the prevention of malarial conditions produced during the construction of roads and railways 253

AFRIDI, M. K., and BHATIA, M. L. Malaria control of villages around Quetta (Baluchistan) with D.D.T. 279

GANGULI, N. Preliminary note on investigation of malaria in Bengal-Orissa border, south of Khargpur 289

DAKSHINAMURTY, S. Measurements of malaria. Part I 301

VISWANATHAN, D. K., and BAILY, J. D. Experiments with paludrine in the chemotherapy of malaria 307

MULLIGAN, H. W., and SOMMERVILLE, T. Malaria in the Malabar squirrel ... 329

ADHIKARI, A. K. Suppressive mepacrine treatment to the staff of B. A. Railway in 1945 337

No. 3 (September 1947).

AFRIDI, M. K. A critical review of therapeutic trials on paludrine carried out in India during 1946 347

SRIVASTAVA, R. S. Final report on the field trials of 'paludrine' in selected hyporendemic malarious areas of Naini Tal Tarai in the United Provinces (11th September to 31st December, 1946) 361

LAFAR, M. Preliminary report on the use of paludrine in the field ... 365

GHOSH, B. N. Preliminary report on the result of treatment of malaria with paludrine 369

DE, M. N., and DATTA, P. N. Final report on the study of 58 cases of malaria treated with paludrine 373

PARIKH, J. G., and BOGHANI, B. P. Report on the use of paludrine tablets 383

LOMAX, P. H. Paludrine treatment enquiry in Assam 389

No. 4 (December 1947).

PETTMAN, W. E. C. Flushing streams as an antimalaria measure under field service conditions 393

DE BURCA, B., and JACOB, U. P. Further notes on malaria in Fort Sandeman 413

PAGE

DE BURCA, B., and FORSHAW, H. W. Winter variations of the larva of *A. fluviatilis* from Northern India and Bombay Presidency 417

RAO, V. V., and RAMAKRISHNA, V. Control of breeding of *A. sundaicus* by *Eichhornia*-cover 419

AFRIDI, M. K., and DALIP SINGH. A scheme for the control of malaria in villages in Delhi Province 423

JAFAR, M., and IYENGAR, M. O. T. The incidence of malaria in a deltaic area of Lower Bengal between the Damodar and the Hooghly rivers ... 441

YACOB, M., and SATYA SWAROOP. Malaria and spleen rate in the Punjab 469

YACOB, M., and SATYA SWAROOP. Preliminary forecasts of the incidence of malaria in the Punjab 491

VISWANATHAN, D. K., and RAMACHANDRA RAO, T. Control of rural malaria with DDT indoor residual spraying in Kanara and Dharwar Districts, Bombay Province. First year's results 503

INDEX OF AUTHORS 543

INDEX OF SUBJECTS 547

Indian Journal of Malariology, **1**, 1, March 1947.

THE MALARIA INSTITUTE OF INDIA, 1938–47

BY

MAJOR-GENERAL SIR GORDON COVELL, M.D., D.P.H., I.M.S.
(*Director, Malaria Institute of India.*)

[October 4, 1946.]

CONTENTS.

	PAGE.
INTRODUCTION	1
STAFF	2
SOUTHERN INDIA BRANCH	2
WAR ACTIVITIES	3
Military antimalaria organization in India and overseas	3
ANTIMALARIA OPERATIONS IN DELHI URBAN AREA	4
MALARIA ORGANIZATIONS IN OTHER CENTRALLY ADMINISTERED AREAS	4
MALARIA CONTROL ORGANIZATIONS IN INDIAN COALFIELDS	5
PREVENTIVE MEASURES AGAINST YELLOW FEVER	5
BUILDINGS	6
PUBLICATIONS	6
RESEARCHES	6
Laboratory researches	6
Field researches	7
MALARIA SURVEYS	7
POST-WAR ACTIVITIES	8
REFERENCES	8
APPENDIX I.—Activities of the Malaria Institute of India	9
APPENDIX II.—	
Programme of malaria course for medical officers	10
Programme of malaria course for engineers	16
Programme of malaria course for inspectors	17
APPENDIX III.—Classified list of publications	21

INTRODUCTION.

THE opening paper which appeared in Volume I of the *Journal of the Malaria Institute of India* traced the origin of the Malaria Survey of India and gave an account of its activities during the period 1927–37 (Covell, 1938). At the time when this article was written, the designation of the Central Malaria Organization of the Government of India had recently been changed from that of *Malaria Survey of India* to *Malaria Institute of India* and the title of its journal, originally *Records*

of the Malaria Survey of India, had been altered in conformity with the new designation. Since a number of the papers which appear in the journal emanate from other sources than the Institute, it has now been considered advisable to change its title once more to that of *Indian Journal of Malariology*. This change of title coincides with a notable expansion in the staff of the Institute, and with the completion of new buildings and animal houses which provide a much-needed extension of accommodation. A new chapter in the history of the Institute is about to open, and this seems to be an appropriate occasion to present an account of its activities during the second decade of its existence.

The Central Malaria Organization was financed entirely by the Indian Research Fund Association from its inception until 1940, when the public health section was taken over by the Government of India. Its research activities continued to be financed by the I.R.F.A. till 1946, when the Government of India assumed responsibility for this section also.

The wide range of activities which the Institute is now called upon to perform is diagrammatically represented in Appendix I.

STAFF.

In January 1938, the senior staff of the Institute consisted of Lieut.-Colonel G. Covell, I.M.S., Director; Major M. K. Afridi, I.M.S., Assistant Director; Major Jaswant Singh, I.M.S., Research Officer; Dr. I. M. Puri, Entomologist and Rai Bahadur Khazan Chand, P.C.M.S., Assistant to the Director.

Covell has remained Director throughout the period under review and has combined this post with that of Consultant Malariologist, General Headquarters (India), since 1942. Afridi was recalled to military employ in August 1940 and successively occupied the posts of Malariologist to the forces in Sudan and later in Iraq, Assistant Director of Malariology, G.H.Q. (I.), and Consultant Malariologist, South East Asia Command. Before rejoining the staff of the Institute as Deputy Director in April 1946, he was employed as Officer on Special Duty (Antimalaria) with the Director-General, Indian Medical Service. Jaswant Singh was Assistant Director from August 1940 to September 1944, when he became Deputy Director. Puri became Assistant Director in February 1945. Dr. M. L. Bhatia succeeded him as Entomologist.

The total sanctioned staff of the Institute now includes—

1 Director.	1 Overseer.
2 Deputy Directors.	1 Mechanic.
6 Assistant Directors.	2 Draftsmen.
1 Entomologist.	1 Chainman.
1 Assistant to the Director.	3 Senior Laboratory Assistants.
1 Assistant Entomologist.	12 Laboratory Assistants.
13 Malaria Assistants.	13 Insect Collectors.
1 Curator of Museum.	16 Laboratory Attendants.

SOUTHERN INDIA BRANCH.

In 1942, advantage was taken of the generous offer of the Rockefeller Foundation to donate the equipment of its malaria research unit at Coonoor to form a

PLATE I.

Major-General Sir GORDON COVELL, C.I.E., K.H.P., I.M.S.,
Director, Malaria Institute of India, 1936–47.

much-needed Southern India Branch of the Institute. Owing to shortage of personnel during the war period, the activities of the Southern India Branch have been greatly restricted. It is hoped that the expansion of staff now sanctioned will enable its activities to be considerably extended. Among its functions will be the provision of advice and guidance not only to the Madras and Bombay presidencies, Coorg Province and neighbouring Indian States, but also to the numerous tea and coffee plantations and other industrial concerns located in South India.

WAR ACTIVITIES.

During the period 1939–45, the activities of the Institute were devoted almost exclusively to matters directly connected with the war effort. Chief among these were :—

1. *Training of antimalaria staff.*—During the war period, 21 intensive courses in malariology, each lasting for 4 to 6 weeks, were held at which 522 officers received training. A number of shorter courses were also held for various classes of subordinate personnel. The total number trained in antimalaria duties during this period was :—

Officers	555
I. H. C. personnel and sanitary inspectors ...	426
Engineers	87
TOTAL	1,068

2. *Development of spraying equipment.*—The MISH hand sprayer for the application of insecticides was designed at the Institute and several hundreds of thousands have been supplied to the Defence Forces. A knapsack sprayer designed at the Institute was also adopted for use by the Defence Forces.

3. *Development and testing of mosquito repellents.*—Many hundreds of these were tested and the repellent vanishing cream finally adopted by the Army in India was evolved at this Institute.

4. *Development and testing of insecticides and larvicides.*—A very extensive series of controlled experiments was carried out, particularly in connection with the production of a suitable D.D.T. emulsion concentrate.

5. *Testing of indigenous and synthetic drugs* on monkey malaria.

6. *Direction of antimalaria measures* in the numerous military and R. A. F. camps in Delhi urban area.

MILITARY ANTIMALARIA ORGANIZATION IN INDIA AND OVERSEAS.

Prior to the outbreak of war, the Army in India possessed no regular organization for the control of malaria, either in cantonments or in the field. The first two military antimalaria units to be formed during the war period were staffed by personnel of the Malaria Institute of India, and proceeded overseas early in 1940. These were the forerunners of more than 100 antimalaria units which were

subsequently created. The officers attached to these units, as well as the antimalaria staff officers and the malaria officers of all cantonments in India, underwent intensive courses in malariology at this Institute. The success of the Burma campaign was largely due to the remarkable results achieved by the military malaria organization, which could not have been brought into existence without the intensive training provided by the Malaria Institute of India. Since the termination of the war one of the principal tasks of the Director and his Deputies has been to allocate the antimalaria staff now being released from military duties to fill the new posts created in the provinces and at the centre, in order to implement the Government of India's post-war development policy.

ANTIMALARIA OPERATIONS IN DELHI URBAN AREA.

The antimalaria campaign now in progress throughout Delhi urban area, which covers 65 square miles of country with a population of over one million, was inaugurated in 1936, and has effected a marked reduction in the incidence of the disease. The task of controlling malaria in this area was greatly augmented during the war period owing to the enormous increase in the population and the introduction of a large labour force engaged in carrying out an ever-expanding programme of building construction. The antimalaria staff, which operates directly under the supervision of the Malaria Institute of India, has recently been strengthened by the appointment of an Assistant Officer-in-Charge and two Malaria Assistants. The total technical staff now includes :—

1 Assistant Officer-in-Charge.
2 Malaria Assistants.
6 Malaria Inspectors.
12 Insect Collectors.

MALARIA ORGANIZATIONS IN OTHER CENTRALLY ADMINISTERED AREAS.

It is intended that these organizations, which are now in process of formation, will operate under the direction of the Malaria Institute of India.

(*i*) *Delhi Province.*—Three rural control units have been created, each under the immediate charge of a Malaria Assistant.

(*ii*) *Ajmer-Merwara* and (*iii*) *Coorg.*—In each of these provinces there will be in the first instance a headquarters unit under a Malaria Officer with appropriate staff, which will take up work in the capital and in a circle of villages immediately around it. Control units will be added in due course up to a maximum of 5 in each province, their activities being based on the headquarters unit.

(*iv*) *Baluchistan.*—There will be in the first instance a headquarters unit under a Malaria Officer and two malaria control units with a Malaria Assistant in charge of each.

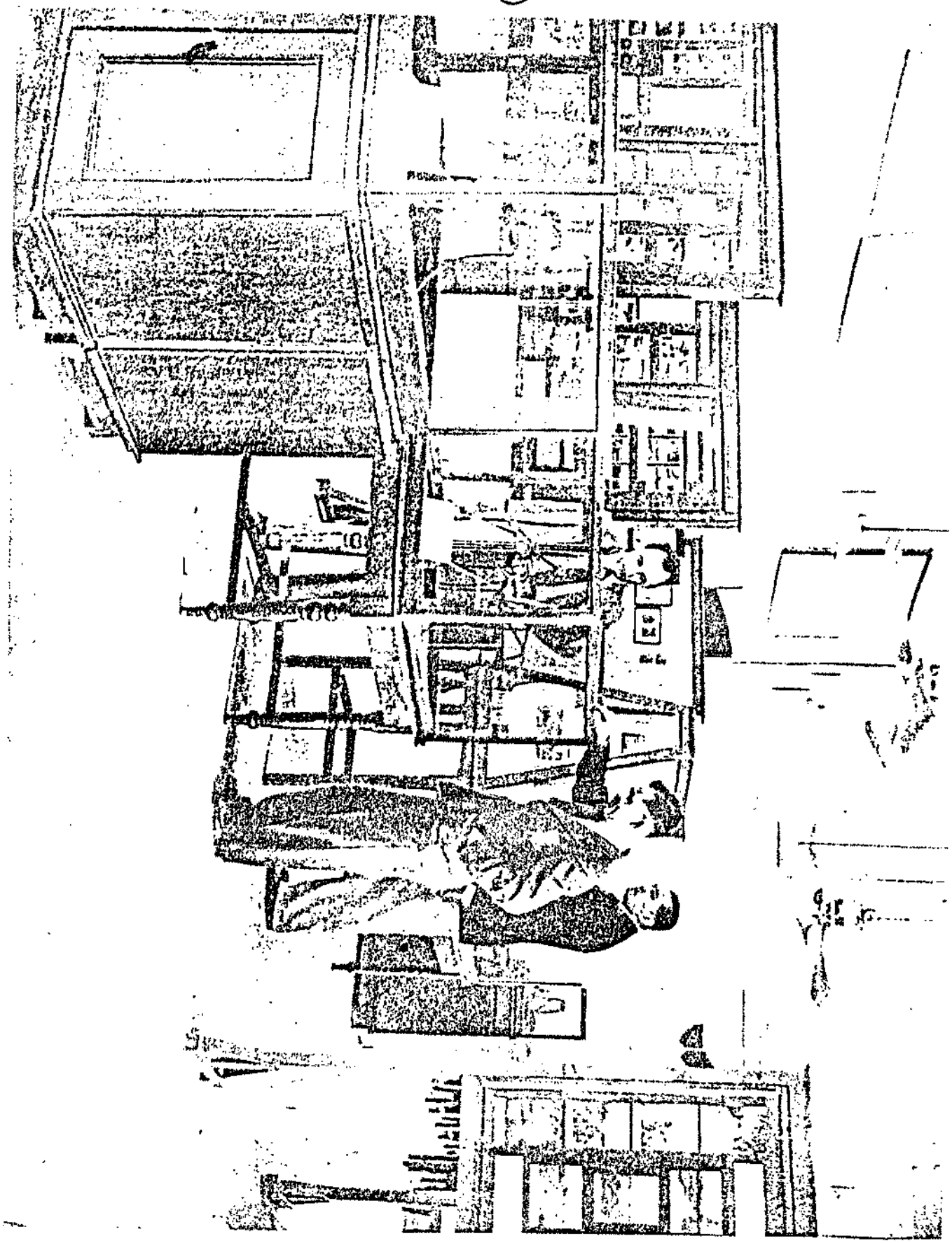
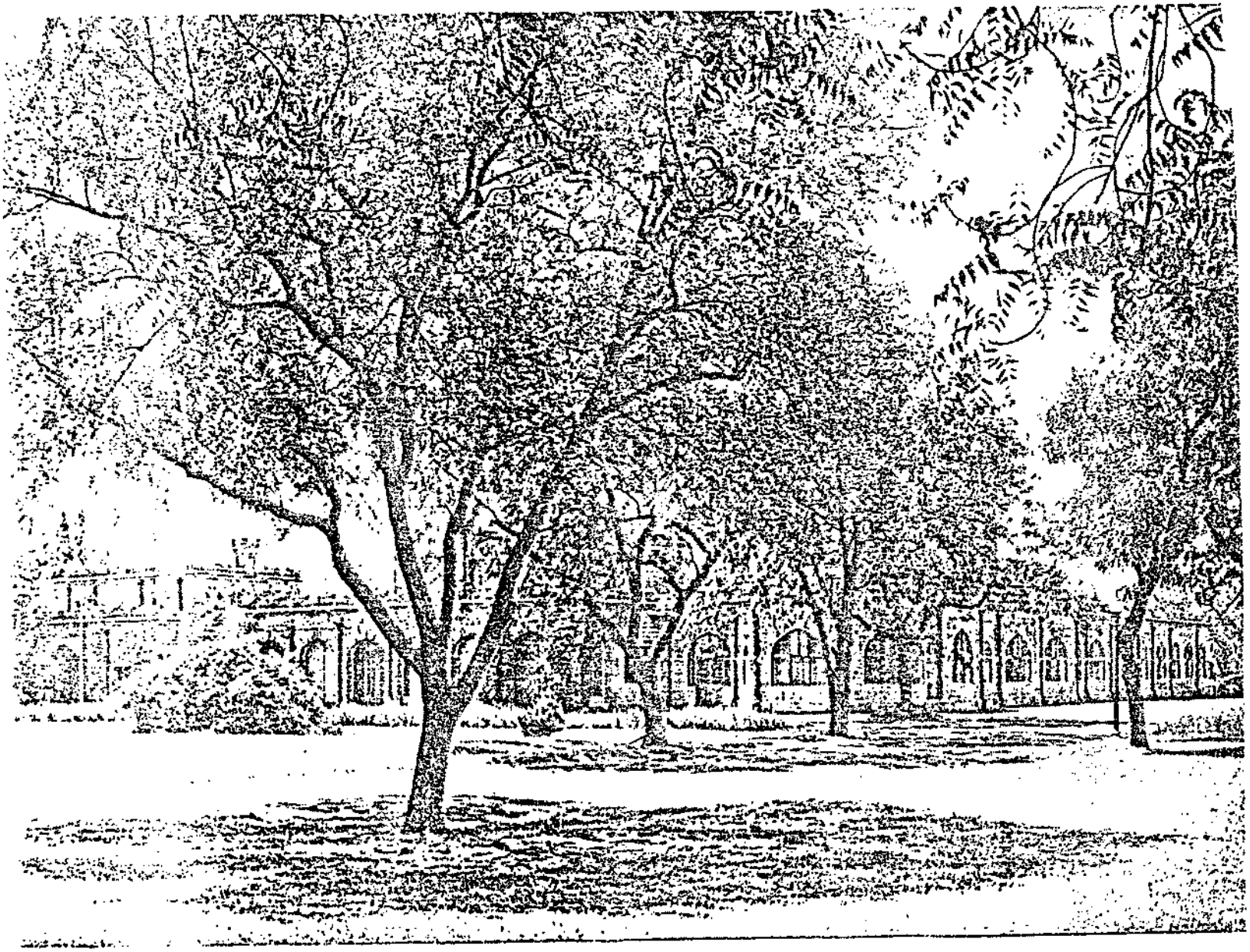


PLATE II.



The total staff of the centrally administered areas (excluding Delhi urban area) includes :—

3 Malaria Officers.	2 Overseers.
7 Malaria Assistants.	12 Laboratory Assistants.
2 Assistant Entomologists.	18 Insect Collectors.
29 Malaria Inspectors.	7 Mechanics.

The above schemes are intended not only to benefit those areas directly dependent on the Central Government, but also to demonstrate to other administrative units in India the results which can be achieved by such schemes operating under the direction of a properly established and adequately staffed organization at the centre.

MALARIA CONTROL ORGANIZATIONS IN INDIAN COALFIELDS.

In 1944, the Institute was called upon to undertake the task of organizing malaria control measures in the coalfields throughout India, on account of the urgent necessity of increasing the output of coal to its utmost capacity for the furtherance of the war effort. Antimalaria schemes under the direct control of the Institute are now in operation in five of the most important coalfields, *i.e.* Jharia (Bihar), Raniganj (Bengal), Pench Valley (C. P.), Margherita (Assam) and Korea (State). Schemes for two other coalfields (Chanda in the C. P. and Hazaribagh in Bihar) have been sanctioned, and will come into operation shortly. With the establishment of three further schemes in Rewa, Baluchistan and Assam now under consideration, all the important coalfields in India, representing more than 95 per cent of the country's total coal output, will have been covered. The technical staff of the coalfield antimalaria organizations is given below :—

1 Assistant Director (Coalfields).	8 Laboratory Assistants.
7 Malaria Officers.	57 Insect Collectors.
1 Entomologist.	3 Surveyors.
3 Assistant Entomologists.	3 Draftsmen.
103 Malaria Inspectors and Sub-Inspectors.	2 Chainmen.
	7 Fitters.

Most of the schemes have now been in operation for two or three years and they have already provided a striking demonstration of the importance of malaria control in the economic life of the country.

PREVENTIVE MEASURES AGAINST YELLOW FEVER.

In addition to its main function of dealing with problems connected with malaria, the Institute is frequently called upon to advise on measures directed against other insect-borne diseases, notably yellow fever. In the course of visits to mid-East in 1941, Covell made a special tour through the Sudan and Kenya Colony to study and report on the anti-Aëdes measures adopted in these countries in connection with seaports, ships, airfields and aircraft. In November 1944, Puri visited a number of stations on the air route from Cairo to Khartoum to

investigate the measures in force for the disinsectization of aircraft, and he and Covell toured in Egypt, Eritrea and the Sudan in the same connection in March 1946. These two officers have made a number of other visits in recent years to Bombay, Calcutta and Karachi with a similar purpose in view. The experience gained during these tours, together with the data obtained from investigations carried out at the Institute in regard to insecticides, aerosol dispensers and other spraying equipment, have formed the basis of the quarantine regulations issued from time to time by the Government of India for preventing the introduction of yellow fever into this country.

BUILDINGS.

The headquarters of the Institute were originally located at Kasauli in the Simla Hills, and the field station at Karnal, Punjab, 75 miles north of Delhi. In 1938, the field station was transferred to Delhi, the building formerly occupied by the Commander-in-Chief, India, having been acquired for that purpose. The headquarters of the Institute were transferred from Kasauli to Delhi in 1943. With the recent expansion of the staff and activities of the Institute the accommodation available in Delhi became inadequate, and a much-needed new laboratory block and animal houses have recently been constructed.

PUBLICATIONS.

As was to be expected, the output of literature emanating from the Malaria Institute of India was considerably curtailed during the war period. *The Journal of the Malaria Institute of India* continued to appear, but the number of issues was reduced from four to two per year, so that each volume covered a period of two years instead of one. With the change in title now adopted, the former practice of issuing four numbers per annum is being resumed.

The issue of new editions of the 13 Malaria Bulletins included in the Health Bulletin series of the Government of India has been continued as in former years, and the demand for them both in India and in other countries is as great as ever. A complete list of all publications issued since the establishment of the organization in 1927 is given in Appendix III.

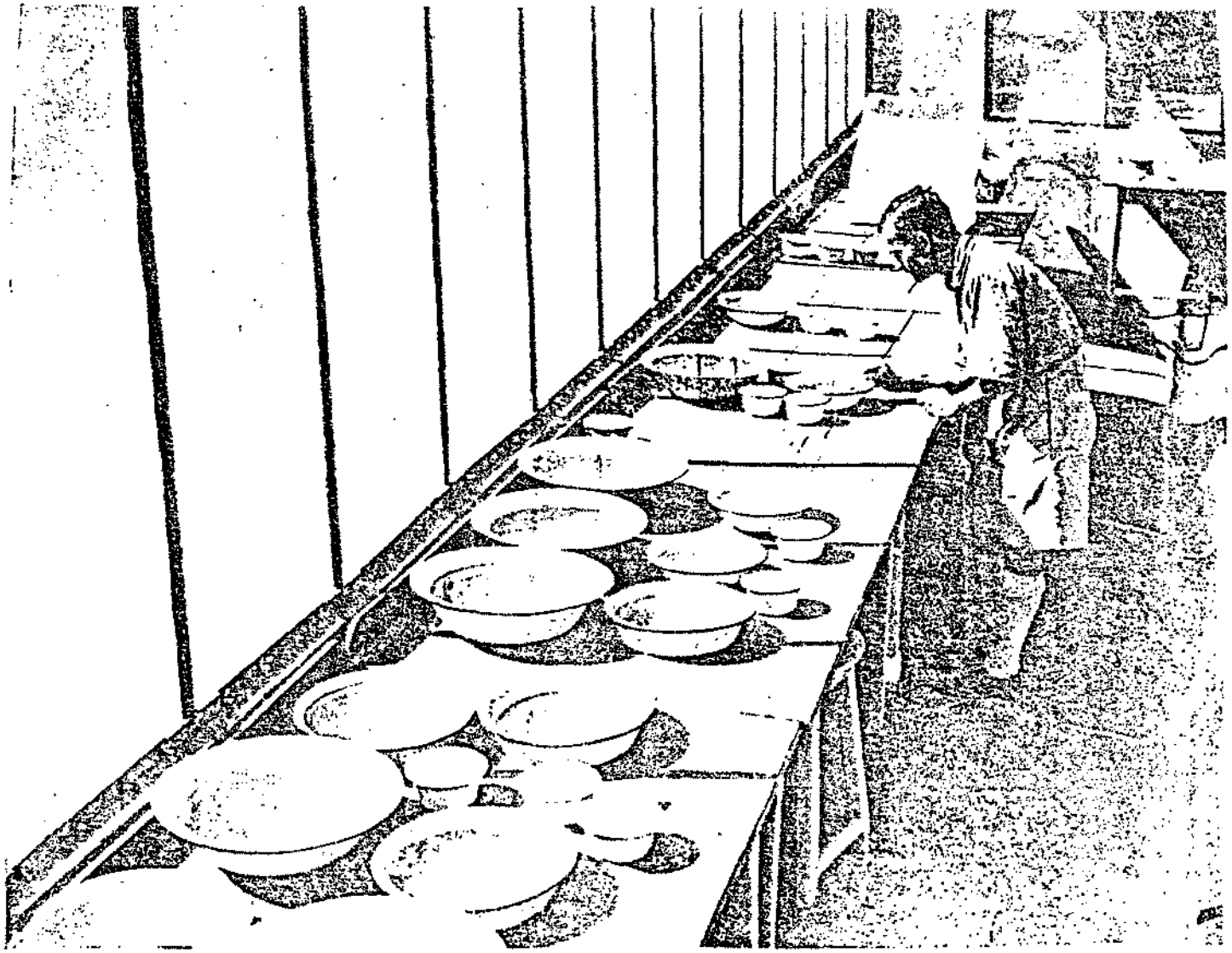
RESEARCHES.

Laboratory researches.

Laboratory research work has been severely curtailed during the war period, and has chiefly been directed towards the testing and development of insecticides, larvicides and repellents and to the designing of anti-mosquito equipment. The importance of these researches as a contribution to the war effort has already been mentioned.

In the laboratories at Delhi, important work has been carried out in the development of stains for the diagnosis of malaria parasites. The J. S. B. water-soluble stain for the rapid diagnosis of malaria parasites, developed by Lieut.-Colonel Jaswant Singh and Dr. L. M. Bhattacharji, has been generally accepted

PLATE IV.



Malaria Institute of India—Insectarium.

as a valuable contribution to laboratory technique, particularly applicable to field conditions. The same workers have more recently produced a formula which has proved an effective substitute for both Leishman and Giemsa stains. All these stains can be prepared from materials obtainable in India at moderate cost.

Laboratory strains of monkey malaria have been maintained at Delhi and have been used for testing of a number of indigenous and synthetic drugs. The determination of the source of mosquito blood meals and the preparation of antisera for this purpose has been continued during the war period, though on a reduced scale.

At the Southern India Branch, laboratory research activities have been directed chiefly to investigation of the bionomics of *A. fluviatilis*, the principal vector of malaria in the foothills of South India. A strain of *P. gallinaceum* has been maintained in this laboratory.

Field researches.

A number of important field investigations have been carried out with D.D.T. solutions, emulsions and suspensions and also to a more limited extent with gammexane. A special investigating unit, known as the Insecticide and Mosquito Repellent Inquiry, operating under the Director of the Institute, has been financed by the Indian Research Fund Association for this purpose. These investigations have been carried out in South India, in the Himalayan foothills, Bengal and more recently in Baluchistan.

During the past 12 months a number of field trials with paludrine and other synthetic antimalaria drugs have been in progress in various parts of India under the direction of the Malaria Institute of India by special arrangement with the Medical Research Council in England. These experiments have been carried out in Assam, Baluchistan, Bengal, Bihar, Bombay, Madras and the United Provinces. Their object has been to assess the value of these drugs in the prophylaxis and treatment of malaria particularly in villages and among labour forces employed in coalfields, plantations and other industrial concerns.

MALARIA SURVEYS.

Afridi investigated malaria conditions in Bahrein Islands, Persian Gulf, in 1938 with Abdul Majid, and at Bazpur in the Terai area of the United Provinces in 1938–40 with Imdad Ali Shah. He also carried out an Aëdes survey of Hog Island, Bombay, in 1938.

Surveys were carried out in the Wynaad, South India, by Covell and Harbhagwan in 1938-39 and in the coastal belt of Orissa by Covell and Pritam Singh in 1939–42.

Jaswant Singh and Jacob carried out surveys in Ahmedabad in 1941 and in North Kanara, Bombay Presidency, in 1942-43.

POST-WAR ACTIVITIES.

With the termination of the war the training of personnel at the Institute for the Defence Forces has ceased and the annual malariology course for civilian medical officers has been resumed. The length of the course has once more been extended to its pre-war schedule of six weeks' intensive training. The short courses for engineers, held in abeyance since 1941, have also been resuscitated.

It is expected that the activities of the various provincial antimalaria organizations and those of the principal Indian States will continue to be closely linked with those of the Central Institute.

In the general scheme for malaria control throughout India it is intended that the training of subordinate antimalarial personnel for the provinces will be a function of the provincial organizations, but until these are set up and begin to function effectively, training courses will be arranged for such personnel at the centre as required.

It has been proposed that an officer of the Institute shall function as a member of the Central Waterways Irrigation and Navigation Commission, but until such an individual is appointed his duties will devolve on the Director. The Coalfields Malaria Organization and the malaria schemes in Delhi urban and rural areas, Baluchistan, Coorg and Ajmer will remain under the direction of the Institute. It is hoped that the Southern India Branch will now be expanded and developed, so that it may perform for Southern India the functions carried out at present for the whole country by the Malaria Institute of India.

There is urgent need for intensive investigation on a number of unsolved problems, and now that the staff of the Institute has been augmented and the necessity for training large numbers of personnel for the Defence Services no longer exists, the various research activities which have suffered so much curtailment during the war years will be resumed with undiminished vigour, so that the Institute may maintain the high standard attributed to it by the Health Survey and Development Committee (1946): 'Although the Malaria Institute has been in existence for less than twenty years, it has carried out a large volume of research work of the highest quality and has established for itself a reputation for malaria research which is probably unequalled by any other single organization in the world.'

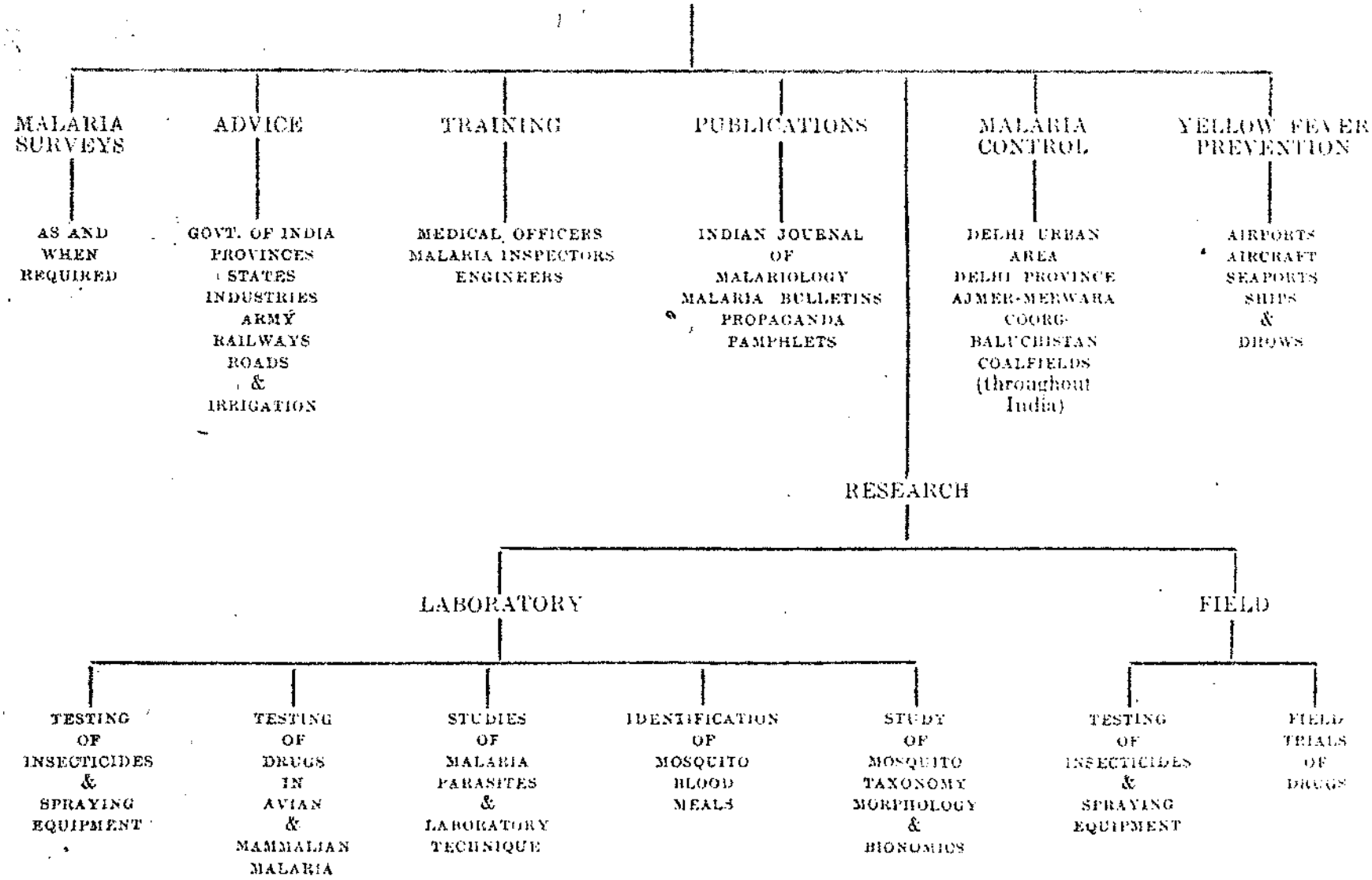
REFERENCES.

COVELL, G. (1938) ... ... The Malaria Survey of India, 1927–37. *J. Mal. Inst. Ind.*, **1**, 1, pp. 1–31.

HEALTH SURVEY AND DEVELOPMENT COMMITTEE (1946). *Report*, **1**, p. 186.

APPENDIX I.

THE MALARIA INSTITUTE OF INDIA.



Gordon Covell.

APPENDIX II.*

PROGRAMME OF MALARIA COURSE FOR MEDICAL OFFICERS—*First week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8.45—9.45 a.m.	.....	PRACTICAL I. **Laboratory.** Preparation and staining of blood films.	PRACTICAL II. **Laboratory.** Study of malaria parasites.	PRACTICAL III. **Laboratory.** Study of malaria parasites.	PRACTICAL IV. **Laboratory.** General characters of mosquitoes.	PRACTICAL V. **Laboratory.** Morphology of adult mosquitoes.
9.45—10.45 a.m.	LECTURE I. Introductory.					
10.45—11 a.m.	**INTERVAL.**					
11 a.m. to 12 noon	Taking over and checking of equipment. *Film*—Life history of mosquito.	PRACTICAL I. (*Contd.*)	PRACTICAL II. (*Contd.*)	PRACTICAL III. (*Contd.*)	PRACTICAL IV. (*Contd.*)	PRACTICAL V. (*Contd.*)
12 noon to 1 p.m.	LECTURE II. **Hæmatology.** Blood films, staining methods, blood elements, etc.	LECTURE III. **Parasitology 1.** The malaria parasites.	LECTURE IV. **Parasitology 2.** The malaria parasites.	LECTURE V. **Entomology 1.** General characters of mosquitoes.	LECTURE VI. **Entomology 2.** Morphology of mosquitoes.	LECTURE VII. **Entomology 3.** Morphology of mosquitoes.
1—3 p.m.	**LUNCHEON.**					
3—5 p.m.	.....	PRACTICAL I. (*Contd.*)	PRACTICAL II. (*Contd.*)	PRACTICAL III. (*Contd.*)	PRACTICAL IV. (*Contd.*)	PRACTICAL V. (*Contd.*)

* A full account of the origin and development of these courses was given by Covell (1938).

PROGRAMME OF MALARIA COURSE FOR MEDICAL OFFICERS—*Second week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8.45—9.45 a.m.	PRACTICAL VI. **Laboratory.** Morphology of wings, scales and mouth parts.	PRACTICAL VII. **Field.** Collection of larvæ and pupæ.	LECTURE X. **Surveying.** Elementary surveying and map-making.	PRACTICAL XI. **Laboratory.** General characters of larvæ.	PRACTICAL XII. **Laboratory.** General characters of larvæ and pupæ.	PRACTICAL XIII. **Field.** Collection of adult mosquitoes.
9.45—10.45 a.m.	.....	.....	PRACTICAL VIII. (*Contd.*)	.....	.....	.....
10.45—11 a.m.	**INTERVAL.**					
11 a.m. to 12 a.m.	PRACTICAL VI. (*Contd.*)	PRACTICAL VIII. **Laboratory.** Examination and arrangement of collections.	PRACTICAL IX. **Field.** Allocation of areas to be surveyed and reported on by students during course.	PRACTICAL XI. (*Contd.*)	PRACTICAL XII. (*Contd.*)	PRACTICAL XIII. **Laboratory.** Examination of specimens collected and of eggs.
12 noon to 1 p.m.	LECTURE VIII. **Entomology 4.** Collection of larvæ and pupæ.	LECTURE IX. **Entomology 5.** Examination of larvæ.	PRACTICAL X. **Laboratory.** Duplicating and enlarging maps, etc.	LECTURE XI. **Entomology 6.** Internal anatomy and habits of larvæ; general characters of pupæ.	LECTURE XII. **Entomology 7.** Collection and distribution of adults; general characters of eggs.	LECTURE XIII. **Entomology 8.** Mounting and examining adult mosquitoes.
1—3 p.m.	**LUNCHEON.**					
3—5 p.m.	PRACTICAL VI. (*Contd.*)	PRACTICAL VIII. (*Contd.*)	PRACTICAL X. (*Contd.*)	PRACTICAL XI. (*Contd.*)	PRACTICAL XII. (*Contd.*)	PRACTICAL XIII. (*Contd.*)

APPENDIX II—*contd.*

PROGRAMME OF MALARIA COURSE FOR MEDICAL OFFICERS—*Third week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8.45—9.45 a.m.	PRACTICAL XIV. **Laboratory.** Mounting and examining adult mosquitoes.	PRACTICAL XV. **Laboratory.** Identification of adult mosquitoes.	PRACTICAL XVI. **Laboratory.** Identification of larvæ.	PRACTICAL XVII. **Laboratory.** Identification of adults and larvæ. (1) Demonstration of methods of first precipitin tests. (2) Marking of adult mosquitoes.	LECTURE XVIII. **Entomology 13.** Anatomy, histology and dissection of salivary glands. Bionomics (*contd.*)	LECTURE XIX **Entomology 14.** Reproductive organ determination age of mosquito
9.45—10.45 a.m.	.....	.....	.....	.....	PRACTICAL XVIII. **Laboratory.** Dissection of gut and salivary glands.	PRACTICAL XIX **Laboratory.** Dissection of and salivary glan (*contd.*)
10.45—11 a.m.	INTERVAL.					
11 a.m. to 12 noon.	PRACTICAL XIV. (*Contd.*)	PRACTICAL XV. (*Contd.*)	PRACTICAL XVI. (*Contd.*)	PRACTICAL XVII. (*Contd.*)	PRACTICAL XVIII. (*Contd.*)	PRACTICAL XI (*Contd.*)
12 noon to 1 p.m.	LECTURE XIV. **Entomology 9.** Identification of adult mosquitoes.	LECTURE XV. **Entomology 10.** Identification of larvæ.	LECTURE XVI. **Entomology 11.** Bionomics of mosquitoes.	LECTURE XVII. **Entomology 12.** Internal anatomy and dissection of alimentary canal of mosquitoes. Bionomics (*contd.*)	PRACTICAL XVIII. (*Contd.*)	LECTURE XX **Entomology 15** Demonstration, ral enemies of quitoes.
1—3 p.m.	LUNCHEON.					
3—5 p.m.	PRACTICAL XIV. (*Contd.*)	PRACTICAL XV. (*Contd.*)	PRACTICAL XVI. (*Contd.*)	PRACTICAL XVII. (*Contd.*)	PRACTICAL XVIII. (*Contd.*)	PRACTICAL XI (*Contd.*)

APPENDIX II—*contd.*

PROGRAMME OF MALARIA COURSE FOR MEDICAL OFFICERS—*Fourth week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8.45—9.45 a.m.	PRACTICAL XX. **Laboratory.** Dissection of ovaries and male reproductive organs.	LECTURE XXII. **Pathology.** Pathology of malaria.	LECTURE XXIV. **Epidemiology 1.** Basic etiology of malaria. Malariometry.	PRACTICAL XXIII. **Field.** Examination of spleens and blood in Nangli Village.	PRACTICAL XXIV. **Field.** Demonstration of D.D.T. spraying.	HOLIDAY.
9.45—10.45 a.m.	.....	PRACTICAL XXI. Dissection of infected mosquitoes.	PRACTICAL XXII. Revision of parasitology.	.....	.....	
10.45—11 a.m.	INTERVAL.					
11 a.m. to 12 noon.	PRACTICAL XX. (*Contd.*)	PRACTICAL XXI. (*Contd.*) Study of oöcysts and sporozoites. Method of making permanent preparations of infected guts and glands.	PRACTICAL XXII. (*Contd.*)	PRACTICAL XXIII. **Laboratory.** (*i*) Study and recording of data collected. (*ii*) Study of blood slides collected in the field.	PRACTICAL XXIII. (*Contd.*)	
12 noon to 1 p.m.	LECTURE XXI. **Parasitology 3.** Cycle in mosquito. Factors influencing parasitic development: oöcyst and sporozoite rate.	LECTURE XXIII. **Parasitology 4.** Cycle in mosquito. (*Contd.*)	LECTURE XXV. **Epidemiology 2.** Endemic malaria.	LECTURE XXVI. **Epidemiology 3.** Epidemic malaria.		
1—3 p.m.	LUNCHEON.					
3—5 p.m.	PRACTICAL XX. (*Contd.*)	PRACTICAL XXI. (*Contd.*)	PRACTICAL XXII. (*Contd.*)	PRACTICAL XXIII. (*Contd.*)	PRACTICAL XXIII. (*Contd.*)	

APPENDIX II—c.

PROGRAMME OF MALARIA COURSE FOR MEDICAL OFFICERS—*Fifth week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8.45—9.45 a.m.	**Laboratory.** Revision.	PRACTICAL XXV. **Field.** Examination of spleens and blood in allotted areas.	LECTURE XXXI. **Epidemiology 6.** Summary of methods used in malaria surveys.	PRACTICAL XXVII. **Field.** Malaria surveys of allocated areas. (Demonstration by students.)	LECTURE XXXV. **Malaria control 3.** Chemical larvicides.	PRACTICAL XXX. **Field.** Demonstration of oiling and drainage.
9.45—10 a.m.	.....	.....	PRACTICAL XXVI. **Laboratory.** Preparation of reports on allocated areas.	.....	PRACTICAL XXIX. **Field.** Application of chemical larvicides.	.....
10.45—11 a.m.	**INTERVAL.**					
11 a.m. to 12 noon.	**Laboratory.** Revision.	PRACTICAL XXV. (*Contd.*) **Laboratory.** Recording of data and study of blood films collected in the field.	PRACTICAL XXVI. (*Contd.*)	PRACTICAL XXVIII. **Laboratory.** Completion of reports on allocated areas.	PRACTICAL XXIX. (*Contd.*) **Laboratory.** Completion of toxicity tests.	LECTURE XXXVII. **Malaria control 5.** Drainage. PRACTICAL XXXI. **Laboratory.** Demonstration of oiling apparatus.
12 noon to 1 p.m.	LECTURE XXVII. **Statistics 1.**	LECTURE XXIX. **Statistics 2.**	PRACTICAL XXVI. (*Contd.*)	LECTURE XXXIII. **Statistics 3.**	PRACTICAL XXIX. (*Contd.*)	PRACTICAL XXXI. (*Contd.*)
1—3 p.m.	**LUNCHEON.**					
3—4 p.m.	**Laboratory.** Revision.	PRACTICAL XXV. (*Contd.*)	PRACTICAL XXVI. (*Contd.*)	PRACTICAL XXVIII. (*Contd.*)	PRACTICAL XXIX. (*Contd.*)	PRACTICAL XXXI. (*Contd.*)
4—5 p.m.	LECTURE XXVIII. **Epidemiology 4.** Meteorological and other factors affecting malarial incidence.	LECTURE XXX. **Epidemiology 5.** Malaria and irrigation.	LECTURE XXXII. **Malaria control 1.** General principles.	LECTURE XXXIV. **Malaria control 2.** Personal protection. Screening.	LECTURE XXXVI. **Malaria control 4.** Oil as larvicide.	LECTURE XXXVIII. **Malaria control 6.** Spray-killing adult mosquitoes.

APPENDIX II—*contd.*

PROGRAMME OF MALARIA COURSE FOR MEDICAL OFFICERS—*Sixth week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8.45—9.45 a.m.	PRACTICAL XXXII. **Field.** Demonstration of Delhi antimalaria works.	PRACTICAL XXXIII. **Field.** Demonstration of Delhi antimalaria works.	LECTURE XLII. **Malaria control 10.** Summary of control measures.	**Laboratory.** Revision.	PRACTICAL EXAMINATION.	WRITTEN AND *VIVA VOCE* EXAMINATION.
9.45 a.m. to 12 noon.	.....	.....	**Laboratory.** Revision.	.....	.....	.....
12 noon to 1 p.m.	LECTURE XXXIX and LECTURE XL. **Malaria control 7 and 8.** Spray-killing adult mosquitoes.	LECTURE XLI. **Malaria control 9.** Naturalistic measures.	**Laboratory.** Revision.	**Laboratory.** Revision.	PRACTICAL EXAMINATION.	
1—3 p.m.	**LUNCHEON.**					
3—5 p.m.	**Laboratory.** Revision.	**Laboratory.** Revision.	**Laboratory.** Discussion of students' reports on allocated areas.	**Laboratory.** Revision.	Handing in equipment by students.	

APPENDIX II—*contd.*

PROGRAMME OF MALARIA COURSE FOR ENGINEERS.

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
		FIELD DEMONSTRATIONS OF DELHI MALARIA PROBLEMS.				
8.30—10.30 a.m.	.....	Timarpur to Power House.	Power House to Drain 14 and Central Vista Tanks.	Barapula Nala, Jangpura and Brickfield area.	Southern Ridge. (Reservoirs, nalas and quarries.)	Western Jumna Canal system, Darbacia Escape and Najafgarh Cut.
10.30—11.15 a.m.	LECTURE I. Object and scope of course. History of malaria and its social and economic importance.	LECTURE III. How malaria is transmitted. The parasites of human malaria and their life cycle in man and in the mosquito.	LECTURE V. Factors influencing the incidence of malaria — topography, climate, agricultural and economic conditions, types of irrigation, local mosquito bionomics, etc.	LECTURE VII. Principles and economics of anti-malarial sanitation. Costs of permanent and recurring control measures.	LECTURE IX. Special malaria problems. Malaria and irrigation, malaria and rice cultivation (lantern slides).	LECTURE XI. Personal prophylaxis and prevention of malaria among labour forces. Site selection.
11.15 a.m. to 12 noon.	MUSEUM DEMONSTRATION.	LABORATORY DEMONSTRATION. Malaria parasites in the blood and in mosquitoes.	LABORATORY DEMONSTRATION. Mosquitoes — egg, larva, pupa, and adult stages.	PRACTICAL DEMONSTRATION. Spray-killing adult mosquitoes.	PRACTICAL DEMONSTRATION. Antilarval methods.	CINEMA FILM. Malaria control methods in Malaya.
12 noon to 1 p.m.	LECTURE II. Malaria problems in Delhi antimalaria engineering works.	LECTURE IV. Recurring control measures in Delhi. Life history of the mosquito (cinema film).	LECTURE VI. Spray-killing of adult mosquitoes. Application of oil and paris green to breeding places (epidiascope).	LECTURE VIII. Antimalarial drainage (epidiascope).	LECTURE X. Naturalistic control measures (lantern slides).	LECTURE XII. Summary of methods of investigation and control of malaria.

APPENDIX II—*contd.*

PROGRAMME OF MALARIA COURSE FOR INSPECTORS—*First week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8—10 a.m.	LECTURE I. **Introductory.**	LECTURE III. **Parasitology 1.**	LECTURE IV. **Parasitology 2.**	LECTURE V. **Entomology 1.**	LECTURE VI. **Entomology 2.**	PRACTICAL V. **Field.** Collection of larvæ and pupæ.
10—11 a.m.	LECTURE II. **Hæmatology.**	PRACTICAL I. **Laboratory.** Preparation and staining of blood films.	PRACTICAL II. **Laboratory.** Study of malaria parasites.	PRACTICAL III. **Laboratory.** Study of malaria parasites.	PRACTICAL IV. **Laboratory.** Morphology of adult mosquitoes.	LECTURE VII. **Entomology 3.** Habits of larvæ, pupæ and adults.
11 a.m. to 1 p.m.	Taking over and checking of equipment by students.					PRACTICAL VI. **Laboratory.** Mounting and examination of larvæ.
1—3 p.m.	**LUNCHEON.**					
3—5 p.m.	.....	PRACTICAL I. (*Contd.*)	PRACTICAL II. (*Contd.*)	PRACTICAL III. (*Contd.*)	PRACTICAL IV. (*Contd.*)	PRACTICAL VI. (*Contd.*)

APPENDIX II—*contd.*

PROGRAMME OF MALARIA COURSE FOR INSPECTORS—*Second week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8—10 a.m.	LECTURE VIII. **Entomology 4.** Collection, mounting and distribution of mosquitoes.	PRACTICAL VIII. **Field.** Collection of adult mosquitoes. (*Contd.*) (up to 11 a.m.)	LECTURE X. **Entomology 6.** Dissection of mosquitoes.	LECTURE XI. **Malaria control 1.** Personal protection measures against adult mosquito bite.	LECTURE XII. **Malaria control 2.** Measures against adults.	LECTURE XIII. **Malaria control 3.** Insecticides and their application.
10 a.m. to 1 p.m.	PRACTICAL VII. **Laboratory.** General characters of larvæ, pupæ and adults.	LECTURE IX. **Entomology 5.** Identification of adult mosquitoes (11 a.m. to 12 noon).	PRACTICAL IX. **Laboratory.** Identification of adult mosquitoes.	PRACTICAL X. **Laboratory.** Dissection of adult mosquitoes.	PRACTICAL XI. **Laboratory.** Dissection of infected mosquitoes.	PRACTICAL XII. **Laboratory.** Dissection of infected mosquitoes. LECTURE XIV. **Malaria control 4.**
1—3 p.m.	**LUNCHEON.**					Oiling and demonstration of equipment.
3—5 p.m.	PRACTICAL VII. (*Contd.*)	PRACTICAL VIII. (*Contd.*)	PRACTICAL IX. (*Contd.*)	PRACTICAL X. (*Contd.*)	PRACTICAL XI. (*Contd.*)	PRACTICAL XII. (*Contd.*)

APPENDIX II—*contd.*

PROGRAMME OF MALARIA COURSE FOR INSPECTORS—*Third week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8.30—9.30 a.m.	LECTURE XV. **Entomology 7.**	LECTURE XVII. **Malaria control 5.** Basic principles. Methods specially applicable in war. Measures of personal protection.	LECTURE XIX. **Epidemiology 1.** Basic etiology of malaria. Spleen census and methods.	PRACTICAL XV. **Field.** Examination of spleen and blood.	LECTURE XXII. **Epidemiology 4.** (i) Effect of irrigation. (ii) Malaria surveys (summary of methods).	LECTURE XXIII. **Malaria control 7.** Organization of recurrent measures. Malaria problems in Delhi. Demonstration of spray-killing of adult mosquitoes (2 batches).
9.30—10.30 a.m. 10.30—11.30 a.m.	PRACTICAL XII. (*Contd.*)	PRACTICAL XIII. **Laboratory.** Dissection of infected mosquitoes.	PRACTICAL XIV. **Laboratory.** Dissection of infected mosquitoes.	PRACTICAL XVI. **Field.** Demonstration of D.D.T. spraying.	PRACTICAL XVIII. **Laboratory.** Examination of spleen and blood.	PRACTICAL XVIII. (*Contd.*)
11.30 a.m. to 12.30 p.m.	LECTURE XVI. **Parasitology 3 and 4.**	LECTURE XVIII. **Malaria control 6.** Measures against adult mosquitoes. Pyrethrum insecticide, D.D.T.	LECTURE XX. **Epidemiology 2.** Significance of spleen rate and AES. Endemic malaria. Degree of endemicity. Malaria map of India. Course of an epidemic.	LECTURE XXI. **Epidemiology 3.** Influence of climate. Epidemic malaria.	PRACTICAL XVIII. (*Contd.*)	LECTURE XXIV. **Malaria control 8.** Chemical larvicides. D.D.T., paris green, cresol, copper cyanide, etc.
12.30—2.30 p.m.	**LUNCHEON.**					
2.30—4.30 p.m.	PRACTICAL XII. (*Contd.*)	PRACTICAL XIII. (*Contd.*)	PRACTICAL XIV. (*Contd.*)	PRACTICAL XVII. **Laboratory.** Study of data and blood slides collected in field.	PRACTICAL XVIII. (*Contd.*)	PRACTICAL XVIII. (*Contd.*)

PROGRAMME OF MALARIA COURSE FOR INSPECTORS—*Fourth week.*

	MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
8.30—9.30 a.m.	LECTURE XXV. **Malaria control 9.** Use of oil. Demonstration of oiling apparatus.	PRACTICAL XX. **Field.** Demonstration of oiling and drainage.	PRACTICAL XXII. **Field.** Demonstration of Delhi antimalaria works.	**Laboratory.** Revision.	PRACTICAL EXAMINATION. **Part I.**	WRITTEN AND *VIVA VOCE* EXAMINATION.
9.30—11.30 a.m.	PRACTICAL XIX. **Field.** Demonstration—D.D.T. residual and larvicidal.	.....	.....	.....	PRACTICAL EXAMINATION. **Part II.**	.....
10.30—11.30 a.m.	PRACTICAL XIX. (*Contd.*)	.....	.....	.....		.....
11.30 a.m. to 12.30 p.m.	.....	LECTURE XXVII. **Malaria control 11.** Naturalistic methods. Demonstration of flushing methods.	LECTURE XXVIII. **Malaria control 12.** Summary of control measures.	**Laboratory.** Revision.	.....	.....
12.30—2.30 p.m.	**LUNCHEON.**					
2.30—3.30 p.m.	PRACTICAL XIX. (*Contd.*) **Laboratory.** Demonstration of dustless paris green methods.	PRACTICAL XXI. **Laboratory.** Revision.	PRACTICAL XXIII. **Field.** Demonstration of spray-killing of adult mosquitoes in habitations.	**Laboratory.** Revision.	PRACTICAL EXAMINATION. **Part III.**	
3.30—4.30 p.m.	LECTURE XXVI. **Malaria control 10.** Drainage, treatment of borrowpits.	.....	.....	.....	Handing in equipment by students.	

APPENDIX III.

CLASSIFIED LIST OF PUBLICATIONS

ANTIMOSQUITO MEASURES.

BUTT, N. M. (1931) ... ... A simple and inexpensive portable screener for use with paris green diluents. *Rec. Mal. Surv. Ind.*, **2**, 2, p. 333.

Idem (1938) ... ... An inexpensive apparatus for mixing larvicides. *J. Mal. Inst. Ind.*, **1**, 2, pp. 147-148.

COVELL, G. (1931) ... ... Malaria control by antimosquito measures. (Thacker, Spink & Co., Calcutta.)

Idem (1935) ... ... The effect of paris green dusting on rice crops. *Rec. Mal. Surv. Ind.*, **5**, 2, p. 153.

Idem (1937) ... ... Malaria and its control with special reference to anti-malarial operations in the Delhi urban area. (I. M. H. Press, Delhi.)

Idem (1937) ... ... Malaria and its control with special reference to antimalarial operations in the Delhi urban area. (Three pts. in *Jl. Indian Red Cross Society*, **11**, 1937.)

Idem (1940) ... ... Malaria control with insecticidal sprays. *Bull. Office Internat. d'Hyg. Publique*, **32**, 5-6, pp. 564–569.

Idem (1945) ... ... The rôle of DDT in combating disease among civil populations. *Ind. Hlth. Gaz.*, **3**, pp. 1–5.

Idem (1947) ... ... Bats, clover, water lettuce and malaria. *Ind. J. Mal.* (in press).

COVELL, G., and AFRIDI, M. K. (1937) ... Experimental application of paris green from aircraft. *Rec. Mal. Surv. Ind.*, **7**, 1, p. 93.

COVELL, G., BAILY, J. D., and PRASAD, V. (1935). An experiment with paris green in a hyperendemic village in Sind. *Ibid.*, **5**, 2, p. 131.

COVELL, G., MULLIGAN, H. W., and AFRIDI, M. K. (1938). An attempt to control malaria by the destruction of adult mosquitoes with insecticidal sprays. *J. Mal. Inst. Ind.*, **1**, 1, pp. 105–113.

MAYNE, B. (1930) ... ... Tests on the effects of Coumarin on the life of the mosquito and the malaria parasite. *Ind. J. Med. Res.*, **17**, 3, p. 963.

MULLIGAN, H. W., and MAJID, A. (1932) Some experiments to determine the efficacy of wire gauze screens of different apertures in excluding anopheline mosquitoes in India. *Rec. Mal. Surv. Ind.*, **3**, 1, p. 163.

MULLIGAN, H. W., and MAJID, S. A. (1936). Some notes on the care, transportation, and use of *Gambusia affinis*, under Indian conditions. *Ibid.*, **6**, 4, p. 537.

PURI, I. M. (1947) ... ... The practical application of DDT for malaria control in rural and urban areas in India. *Ind. J. Mal.*, **1**, 1, pp. 211–220.

PURI, I. M., and BHATIA, M. L. (1947) ... Studies on some insecticides against anopheline adults and larvæ. Pt. III. *Ibid.*, pp. 183–191.

PURI, I. M., and KRISHNASWAMI, A. K. (1947). Studies on some insecticides against anopheline adults and larvæ. Pt. II. *Ibid.*, pp. 159–181.

Idem (1947) ... Studies on some insecticides against anopheline adults and larvæ. Pt. IV. *Ibid.*, pp. 193–209.

PURI, I. M., and RAJINDAR PAL (1947) ... Studies on some insecticides against anopheline adults and larvæ. Pt. I. *Ibid.*, pp. 133–158.

RAJA RAM (1935) ... ... Antimalarial engineering: control of anopheline larvæ in running water by means of mechanical devices for flushing and flooding. *Indian Engineering*, **98**, October, p. 122.

ANTIMOSQUITO MEASURES—*concld.*

RAJA RAM (1937) ... ... Design and construction of mosquito-proof buildings in India. *Jl. Institution of Engineers (India)*, 17, July.

SISTON, J. A., and MAJID, S. A. (1935) The dispersion of anopheline larvæ by the flow of streams, and the effect of larvicides in preventing this. *Rec. Mal. Surv. Ind.*, **5**, 1, p. 3.

SISTON, J. A., and WATS, R. C. (1935) The efficacy of various insecticidal sprays in the destruction of adult mosquitoes. *Ibid.*, **5**, 3, p. 275.

BIOCHEMISTRY.

BIRD, W. (1928) ... ... The effects of a diet rich in sugar on the relapse rate in chronic benign tertian malaria. *Ind. J. Med. Res.*, **16**, 1, p. 109.

GHOSH, B. N., and NATH, M. C. (1934) The chemical composition of malaria pigment (hæmozoin). *Rec. Mal. Surv. Ind.*, **4**, 3, p. 321.

GHOSH, B. N., and SISTON, J. A. (1934) Studies of malaria pigment (hæmozoin). Pt. II. The reactions of hæmozoin to tests for iron. *Ibid.*, **4**, 1, p. 43.

Idem (1935) Quantitative changes in the proteins of the blood sera of monkeys infected with malarial plasmodia. *Ibid.*, **5**, 2, p. 173.

KEHAR, N. D. (1930) ... ... Some aspects of the behaviour of cinchona alkaloids towards living cells. Pt. I. *Ind. J. Med. Res.*, **18**, 1, p. 203.

Idem (1931) ... ... Some aspects of the behaviour of cinchona alkaloids towards living cells. Pt. II. Penetration of the various cinchona alkaloids into colloidal gels. *Ibid.*, **18**, 3, p. 987.

Idem (1931) ... ... Some aspects of the behaviour of cinchona alkaloids towards living cells. Pt. III. The effect of plasmoquine on the penetration of the cinchona alkaloids. *Ibid.*, **18**, 3, p. 1001.

Idem (1932) ... ... Ultraviolet absorption spectra studies in malarial sera. *Rec. Mal. Surv. Ind.*, **3**, 1, p. 171.

Idem (1935) ... ... Observations on the absorption and excretion of atebrin. *Ibid.*, **5**, 4, p. 393.

Idem (1935) ... ... The influence of food in the stomach on the absorption and excretion of atebrin. *Ibid.*, **5**, 4, p. 405.

Idem (1936) ... ... Some physico-chemical factors and their relationship to protein fractions, blood cells and parasite counts, in the blood sera of monkeys infected with *Plasmodium knowlesi*. *Ibid.*, **6**, 3, p. 499.

Idem (1937) ... ... Cholesterol and lecithin in malaria. *Ibid.*, **7**, 2-3, p. 117.

SENIOR WHITE, R. (1928) ... ... On the relationship existing between carbonates and pH and conductivity in natural waters. *Ind. J. Med. Res.*, **15**, 4, p. 989.

SISTON J. A., and GHOSH, B. N. (1934) Studies of malarial pigment (hæmozoin). Pt. I. Investigation of the action of solvents on hæmozoin and the spectroscopical appearances observed in the solutions. *Rec. Mal. Surv. Ind.*, **4**, 1, p. 15.

Idem (1934) Studies of malarial pigment (hæmozoin). Pt. III. Further researches into the action of solvents, and the results of observations on the action of oxidizing and reducing agents, on optical properties, and on crystallization. *Ibid.*, **4**, 2, p. 205.

BIOCHEMISTRY—*concld.*

SINTON, J. A., and KEHAR, N. D. (1931) ...	Changes in the amount of blood sugar in malaria. *Rec. Mal. Surv. Ind.*, **2**, 2, p. 287.
WATS, R. C., and GHOSH, B. N. (1934) ...	Quantitative and qualitative methods for detection of atebrin in urine. *Ibid.*, **4**, 4, p. 367.

ENTOMOLOGY.

AFRIDI, M. K., JASWANT SINGH and HARWANT SINGH (1939).	Food preferences of Anopheles mosquitoes in the Delhi urban area. *J. Mal. Inst. Ind.*, **2**, 3, pp. 219–227.
AFRIDI, M. K., and MAJID, S. A. (1938)	Observations on the range of dispersion of *C. fatigans* and its infiltration into the Delhi urban area. Pt. I. *Ibid.*, **1**, 2, pp. 155–167.
AFRIDI, M. K., MAJID, S. A., and PRASAD, V. (1940).	Observations on the range of dispersion of *C. fatigans*. Pt. II. *Ibid.*, **3**, 1, pp. 143–152.
AFRIDI, M. K., MAJID, S. A., and SHAH, I. A. (1940).	Studies on the behaviour of adult *A. culicifacies*. Pt. II. *Ibid.*, pp. 23–52.
AFRIDI, M. K., and PURI, I. M. (1940) ...	Studies on the behaviour of adult *A. culicifacies*. Pt. I. *Ibid.*, pp. 1–22.
BARRAUD, P. J. (1927)	A note on rat fleas collected in Assam. *Ind. J. Med. Res.*, **15**, 2, p. 519.
Idem (1928)	A revision of the culicine mosquitoes of India. Pt. XXIII. The genus *Aedes* (Sens. Lat.) and the classification of the subgenera. Descriptions of the Indian species of *Aedes* (*Aedimorphus*), *Aedes* (*Ochlerotatus*), and *Aedes* (*Banksinella*) with notes on *Aedes* (*Stegomyia*) *variegatus*. *Ibid.*, **15**, 3, p. 653.
Idem (1928)	A revision of the culicine mosquitoes of India. Pt. XXIV. The Indian species of the subgenera *Skusea* and *Aedes*, with description of eight new species, and remarks on a new method for identifying the females of the subgenus *Aedes*. *Ibid.*, **16**, 2, p. 357.
Idem (1929)	A revision of the culicine mosquitoes of India. Pt. XXV. The genera *Mucidus*, *Mimomyia*, *Ficalbia*, *Rachionotomyia*, and *Hodgesia*. *Ibid.*, **16**, 4, p. 1052.
Idem (1929)	A revision of the culicine mosquitoes of India. Pt. XXVI. The genera *Heizmannia*, *Haemagogus*, *Topomyia* and *Megarhinus*. *Ibid.*, **17**, 1, p. 259.
Idem (1931)	The early stages of some Indian mosquitoes *Megarhinus*. *Ibid.*, **18**, 4, p. 1127.
Idem (1931)	Notes on some Indian mosquitoes of the subgenus *Stegomyia*, with descriptions of new species. *Ibid.*, **19**, 1, p. 221.
Idem (1931)	Descriptions of eight new species of Indian culicine mosquitoes. *Ibid.*, **19**, 2, p. 609.
Idem (1932)	The early stages of some Indian mosquitoes *Orthopodomyia*. *Ibid.*, **19**, 4, p. 1013.
Idem (1932)	*Anopheles aitkeni* James var. n. *pinjaurensis*. *Rec. Mal. Surv. Ind.*, **3**, 2, p. 353.
Idem (1933)	Additional records of the distribution of anopheline mosquitoes in India (from January 1, 1931 to April 15, 1933). *Ibid.*, **3**, 3, p. 507.
Idem (1933)	Note on a mosquito with the Pollinia of an *Orchis* attached to its proboscis. *Ibid.*, **3**, 3, p. 527.

ENTOMOLOGY—*contd.*

BARRAUD, P. J. (1934) ... ... Fauna of British India. Diptera. Vol. V. Family Culicidæ. Tribes Megarhinini and Culicini. (463 pp., 8 plates, 106 figs., one map, and 11 pp. references.) London: Taylor and Francis.

BARRAUD, P. J., and CHRISTOPHERS, S. R. (1931). On a collection of anopheline and culicine mosquitoes from Siam. *Rec. Mal. Surv. Ind.*, **2**, 2, p. 269.

BARRAUD, P. J., and COVELL, G. (1928) The morphology of the buccal cavity in anopheline and culicine mosquitoes. *Ind. J. Med. Res.*, **15**, 3, p. 671.

Idem (1929) The morphology of the buccal cavity of the mosquito. (*Trans. F. E. A. T. M., 7th Cong., held in India*, Dec. 1927, **3**, p. 98.)

CHOWDHURY, K. L. (1931) ... ... Some observations on the hibernation and 'wintering' of anophelines in the Punjab. *Rec. Mal. Surv. Ind.*, **2**, 3, p. 407.

CHRISTOPHERS, S. R., and BARRAUD, P. J. (1931). The eggs of Indian *Anopheles* with descriptions of the hitherto undescribed eggs of a number of species. *Ibid.*, **2**, 1, p. 161.

CHRISTOPHERS, S. R., and PURI, I. M. (1931). Species and varieties of the *funestus* series of *Anopheles*. *Ibid.*, **2**, 3, p. 481.

COVELL, G. (1926) ... ... The anopheline mosquitoes of the Andamans. Government Press, Port Blair.

Idem (1927) ... ... The distribution of anopheline mosquitoes in India and Ceylon. *Ind. Med. Res. Memoir, No.* 5.

Idem (1927) ... ... A new species of *Anopheles* from Eastern India, *A.* (*Myzomyia*) *ramsayi*; with a new description of *A.* (*Myzomyia*) *jamesii* Theobald. *Ind. J. Med. Res.*, **14**, 4, p. 1019.

Idem (1927) ... ... A critical review of the data recorded regarding the transmission of malaria by the different species of *Anopheles*; with notes on distribution, habits, and breeding places. *Ind. Med. Res. Memoir, No.* 7.

Idem (1928) ... ... A note on variations of the hind tarsal markings in *Anopheles fuliginosus* Giles and *Anopheles ramsayi* Covell. *Ind. J. Med. Res.*, **15**, 4, p. 1059.

Idem (1928) ... ... A note on the local variations and distribution of *Anopheles philippinensis* Ludlow. *Ibid.*, **15**, 4, p. 1063.

Idem (1931) ... ... The present state of our knowledge regarding the transmission of malaria by the different species of anopheline mosquitoes. *Rec. Mal. Surv. Ind.*, **2**, 1, p. 1.

Idem (1931) ... ... The distribution of anopheline mosquitoes in India and Ceylon: Additional records, 1926–1930. *Ibid.*, **2**, 2, p. 225.

Idem (1944) ... ... Notes on the distribution, breeding places, adult habits and relation to malaria of the anopheline mosquitoes of India and the Far East. *J. Mal. Inst. Ind.*, **5**, 4, pp. 399–434.

JASWANT SINGH (1933) ... ... Some observations on the mosquitoes and sandflies of Rajputana. *Rec. Mal. Surv. Ind.*, **3**, 3, p. 579.

MAJID, S. A., and SINTON, J. A. (1933) ... The longevity of females of *Culex fatigans* under experimental conditions, and the duration of malarial infections in these insects. *Ind. J. Med. Res.*, **21**, 2, p. 455.

ENTOMOLOGY—*contd.*

MAYNE, B. (1928)	A note on some recent attempts to transmit malaria organisms mechanically through mosquito-biting. *Ind. J. Med. Res.*, **15**, 4, p. 1067.
Idem (1928)	An anopheline mosquito as host for the parasites of bird malaria. *Ibid.*, **16**, 2, p. 557.
Idem (1929)	A note on some experimental attempts to transmit mechanically malaria organisms through mosquito-biting. (*Trans. F. E. A. T. M., 7th Cong., held in India*, Dec. 1927, **2**, p. 745.)
Idem (1930)	A study of the influence of relative humidity on the life and infectibility of the mosquito. *Ind. J. Med. Res.*, **17**, 4, p. 1119.
MCCOMBIE YOUNG, T. C., and MAJID, S. A. (1928).	A variety of *Anopheles karwari* collected in Coorg, S. India. *Ibid.*, **16**, 2, p. 169.
MEHTA, D. R. (1934)	Ratio of sexes of some Indian anophelines hatching under controlled conditions in the laboratory. *Rec. Mal. Surv. Ind.*, **4**, 1, p. 65.
Idem (1934)	Studies on the longevity of some Indian anophelines. Pt. I. Survival of *Anopheles subpictus* Grassi under controlled conditions of temperature and humidity. *Ibid.*, **4**, 3, p. 261.
Idem (1934)	Effect of 'saline and free' ammonia on the oviposition of *Anopheles culicifacies* and *Anopheles subpictus* (*rossi*). *Ibid.*, **4**, 4, p. 411.
MULLIGAN, H. W., and PURI, I. M. (1936)	Description of *Anopheles* (*Anopheles*) *habibi* n. sp. from Quetta, Baluchistan. *Ibid.*, **6**, pp. 67 and 513.
PURI, I. M. (1935)	Schematic table for the identification of the Indian anopheline mosquitoes. Pt. I. Adults. *Ibid.*, **5**, 3, p. 265.
Idem (1935)	Schematic table for the identification of the Indian anopheline mosquitoes. Pt. II. Full-grown larvæ. *Ibid.*, **5**, 3, p. 269.
Idem (1936)	The distribution of anopheline mosquitoes in India: Additional records, 1931–1935. *Ibid.*, 6, 2, p. 177.
RAJINDAR PAL (1944)	Nephrocytes in some culicidæ-diptera. *Ind. J. Ent.*, **6**, pp. 143–145.
Idem (1945)	On the bionomics of *A. culicifacies* Giles. Pt. II. The behaviour of adults. *J. Mal. Inst. Ind.*, **6**, 2, pp. 217–238.
Idem (1945)	On the bionomics of *A. culicifacies* Giles. Pt. III. The behaviour of adults. *Ibid.*, pp. 239–245.
SENIOR WHITE, R. (1928)	Algæ and the food of anopheline larvæ. *Ind. J. Med. Res.*, **15**, 4, p. 969.
Idem (1928)	Physical factors in mosquito ecology. Pt. II. *Ibid.*, **16**, 1, p. 11.
SINTON, J. A. (1927)	Notes on some Indian species of the genus *Phlebotomus*. Pt. XVI. Two Assamese 'sandflies' resembling *P. malabaricus*. *Ibid.*, **14**, 4, p. 933.
Idem (1927)	Notes on some Indian species of the genus *Phlebotomus*. Pt. XVII. Further records of the geographical distribution. *Ibid.*, **14**, 4, p. 941.
Idem (1927)	Notes on some Indian species of the genus *Phlebotomus*. Pt. XVIII. Miscellaneous notes. *Ibid.*, **14**, 4, p. 947.

ENTOMOLOGY—*contd.*

SINTON, J. A.	(1927)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XIX. The value of the female genitalia in the identification of species. *Ind. J. Med. Res.*, **15**, 1, p. 21.
Idem	(1927)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XX. The morphology of the buccal cavity in some species. *Ibid.*, **15**, 1, p. 29.
Idem	(1927)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXI. *Phlebotomus christophersi* n. sp. *Ibid.*, **15**, 1, p. 33.
Idem	(1927)	...	... Some Indian species of the genus *Phlebotomus* with special reference to new aids to the differentiation of species. (Designation of a new species.) *Trans. Roy. Soc. Trop. Med. Hyg.*, **21**, 1, p. 5.
Idem	(1928)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXII. The female of *P. newsteadi* Sinton 1926. *Ind. J. Med. Res.*, **15**, 3, p. 589.
Idem	(1928)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXIII. *Phlebotomus clydei* n. sp. *Ibid.*, **16**, 1, p. 179.
Idem	(1928)	...	... The synonymy of the Asiatic species of *Phlebotomus*. *Ibid.*, **16**, 2, p. 297.
Idem	(1929)	...	... The identification and classification of the species of the genus *Phlebotomus*, with some remarks on their geographical distribution in relation to disease. (*Trans. F. E. A. T. M., 7th Cong., held in India*, Dec. 1927, **3**, p. 172.)
Idem	(1929)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXIV. *Phlebotomus barraudi* n. sp. *Ind. J. Med. Res.*, **16**, 3, p. 716.
Idem	(1930)	...	... The female of *Phlebotomus nicnic* Banks, 1919. *Ibid.*, **18**, 1, p. 165.
Idem	(1930)	...	... Some new species and records of *Phlebotomus* from Africa. *Ibid.*, **18**, 1, p. 171.
Idem	(1930)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXV. *Phlebotomus maynei* n. sp. *Ibid.*, **18**, 1, p. 195.
Idem	(1931)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXVI. *Phlebotomus eleanorae* n. sp. *Ibid.*, **18**, 3, p. 817.
Idem	(1931)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXVII. *Phlebotomus bailyi* n. sp. *Ibid.*, **18**, 3, p. 821.
Idem	(1931)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXVIII. *Phlebotomus purii* n. sp. *Ibid.*, **18**, 4, p. 1203.
Idem	(1931)	...	... *Phlebotomus stantoni* Newstead, 1914, and some other Siamese sandflies. *Ibid.*, **19**, 1, p. 99.
Idem	(1931)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXIX. *Phlebotomus arboris* n. sp. *Ibid.*, **19**, 1, p. 107.
Idem	(1932)	...	... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXX. Diagnostic table for the females of the species recorded from India. *Ibid.*, **20**, 1, p. 55.

ENTOMOLOGY—*concld.*

SINTON, J. A. (1932) ... ... Some further records of *Phlebotomus* from Africa. *Ind. J. Med. Res.*, **20**, 2, p. 565.

Idem (1932) ... ... Helminthic infections in Indian anopheline mosquitoes. *Rec. Mal. Surv. Ind.*, **3**, 2, p. 347.

Idem (1932) ... ... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXXI. *Phlebotomus cadithae* n. sp. *Ind. J. Med. Res.*, **20**, 2, p. 577.

Idem (1933) ... ... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXXII. *Phlebotomus dentatus* n. sp. *Ibid.*, **20**, 3, p. 869.

Idem (1933) ... ... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXXIII. *Phlebotomus hodgsoni*. *Ibid.*, **20**, 3, p. 873.

Idem (1933) ... ... A new African sandfly *Phlebotomus transvaalensis* n. sp. *Ibid.*, **20**, 3, p. 879.

Idem (1933) ... ... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXXIV. *Phlebotomus iyengari* n. sp. *Ibid.*, **21**, 1, p. 221.

Idem (1933) ... ... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXXV. Additions and alterations to the diagnostic table of females. *Ibid.*, **21**, 1, p. 225.

Idem (1933) ... ... Notes on some Indian species of the genus *Phlebotomus*. Pt. XXXVI. Diagnostic table for the male of the species recorded from India. *Ibid.*, **21**, 2, p. 417.

SINTON, J. A., and BARRAUD, P. J. (1928) Improved methods for the identification of some species of *Phlebotomus* used in experimental work. *Ibid.*, **16**, 2, p. 325.

SINTON, J. A., and COVELL, G. (1927) ... The relation of the morphology of the buccal cavity to the classification of anopheline mosquitoes. *Ibid.*, **15**, 2, p. 301.

EPIDEMIOLOGY.

COVELL, G. (1929) ... ... Measurement of the enlarged spleen in adults. (*Trans. F. E. A. T. M., 7th Cong., held in India*, Dec. 1927, **2**, p. 781.)

COVELL, G., and BAILY, J. D. (1927) ... Observations on malaria in the Andamans with special reference to the enlarged spleen in adults. *Ind. J. Med. Res.*, **15**, 2, p. 309.

Idem (1932) ... The study of a regional epidemic of malaria in Northern Sind. *Rec. Mal. Surv. Ind.*, **3**, 2, p. 279.

Idem (1936) ... Further observations on a regional epidemic of malaria in Northern Sind. *Ibid.*, **6**, 3, p. 411.

HICKS, E. P., and DIWAN CHAND (1936) ... Transport and control of *Aedes aegypti* in aeroplanes. *Ibid.*, **6**, 1, p. 73.

HICKS, E. P., and MAJID, S. A. (1937) A study of the epidemiology of malaria in a Punjab district. *Ibid.*, **7**, 1, p. 1.

MACDONALD, G. (1931) ... ... The mechanism of infection with malaria in children living under endemic and hyperendemic conditions. *Ind. J. Med. Res.*, **18**, 4, p. 1347.

Idem (1931) ... ... The significance of the various degrees of splenic enlargement in malarious communities. *Rec. Mal. Surv. Ind.*, **2**, 4, p. 569.

EPIDEMIOLOGY—*concld.*

MAYNE, B. (1928) ... ... The influence of relative humidity on the presence of parasites in the insect carrier and the initial seasonal appearance of malaria in a selected area in India. *Ind. J. Med. Res.*, **15**, 4, p. 1073.

Idem (1929) ... ... Initial seasonal appearance of malaria in a selected area in India, demonstrated by presence of parasites in the insect carrier. (*Trans. F. E. A. T. M., 7th Cong., held in India*, Dec. 1927, **2**, p. 740.)

SINTON, J. A. (1933) ... ... Rice cultivation in Spain, with special reference to the conditions in the delta of the River Ebro. *Rec. Mal. Surv. Ind.*, **3**, 3, p. 495.

Idem (1934) ... ... Suggestions with regard to the prevention of the spread of yellow fever to India by air traffic with special reference to insect transmission. *Health Bulletin No.* 20, Delhi.

IMMUNOLOGY.

JASWANT SINGH and HARWANT SINGH (1940). Observations on immunity in monkey malaria. *J. Mal. Inst. Ind.*, **3**, 1, pp. 99–114.

Idem (1940) Passive immunity in monkey malaria. *Ibid.*, pp. 137–142.

MULLIGAN, H. W., and SINTON, J. A. (1933). Studies in immunity in malaria. Pt. II. Superinfection with various strains of monkey malarial parasites. *Rec. Mal. Surv. Ind.*, **3**, 3, p. 529.

Idem (1933) ... Studies in immunity in malaria. Pt. III. Multiple superinfections with various strains of *Plasmodium knowlesi*. *Ibid.*, **3**, 4, p. 809.

SINTON, J. A. (1935) ... ... Studies in immunity in malaria. Pt. V. The nature of the tolerance shown by *Silenus irus* to infection with *Plasmodium knowlesi*. *Ibid.*, **5**, 4, p. 501.

SINTON, J. A., and HARBHAGWAN (1935) ... Studies in immunity in malaria. Pt. IV. The results of multiple heterologous superinfections, with a discussion of their relationship to some epidemiological problems and to the general principles of treatment. *Ibid.*, **5**, 3, p. 307.

SINTON, J. A., and MULLIGAN, H. W. (1932) Studies in immunity in malaria. Pt. I. An intradermal reaction in malarial infections in monkeys. *Ibid.*, **3**, 2, p. 323.

MALARIA SURVEYS.

AFRIDI, M. K. (1938) ... ... Antimalaria operations in Delhi. *Proc. Nat. Inst. Sci. Ind.*, **4**, 2, pp. 201-202.

Idem (1939) ... ... Aëdes survey of Hog Island. (Abstract.) *J. Mal. Inst. Ind.*, **2**, 1, pp. 113-114.

AFRIDI, M. K., and MAJID, S. A. (1938) ... Malaria in Bahrein Islands. *Ibid.*, **1**, 4, pp. 427–472.

AFRIDI, M. K., MAJID, S. A., and SINGH, J. (1938). Malaria in Kutch State. *Ibid.*, **1**, 2, pp. 187–213.

COVELL, G. (1927) ... ... Report of an inquiry into malarial conditions in the Andamans. Govt. of India Press, Delhi.

Idem (1928) ... ... Malaria in Bombay. Govt. Central Press, Bombay.

Idem (1930) ... ... The malaria problem in Bombay. *Jl. Bom. Nat. Hist. Soc.*, **34**, 3, p. 736.

Idem (1932) ... ... Malaria in Calcutta. Bengal Secretariat Book Depot, Calcutta.

Idem (1932) ... ... Malaria in Calcutta. *Rec. Mal. Surv. Ind.*, **3**, 1, p. 1.

MALARIA SURVEYS—*contd.*

COVELL, G. (1932) ... ... Malaria in Patiala State. *Rec. Mal. Surv. Ind.*, **3**, 1, p. 83.

Idem (1932) ... ... A further note on malaria in Patiala State. *Ibid.*, **3**, 2, p. 271.

Idem (1934) ... ... Foreword to 'A survey of Aedes mosquitoes in Bombay and the measures suggested for their control', by R. K. Mhatre.

Idem (1934) ... ... Note on the control of mosquitoes and malaria in Delhi. *Rec. Mal. Surv. Ind.*, **4**, 3, p. 273.

Idem (1939) ... ... Antimalaria operations in Delhi. Pt. I. *J. Mal. Inst. Ind.*, **2**, 1, pp. 1–61.

Idem (1939) ... ... Note on antimalaria operations in Delhi. *J. Inst. Civ. Engineers*, **12**, 8, pp. 422-423.

Idem (1940) ... ... Malaria problems in the Wynaad. *Planters' Chronicle*, **35**, 15, pp. 309–312.

Idem (1941) ... ... Antimalaria operations in Delhi. Pt. III. *J. Mal. Inst. Ind.*, **4**, 1, pp. 1–13.

Idem (1944) ... ... Note on malaria situation in Bengal. *Ind. Hlth. Gaz.*, **1**, pp. 16–21.

Idem (1945) ... ... Malaria control in South West Pacific. *J. Uni. Serv. Inst. Ind.*, January.

Idem (1945) ... ... Malaria problem in rural India. *Perspective*, **1**, 2, pp. 11–15.

COVELL, G., and AFRIDI, M. K. (1939) ... Antimalaria operations in Delhi. Pt. II. *J. Mal. Inst. Ind.*, **2**, 4, pp. 315–340.

COVELL, G., and BAILY, J. D. (1930) ... Malaria in Sind. Pt. I. Malaria in the Guni Division of Hyderabad District. (Fuleli Canal Area.) *Rec. Mal. Surv. Ind.*, **1**, 4, p. 523.

Idem (1930) ... Malaria in Sind. Pt. II. Malaria in the Mirpur Khas Division of Thar and Parkar District (Jamrao Canal Area). *Ibid.*, **1**, 4, p. 539.

Idem (1930) ... Malaria in Sind. Pt. III. The factors influencing the normal autumnal incidence of malaria in Larkana Taluka, Larkana District. *Ibid.*, **1**, 4, p. 549.

Idem (1931) ... Malaria in Sind. Pt. IV. Malaria in Nawabshah District. *Ibid.*, **2**, 4, p. 507.

Idem (1931) ... Malaria in Sind. Pt. V. Malaria in Umarkot and Chhachhro Talukas in Thar and Parkar District (Lower Sind). *Ibid.*, **2**, 4, p. 527.

Idem (1931) ... Malaria in Sind. Pt. VI. Post-epidemic conditions in a rice growing area in Kambar Taluka, Larkana District. *Ibid.*, **2**, 4, p. 537.

Idem (1931) ... Malaria in Sind. Pt. VII. Malaria in the Upper Sind Frontier District. *Ibid.*, **2**, 4, p. 545.

Idem (1932) ... Malaria in Sind. Pt. VIII. Malaria in Shahbandar Division, Karachi District, Sind. *Ibid.*, **3**, 1, p. 103.

Idem (1934) ... Malaria in Sind. Pt. IX. Malaria in Sukkur District. *Ibid.*, **4**, 2, p. 119.

Idem (1934) ... Malaria in Sind. Pt. X. Malaria in Dadu District. *Ibid.*, **4**, 2, p. 145.

Idem (1934) ... Malaria in Sind. Pt. XI. Malaria in Larkana District. *Ibid.*, **4**, 2, p. 165.

Idem (1934) ... Malaria in Sind. Pt. XII. A note on malaria in a waterlogged area in Khairpur State. *Ibid.*, **4**, 3, p. 327.

MALARIA SURVEYS—*concld.*

Covell, G., and Baily, J. D. (1935) ...	Malaria in Sind. Pt. XIII. Malaria in Hala Taluka, Hyderabad District, and in Kandiaro, Sinjhoro and Shahdadpur Talukas, Nawabshah District. *Rec. Mal. Surv. Ind.*, **5**, 2, p. 109.
Idem (1935) ...	Malaria in Sind. Pt. XIV. The seasonal incidence of infection with the different species of malaria parasite in Larkana. *Ibid.*, **5**, 2, p. 121.
Idem (1936) ...	Malaria in Sind. Pt. XV. The effects produced by the operation of the Lloyd Barrage Scheme on the incidence of malaria in Sind. *Ibid.*, **6**, 3, p. 387.
Covell, G., and Harbhagwan (1939) ...	Malaria in the Wynaad, South India. *J. Mal. Inst. Ind.*, **2**, 4, pp. 341–376.
Covell, G., and Jaswant Singh (1943)	Antimalaria operations in Delhi. Pt. IV. *Ibid.*, **5**, 1, pp. 87–106.
Covell, G., and Pritam Singh (1942) ...	Malaria in the coastal belt of Orissa. *Ibid.*, **4**, 4, pp. 457–593.
Hicks, E. P., and Diwan Chand (1936) ...	A mosquito survey of Karachi air port. *Rec. Mal. Surv. Ind.*, **6**, 4, p. 515.
Jaswant Singh and Jacob, V. P. (1943)	Malaria in Ahmedabad (Abstract). *J. Mal. Inst. Ind.*, **5**, 1, p. 127.
Idem (1944)	Malaria investigation in North Kanara. *Ibid.*, **5**, 3, pp. 267–303.
McCombie Young, T. C., and Baily, J. D. (1928).	Malaria in Coorg. *Ind. J. Med. Res.*, **15**, 3, p. 745.
McCombie Young, T. C., and Majid, A. (1929).	Further observations on malaria in Coorg. *Ibid.*, **16**, 3, p. 766.
Idem (1930) ...	Malaria in Sind with reference to the Sukkur Barrage Scheme. *Rec. Mal. Surv. Ind.*, **1**, 3, p. 341.
Macdonald, G. (1931)	Report on a malaria survey in Bikaner State. *Ibid.*, **2**, 4, p. 603.
Macdonald, G., and Chowdhury, K. L. (1931).	Report on a malaria survey of the tea gardens in the Mariani Medical Association, Assam. *Ibid.*, **2**, 1, p. 111.
Macdonald, G., and Majid, A. (1931) ...	Report on an intensive malaria survey in the Karnal District, Punjab. *Ibid.*, **2**, 3, p. 423.
Mulligan, H. W. (1935)	Some notes on malaria in Baluchistan. *Ibid.*, **5**, 3, p. 339.
Idem (1936)	Report on malaria in Quetta with special reference to the programme of reconstruction. Govt. of India Press, Simla.
Mulligan, H. W., and Baily, J. D. (1936).	Malaria in Quetta, Baluchistan. *Rec. Mal. Surv. Ind.*, **6**, 2, p. 289.
Senior White, R. A. (1930) ...	Malaria at Delhi: Its incidence and causation. *Ibid.*, **1**, 3, p. 291.
Sinton, J. A. (1930)	Note on malaria in Delhi with special reference to the report of Mr. Senior White. *Ibid.*, **1**, 3, p. 337.
Idem (1930)	Note on the report on 'Malaria in Sind' by Lieut.-Col. McCombie Young and S. A. S. Syed Abdul Majid. (1st Note.) *Ibid.*, **1**, 3, p. 409.
Idem (1930)	Note on malaria and antimalarial measures in the Larkana District of Sind. (2nd Note.) *Ibid.*, **1**, 3, p. 413.
Idem (1931)	Reports on some short malaria surveys undertaken in Kathiawar. *Ibid.*, **2**, 3, p. 349.

PARASITOLOGY.

AFRIDI, M. K. (1938) ... ... Observations on extra-abdominal spleen in monkeys infected with *P. cynomolgi* and *P. knowlesi*. *J. Mal. Inst. Ind.*, **1**, 4, pp. 255–389.

JASWANT SINGH and HARWANT SINGH (1940). Agglutination reactions with *P. knowlesi*. *Ibid.*, **3**, 1, pp. 53–66.

KHAZAN CHAND and HARBHAGWAN (1934) Some unsuccessful attempts to transmit monkey malarial parasites to common laboratory animals. *Rec. Mal. Surv. Ind.*, **4**, 4, p. 373.

MAJID, S. A. (1933) ... ... Note on some unsuccessful attempts to infect a monkey by injections of living malarial sporozoites. *Ibid.*, **3**, 3, p. 475.

MAYNE, B. (1929) ... ... The nature of the 'Black Spores' associated with the malaria parasite in the mosquito and their relationship to the tracheal system. *Ind. J. Med. Res.*, **17**, 1, p. 109.

MULLIGAN, H. W. (1935) ... ... Descriptions of two species of monkey *Plasmodium* isolated from *S. irus*. *Arch. f. Protist.*, **84**, 2, p. 285.

SINGH, J., and HARBHAGWAN (1935) ... Failure to produce infection in two species of the lower Oriental monkeys by the injection of malarial sporozoites from naturally infected anophelines. *Rec. Mal. Surv. Ind.*, **5**, 4, p. 495.

SINTON, J. A. (1934) ... ... The malarial parasites of the Oriental monkey, *Silenus irus*. *Current Science*, **3**, 2, p. 48.

Idem (1934) ... ... A quartan malaria parasite of the lower Oriental monkey, *Silenus irus* (*Macacus cynomolgus*). *Rec. Mal. Surv. Ind.*, **4**, 4, p. 379.

Idem (1937) ... ... Some problems in the host-parasite relationship in the malarial infections of man and other animals. *Ibid.*, **7**, 1, p. 85.

SINTON, J. A., HARBHAGWAN and JASWANT SINGH (1931). The numerical prevalence of parasites in relation to fever in chronic benign tertian malaria. *Ind. J. Med. Res.*, **18**, 3, p. 871.

Idem (1931) ... ... The numerical prevalence of parasites in relation to fever in chronic benign tertian malaria. (*Trans. F. E. A. T. M., 8th Cong., held in Bangkok*, Dec. 1930, **2**, p. 263.)

SINTON, J. A., and MULLIGAN, H. W. (1932). Note on an intradermal reaction in monkey malaria. *Ind. J. Med Res.*, **20**, 2, p. 581.

Idem (1932) ... A critical review of the literature relating to the identification of the malarial parasites recorded from monkeys of the families *Cercopithecidae* and *Colobidae*. (1st half.) *Rec. Mal. Surv. Ind.*, **3**, 2, p. 357.

Idem (1933) ... A critical review of the literature relating to the identification of the malarial parasites recorded from monkeys of the families *Cercopithecidae* and *Colobidae*. Pt. II. *Ibid.*, **3**, 3, p. 381.

Idem (1933) ... Mixed infections in the malaria of the lower monkeys. Pt. I. Mixed infections as the cause of apparent variations in the morphology and pathogenicity of simian plasmodia. *Ibid.*, **3**, 4, p. 719.

Idem (1933) ... Mixed infections in the malaria of the lower monkeys. Pt. II. The probable occurrence of mixed infections in some of the older records of monkey malaria. *Ibid.*, **3**, 4, p. 769.

PATHOLOGY.

KEHAR, N. D. (1936) ... ... The effect of vitamin deficiency on antibody production and resistance to infection. *Rec. Mal. Surv. Ind.*, **6**, 3, p. 487.

KEHAR, N. D., and HARBHAGWAN (1937) Sedimentation rate of erythrocytes in human and monkey malaria. *Ibid.*, **7**, 2-3, p. 131.

MULLIGAN, H. W. (1929) ... ... Studies on the reticulo-endothelial system with special reference to malaria. Pt. I. Introductory. *Ind. J. Med. Res.*, **16**, 4, p. 1099.

Idem (1929) ... ... Studies on the reticulo-endothelial system with special reference to malaria. Pt. II. The large mononuclear cells in the peripheral blood in malaria. *Ibid.*, **16**, 4, p. 1107.

Idem (1931) ... ... Studies on the reticulo-endothelial system with special reference to malaria. Pt. III. The serum bilirubin in malaria. *Rec. Mal. Surv. Ind.*, **2**, 3, p. 495.

SINTON, J. A. (1927) ... ... Discussion on the hæmoglobinurias. *Trans. Roy. Soc. Trop. Med. Hyg.*, **20**, 7, p. 417.

TALIAFERRO, W. H., and MULLIGAN, H. W. (1937). The histopathology of malaria. *Ind. Med. Res. Memoir, No.* 29.

TECHNIQUE.

BARRAUD, P. J. (1929) ... ... A simple method for the carriage of living mosquitoes over long distances in the tropics. *Ind. J. Med. Res.*, **17**, 1, p. 281.

Idem (1931) ... ... Notes on some entomological technique for the malariologist. *Rec. Mal. Surv. Ind.*, **2**, 1, p. 157.

Idem (1933) ... ... A method of making slide smears from female *Anopheles*, for examination for sporozoites of malaria parasites, and of preserving the mosquitoes for reference. *Ind. J. Med. Res.*, **21**, 2, p. 451.

BHATTACHARJI, L. M., JASWANT SINGH and SEN GUPTA, G. P. (1946). A simple methylene blue eosin substitute for Leishman and Giemsa stains. *Ind. Med. Gaz.*, **81**, 10, pp. 400-401.

JASWANT SINGH and BHATTACHARJI, L. M. (1944). Rapid staining of malaria parasites by water soluble stain. *Ibid.*, **79**, 3, pp. 102–104.

Idem (1945) ... Note on the J. S. B. method of staining malaria parasites. *Ibid.*, **80**, 3, p. 159.

MAJID, S. A. (1937) ... ... An improved technique for marking and catching mosquitoes. *Rec. Mal. Surv. Ind.*, **7**, 1, p. 105.

MOHAN, B. N. (1945) ... ... Details of the procedure adopted in maintaining a laboratory colony of *A. fluviatilis*. *J. Mal. Inst. Ind.*, **6**, 1, pp. 75-76.

SINTON, J. A. (1935) ... ... A method for cleaning the capillary tubes used for the enumeration of malarial parasites in the blood. *Rec. Mal. Surv. Ind.*, **5**, 1, p. 1.

SINTON, J. A., and KEHAR, N. D. (1930) ... A field method for the estimation of the salinity of the water in mosquito-breeding places. *Ind. J. Med. Res.*, **18**, 1, p. 199.

SINTON, J. A., and MULLIGAN, H. W. (1930). The staining of malarial parasites in blood smear by the iron-hæmatoxylin method. *Ibid.*, **17**, 4, p. 1329.

THERAPEUTICS.

AFRIDI, M. K., RAMAKRISHNAN, S. P., GOSWAMI, A., and MENON, M. K. (1947). An enquiry on certain aspects of paludrine. *Ind. J. Mal.*, **1**, 1, pp. 221–229.

BIRD, W. (1928) ... ... The treatment of chronic benign tertian malaria with *Smalarina cremonese*. *Ind. J. Med. Res.*, **16**, 2, p. 347.

COVELL, G. (1943) ... ... The prophylaxis and treatment of malaria in war. *J. Mal. Inst. Ind.*, **5**, 2, pp. 129–157.

Idem (1947) ... .. A brief review of the history and development of the more important antimalarial drugs. *Ind. J. Mal.* (in press).

HICKS, E. P. (1935) ... ... Atebrin musonate: a note on the rate of absorption and on the local effects of intramuscular injection. *Rec. Mal. Surv. Ind.*, **5**, 2, p. 203.

HICKS, E. P., and DIWAN CHAND (1935) ... The relative clinical efficacy of totaquina and quinine. *Ibid.*, **5**, 1, p. 39.

JARVIS, O. D. (1932) ... ... Further researches into the treatment of chronic benign tertian malaria with plasmoquine and quinine. *Ind. J. Med. Res.*, **20**, 2, p. 627.

JASWANT SINGH and HARWANT SINGH (1939). Treatment of simian malaria with M. & B. 693. *J. Mal. Inst. Ind.*, **2**, 2, pp. 181–189.

KARAMCHANDANI, P. V. (1933) ... Parenteral *versus* oral administration of quinine. *Rec. Mal. Surv. Ind.*, **3**, 3, p. 445.

SINTON, J. A. (1927) ... ... Studies in malaria with special reference to treatment. Pt. VII. The intravenous injection of sodium stovarsol in the treatment of benign tertian malaria. *Ind. J. Med. Res.*, **15**, 2, p. 287.

SINTON, J. A. (1929) ... ... The effects of treatment on the incidence and degree of splenic enlargement in an adult population infected with malaria. (*Trans. F. E. A. T. M., 7th Cong., held in India*, Dec. 1927, **2**, p. 778.)

Idem (1929) ... ... The treatment of malarial fever. *Ibid.*, **2**, p. 804.

Idem (1930) ... ... Studies in malaria, with special reference to treatment. Pt. XIII. Parosan and dimeplasmine in treatment. *Ind. J. Med. Res.*, **17**, 3, p. 815.

Idem (1930) ... ... A suggested standard treatment of malaria based upon the results of the controlled investigation of over 3,700 cases. *Ind. Med. Gaz.*, **65**, 11, p. 603.

Idem (1930) ... ... Summary of experiments made in India on the value of the different cinchona alkaloids in the treatment of malaria. *Rec. Mal. Surv. Ind.*, **1**, 4, p. 429.

Idem (1930) ... ... Relative values of the cinchona alkaloids in the treatment of malarial fevers. *Ibid.*, **1**, 4, p. 451.

Idem (1931) ... ... Studies in malaria, with special reference to treatment. Pt. XIV. The effects of dosage of drugs and duration of treatment on the production of cure. *Ind. J. Med. Res.*, **18**, 3, p. 831.

Idem (1931) ... ... Studies in malaria, with special reference to treatment. Pt. XV. Does the strain of parasite influence cure? *Ibid.*, **18**, 3, p. 845.

Idem (1931) ... ... Studies in malaria, with special reference to treatment. Pt. XVI. The relationship of season to cure rate. *Ibid.*, **18**, 3, p. 855.

THERAPEUTICS—*concld.*

SINTON, J. A. (1931) ... ... The treatment of the malarial fevers. *Malayan Med J.*, **6**, 2, p. 33.

Idem (1933) ... ... Proposed mass treatment experiment for malaria in rural Bengal. Two notes. ('A New Antimalaria Scheme for Bengal', Bengal Public Health Dept., 1933, for official use only.)

Idem (1934) ... ... The standardization of mixed preparations of the cinchona alkaloids in relation to Indian conditions. *Rec. Mal. Surv. Ind.*, **4**, 1, p. 5.

Idem (1935) ... ... A discussion of some points contained in the 'Third General Report of the Malaria Commission' on 'The Therapeutics of Malaria'. (*Qlg. Bull. Hlth. Orgn., L. of N.*, **4**, p. 643.)

SINTON, J. A., and BIRD, W. (1928) ... Studies in malaria, with special reference to treatment. Pt. IX. Plasmoquine in the treatment of malaria. *Ind. J. Med. Res.*, **16**, 1, p. 159.

Idem (1929) ... Studies in malaria, with special reference to treatment. Pt. XI. The cinchona alkaloids in the treatment of benign tertian malaria. *Ibid.*, **16**, 3, p. 725.

SINTON, J. A., BIRD, W., and EATE, S. N. (1927). Studies in malaria, with special reference to treatment. Pt. VI. The treatment of benign tertian malaria with peracrina 303. *Ibid.*, **15**, 2, p. 277.

Idem (1928) ... Studies in malaria, with special reference to treatment. Pt. VIII. The oral administration of quinine-stovarsol in the treatment of chronic benign tertian malaria. *Ibid.*, **15**, 3, p. 595.

SINTON, J. A., BIRD, W., and ORR, W. B. F. (1928). Studies in malaria, with special reference to treatment. Pt. X. Quinine-troposan in the treatment of chronic benign tertian malaria. *Ibid.*, **16**, 2, p. 333.

SINTON, J. A., SMITH, S., and POTTINGER, D. (1930). Studies in malaria, with special reference to treatment. Pt. XII. Further researches into the treatment of chronic benign tertian malaria with plasmoquine and quinine. *Ibid.*, **17**, 3, p. 793.

WATT, R. C., and HARBHAGWAN (1937) ... A note on the prevention of hæmoglobinuria in *P. knowlesi* infections in *S. rhesus* by methylene blue and its curative value when combined with quinine salts. *Rec. Mal. Surv. Ind.*, **7**, 2-3, p. 179.

MISCELLANEOUS.

COVELL, G. (1930) ... ... Mosquitoes and malaria. (In 'Ghosh's Hygiene and Public Health', 7th ed.)

Idem (1935) ... ... Mosquitoes and malaria. (In 'Ghosh's Hygiene and Public Health', 8th ed.)

Idem (1937) ... ... Scope and syllabus of the annual malaria class for medical officers. (I. M. H. Press, Delhi.)

Idem (1938) ... ... Malaria survey of India, 1927–1937. *J. Mal. Inst. Ind.*, **1**, 1, pp. 1–31.

Idem (1938) ... ... Mosquito and malaria. (In 'Ghosh's Hygiene and Public Health', 9th ed.)

Idem (1939) ... ... The principles and economics of antimalarial sanitation. *J. Malaya Br. Brit. Med. Ass.*, **3**, 2, pp. 128–133.

Idem (1940) ... ... The cultivation of pyrethrum in India. *Planters' Chronicle*, **35**, 18, pp. 370-371.

Idem (1941) ... ... Social aspects of malaria. *Sci. and Cult.*, **6**, pp. 664–666

Idem (1942) ... ... Note on the economy in the use of anti-malarial drugs *Ind. Med. Gaz.*, **77**, 11, pp. 643–646.

MISCELLANEOUS—*contd.*

COVELL, G. (1942) ... The public health aspect of malaria control. *Ind. Med. Gaz.*, 12, pp. 741–744.

Idem (1943) ... Malaria in war. *J. Uni. Serv. Inst. Ind.*, **73**, pp. 298–309.

Idem (1943) ... Mosquito and malaria. (In 'Ghosh's Hygiene and Public Health', 10th ed.)

Idem (1945) ... False economy in the planning and conduct of anti-malaria campaigns. *J. Mal. Inst. Ind.*, **6**, 2, pp. 247–249.

Idem (1945) ... Mosquito and malaria. (In 'Ghosh's Hygiene and Public Health', 11th ed.)

Idem (1946) ... Malaria course for engineers at the Malaria Institute of India, Delhi. Opening address. *J. Mal. Inst. Ind.*, **6**, 3, pp. 317–320.

Idem (1946) ... Malaria and irrigation in India. *Ibid.*, **6**, 4, pp. 403–410.

DAKSHINAMURTY, S. (1947) ... Measurements of malaria. Pt. I. Statistics applied to malariology. *Ind. J. Mal.* (in press).

MULLIGAN, H. W. (1932) ... Mosquitoes and malaria. *Allahabad Farmer*, **6**, 1, p. 2.

RAJA RAM (1935) ... Roads and malaria in India. *Indian Engineering*, **97**, April, p. 17.

Idem (1937) ... Roads and public health in India, with special reference to malaria, borrow-pits and road dust. *3rd Indian Roads Congress, Lucknow*, Paper No. 33.

SHORTT, H. E., SINTON, J. A., and SWAMINATH, C. S. (1935). The probable vector of Oriental sore in the Punjab. *Ind. J. Med. Res.*, **23**, 1, p. 271.

SINTON, J. A. (1927) ... Kala-azar at high altitudes. *Ind. Med. Gaz.*, **62**, 12, p. 723.

Idem (1929) ... A bibliography of malaria in India. *Rec. Mal. Surv. Ind.*, **1**, 1, p. 1.

Idem (1932) ... The transmission of Leishmania infections. (Discussion.) *Trans. Roy. Soc. Trop. Med. Hyg.*, **25**, 5, p. 348.

Idem (1932) ... The late Colonel Sir Ronald Ross, K.C.B., K.C.M.G., F.R.S., LL.D. (1857–1932). *Current Science*, **1**, 4, p. 109.

Idem (1932) ... Colonel Sir Ronald Ross, K.C.B., K.C.M.G., F.R.S., LL.D., I.M.S. (retd.). *Rec. Mal. Surv. Ind.*, **3**, 2, p. 175.

Idem (1935) ... Note on the quinine policy of India. (*12th Conf. Med. Res. Workers, Calcutta*, 1934, p. 144.) Govt. of India Press, Simla, 1935.

Idem (1935) ... What malaria costs India: nationally, socially, and economically. *Rec. Mal. Surv. Ind.*, **5**, 3, p. 223.

Idem (1935) ... What malaria costs India, nationally, socially, and economically (*contd.*). *Ibid.*, **5**, 4, p. 413.

Idem (1936) ... What malaria costs India, nationally, socially, and economically (*concld.*). *Ibid.*, **6**, 1, p. 91.

Idem (1936) ... Malarial prevalence in its relationship to the problems of food supply and increasing population in India. *Ibid.*, **6**, 1, p. 53.

Idem (1936) ... Man-made malaria in India. *Ind. Med. Gaz.*, **71**, 4, p. 181.

SINTON, J. A., and SHORTT, H. E. (1934) Cutaneous leishmaniasis as a natural infection of a dog in India. *Ind. J. Med. Res.*, **22**, 2, p. 393.

VARIOUS AUTHORS (1847–1924) ... Collected memoranda on malaria. *Rec. Mal. Surv. Ind.*, **1**, 2, p. 1.

MALARIA BUREAU BULLETINS.

No. 1. Lectures on malaria. By G. Covell. 3rd edition. 1945. *As.* 5 or 6*d.*

No. 2. Synoptic table for the identification of the anopheline mosquitoes of India. By S. R. Christophers, J. A. Sinton, G. Covell and P. J. Barraud. 3rd edition, revised, enlarged and illustrated by I. M. Puri. 1946. *Re.* 1 6 or 2*s.* 6*d.*

No. 3. Antimosquito measures with special reference to India. By G. Covell. 7th edition. 1946. *As.* 8 or 9*d.*

No. 4. Table for the identification of Indian fresh-water fishes, with description of certain families and observations on the relative utility of the probable larvivorous fishes of India. 2nd edition, revised and enlarged. By S. L. Hora and D. D. Mukerjee. 1938. *As.* 7 or 8*d.*

No. 5. Instructions for collecting and forwarding mosquitoes. By J. A. Sinton. 3rd edition, revised by I. M. Puri. 1945. *As.* 8 or 9*d.*

No. 6. How to do a malaria survey? By S. R. Christophers, J. A. Sinton and G. Covell. 5th edition. 1944. *Rs.* 2 12 or 5*s.*

No. 7. Synoptic table for the identification of the full-grown larvæ of the Indian anopheline mosquitoes. By I. M. Puri. 5th edition. 1945. *As.* 8 or 10*d.*

No. 8. The distribution of anopheline mosquitoes in India. By G. Covell. 2nd edition, revised and brought up to date by I. M. Puri. 1936. *As.* 6 or 8*d.*

No. 9. A practical entomological course for students of malariology. By P. J. Barraud. 3rd edition, revised by I. M. Puri. 1945. *Re.* 1 12 or 2*s.* 6*d.*

No. 10. Man-made malaria in India. By J. A. Sinton and Raja Ram. 3rd edition, revised by G. Covell (in press).

No. 11. Handbook of common water and marsh plants of India and Burma. By C. C. Calder and K. Biswas. 1937. *Rs.* 2 12 or 5*s.*

No. 12. Prevention of malaria incidental to engineering construction. By H. W. Mulligan and M. K. Afridi. 1938. *As.* 7 or 8*d.*

No. 13. What malaria costs India? By J. A. Sinton. 1939. *As.* 14 or 1*s.* 3*d.*

Note.—These bulletins are obtainable from the Manager of Publications, Government of India Central Publication Branch, Civil Lines, Delhi.

INDIAN MEDICAL RESEARCH MEMOIRS.

1. The distribution of anopheline mosquitoes in India and Ceylon. *No.* 5. By G. Covell. 1927.
2. A critical review of the data recorded regarding the transmission of malaria by the different species of Anopheles; with notes on distribution, habits and breeding places. *No.* 7. By G. Covell. 1927.
3. Larvæ of anopheline mosquitoes, with full description of those of the Indian species. *No.* 21. By I. M. Puri. 1931.
4. The histopathology of malaria, with special reference to the function and origin of the macrophages in defence. *No.* 29. By W. H. Taliaferro and H. W. Mulligan. 1937.

THE RELATIONSHIP BETWEEN THE BREEDING OF *A. FLUVIATILIS* AND DISTANCE FROM HUMAN DWELLINGS.

BY

V. VENKAT RAO, F.R.S.T.M. & H., M.R.SAN.I.

AND

M. I. PHILIP, B.A.

(*Malaria Section, Medical Department, B. N. Railway.*)

[September 29, 1946.]

CHRISTOPHERS (1933) stated that the distance traversed by Anopheles from their breeding places in search of food did not usually exceed about a quarter of a mile (1,320 feet), but it has been the general practice to extend anti-larval measures up to a distance of half a mile from the protected area in respect of most of the vector species on the assumption that, though most Anopheles do not traverse more than a quarter of a mile for food, a significant number would usually reach the half-mile limit, especially when the breeding is heavy. If the effective flight range of the vector is curtailed by about a thousand feet or so, there would be a very marked reduction in the cost of control measures. For instance, where the protected area is a small railway station consisting of a few staff quarters, the area under treatment in the half-mile limit would be about 500 acres, whereas if the radius is curtailed by 1,000 feet, the treated area would be not more than 163 acres, a reduction of over 66 per cent. Similarly, any extension beyond the half-mile limit would involve such an increase in acreage that anti-larval measures might well cease to be an economic proposition. Therefore, any curtailment in the acreage under treatment, if it is consistent with safety, is a welcome measure.

Adisubrahmaniam and Vedamanikkam (1943), in the Wynaad area, found larvæ of *A. fluviatilis* up to not more than a thousand feet from human dwellings. They also observed that anti-larval operations covering a radius of 1,000 to 1,200 feet from houses resulted in a marked reduction of *fluviatilis* adults in houses.

They, therefore, concluded that effective control of this species would be possible by confining anti-larval treatment to a maximum radius of 1,500 feet from the limits of the area to be protected.

In order to ascertain whether the conclusions arrived at by these authors would apply to the areas served by the B. N. Railway where *A. fluviatilis* and its closely related species *A. minimus* and *A. varuna* are the vectors, observations were in the first instance carried out at Daghora, a small station on the Jharsuguda-Raigarh section of the B. N. Railway in the Hazaribagh Ranges (*vide* map in Senior White, 1943). The spleen rate of the village near this railway station was 89 per cent in March 1939. There is no evidence that conditions have since improved. In this area, *A. minimus* is extremely rare, while *A. varuna* occurs in such small numbers that it probably plays, if at all, but a minor part in malaria transmission. *A. fluviatilis* is undoubtedly the major vector with an oöcyst rate of 3·4 per cent and a sporozoite rate of 2·5 per cent (Senior White, *loc. cit.*).

The village, which consists of not more than twenty huts, is situated within a hundred yards from the railway station. There are no other human habitations within a radius of a mile and a half. The only *fluviatilis* breeding place is a small nullah, which originates not far from the railway station and runs southwards across the railway for about two miles before it joins a longer nullah. For the purpose of larval collections, the nullah was divided into four sections of 600 feet each, starting from the point where it originated. In each section, 50 ladle-dips were made on each of the three occasions when larval collections were made. The results are set out in Table I.

According to this table, 18·8 per cent of all species and 3·5 per cent of *fluviatilis* were found within the first 600 feet, 22·5 per cent of all species and 13·1 per cent of *fluviatilis* were found between 600 and 1,200 feet, 11·1 per cent of all species and 8·8 per cent of *fluviatilis* were found between 1,200 and 1,800 feet and 47·6 per cent of all species and 74·6 per cent of *fluviatilis* were found between 1,800 and 2,400 feet. These results were thus diametrically opposed to those obtained by Adisubrahmaniam and Vedamanikkam (*loc. cit.*).

At this stage, the authors noticed a review of the paper by Shlenova (1943), in which she stated that anti-adult measures by pyrethrum spraying would eventually result in a decrease of anopheline breeding in the vicinity of sprayed houses through periodical killing of female mosquitoes before oviposition. Though this does not explain why a larger number of larvæ should be found beyond the 1,800-feet limit in the absence of other human habitations, the fact that the railway station was under pyrethrum spraying was accepted as a complicating factor, and it was decided to carry out similar observations at Vamsadhara Railway Bridge in the Jeypore Hills. This place, inhabited only by the railway engineering gangmen, has been without any form of malaria protection. The vectors of this area are *A. fluviatilis*, *A. minimus* and *A. varuna* (Senior White *et al.*, 1945). The only breeding place affecting the gangmen's quarters at the bridge is the Vamsadhara River, which runs at right angles to the railway line. There is no village within two miles of the bridge. The river was divided into five sections down-stream from the bridge, the first three each being 300 feet long and the remaining two 600 feet. A similar division was made up-stream. From the first 300 feet below

and above the bridge, 200 ladle-dips were made on each occasion. The same number of dips were made in the next two sections on either side of the bridge while, in the two larger sections, each 600 feet long, the number of dips was doubled to facilitate comparison. Eight such collections were made from October 1945 to January 1946, when the *fluviatilis* group reaches the peak of its prevalence in this area. The results are set out in Table II.

According to this table, nearly 58 per cent of the total of all species and 59 per cent of the *fluviatilis* group are found within 900 feet, while a considerable amount of breeding, including *fluviatilis*, takes place up to 2,100 feet, which is nearly half a mile.

It would thus appear that the behaviour of *A. fluviatilis* and the related species in the Hazaribagh Ranges and in the Jeypore Hills differs widely from that in the Wynaad area and that it would be unsafe to limit anti-larval operations to less than half a mile in the former two areas.

SUMMARY.

(1) *A. fluviatilis*, *A. minimus* and *A. varuna* breed in significant numbers up to at least half a mile from the place where they feed, and this distance is presumably their usual flight range in search of food.

(2) Anti-larval operations against these species cannot safely be limited to less than half a mile in these areas.

REFERENCES.

ADISUBRAHMANIAM, T. S., and VEDAMANIKKAM, J. C. (1943). *J. Mal. Inst. Ind.*, **5**, pp. 113–115.

CHRISTOPHERS, S. R. (1933) ... *Fauna of British India*, Diptera **1**, Taylor and Francis, London, p. 65.

SENIOR WHITE, R. (1943) ... *J. Mal. Inst. Ind.*, **5**, pp. 207–231.

SENIOR WHITE, R., GHOSH, A. R., and RAO, V. V. (1945). *Ibid.*, **6**, pp. 129–215.

SHLENOVA, M. F. (1943) ... Abst. *Trop. Dis. Bull.*, **40**, pp. 520-521.

TABLE I

Anopheline breeding in the Daghora Nullah.

Date.	0–600 feet.							601–1,200 feet.							1,201–1,800 feet.							1,801–2,400 feet						
	A. hyrcanus.	*A. subpictus.*	*A. culicifacies.*	*A. fluviatilis.*	*A. jeyporiensis.*	*A. maculatus.*	*A. annularis.*	*A. hyrcanus.*	*A. subpictus.*	*A. culicifacies.*	*A. fluviatilis.*	*A. jeyporiensis.*	*A. maculatus.*	*A. annularis.*	*A. hyrcanus.*	*A. subpictus.*	*A. culicifacies.*	*A. fluviatilis.*	*A. jeyporiensis.*	*A. maculatus.*	*A. annularis.*	*A. hyrcanus.*	*A. subpictus.*	*A. culicifacies.*	*A. fluviatilis.*	*A. jeyporiensis.*	*A. maculatus.*	*A. annularis.*
23–11–43 ..	..	..	..	..	..	20	..	4	..	..	12	..	11	3	..	..	..	4	..	1	..	..	..	..	32	2	..	..
7–12–43 ..	..	3	..	1	..	9	3	..	3	..	..	..	5	1	..	..	..	6	..	10	..	..	..	..	18	2	20	..
14–12–43 ..	..	..	..	3	..	7	..	..	..	1	3	..	9	..	..	1	..	..	..	3	2	..	..	..	35	4	3	..
TOTAL ..	..	3	..	4	..	36	3	4	3	1	15	..	28	4	..	1	..	10	..	14	2	..	..	..	85	8	23	..
Percentage of all species in each length.	18·8							22·5							11·1							47·6						
Percentage of *fluviatilis* in each length.	3·5							13·1							8·8							74·6						

TABLE II.

Anopheline breeding in Vamsadhara River.

Date.	0–300 feet.				301–600 feet.				601–900 feet.				901–1,500 feet.				1,501–2,100 feet.			
	A. culicifacies.	*A. fluviatilis.*	*A. varuna.*	*A. maculatus.*	*A. culicifacies.*	*A. fluviatilis.*	*A. varuna.*	*A. maculatus.*	*A. culicifacies.*	*A. fluviatilis.*	*A. varuna.*	*A. maculatus.*	*A. culicifacies.*	*A. fluviatilis.*	*A. varuna.*	*A. maculatus.*	*A. culicifacies.*	*A. fluviatilis.*	*A. varuna.*	*A. maculatus.*
23-10-45 ..	5	9	..	..	3	5	2	..	10	7	..	..	..	..	..	..	..	..	..	..
15-11-45 ..	1	2	1	..	2	17	10	..	..	34	11	..	9	8	10	..	..	..	..	..
4-12-45 ..	1	18	8	5	..	15	12	8	..	15	10	8	4	10	2	11	..	..	..	..
11-12-45 ..	..	8	17	..	..	15	11	3	..	15	7	..	..	12	12	..	..	16	11	..
18-12-45 ..	..	8	14	5	9	1	..	14	..	11	12	5	..	12	20	6	..	30	36	..
2-1-46 ..	5	12	..	5	7	7	2	..	..	3	3	12	20	6	4	8	10	14	..	..
12-1-46 ..	6	12	5	15	4	3	3	12	4	12	..	9	..	10	4	30	4	28	..	18
22-1-46 ..	8	17	..	19	..	4	1	8	3	5	3	8	..	4	4	20	10	4	..	20
TOTAL ..	26	86	45	49	25	67	41	45	17	102	46	42	33	62	56	75	24	92	50	38
Percentage of all species in each length.	20·2				17·1				20·2				22·1				20·0			
Percentage of *fluviatilis* plus *varuna* in each length.	20·5				16·7				22·6				18·2				22·0			

Indian Journal of Malariology, 1, 1, March 1947.

ON GONOTROPHIC DISCORDANCE AMONG CERTAIN INDIAN ANOPHELES.

BY

V. VENKAT RAO, F.R.S.T.M. & H., M.R.San.I.
(*Malaria Section, Medical Department, B. N. Railway.*)

[September 29, 1946.]

GONOTROPHIC dissociation is described as the phenomenon in certain Anopheles of disconnecting the functions of reproduction and nutrition, indicating that the mosquitoes continue to feed but their sexual activity is suspended. Gonotrophic concordance, on the other hand, denotes the habit of keeping the two functions proceeding in step, indicating either that reproduction and nutrition are carried on together or that both the functions are suspended at the same time. These phenomena, which were observed in the Netherlands in Europe in *A. maculipennis* var. *atroparvus* and *A. maculipennis* var. *messeæ*, are described by Swellengrebel and de Buck (1938), whose work should be studied in original for details.

Zhukov and Krasikova (1942) have reported that in Siberia about 30 per cent of the female *messeæ* collected in January and February were 'in a state of gonotrophic dissociation, indicating that repeated feeding was needed to complete ovarian development'. Thus, the behaviour of *messeæ* appears to be quite different at the two extremities of the palæarctic region.

There has been no reference to gonotrophic dissociation in respect of any Anopheles in India till recently. Strickland (1938) said that he suspected gonotrophic dissociation in *A. maculatus* in the Duars, but does not appear to have pursued the study of the subject. Afridi *et al.* (1940) made a negative reference by stating that they found no evidence of gonotrophic dissociation among *A. culicifacies* in the Punjab.

At Bhadrak (Orissa) and Dongargarh (Eastern States Agency), instead of the usual process of ovarian development keeping pace with digestion, another process was observed in some of the female *A. annularis* and *A. culicifacies* respectively, in which the abdomen resumed its normal size as the blood was digested, without corresponding ovarian development occurring. In November 1943, out of 52 *annularis* ♀ ♀ caught at Bhadrak, twelve were found either unfed (abdominal

stage I) or fed but with no evidence of ovaries maturing. Two out of these twelve specimens were dissected, but no eggs were found in them. In November 1944, in the course of a special house catch, the author collected 36 *annularis* ♀ ♀. Of these, 4 (11 per cent) were digesting blood (abdominal stage V) without any sign of ovarian development, one specimen in abdominal stage VI had very immature ova and two specimens, both in abdominal stage VII, had only a small number of mature ova (there were no immature ova), not more than a dozen in each. Thus, on both the occasions, about 20 per cent of *A. annularis* were found in a state of suspended or impaired sexual activity.

Similar observations were made in 1944 at Dongargarh in respect of *A. culicifacies*. During an attempt made to study the malaria situation at this place, it was observed that *A. culicifacies* showed a definite tendency to suspend sexual activity in a small proportion of cases towards the middle of September. This phenomenon was observed to extend to a larger number in the following two months. In the first week of November, 192 *culicifacies* ♀ ♀ were collected from human dwellings in the railway settlement, of which 38 (about 20 per cent) were found to have suspended their sexual activity either completely or partially.

In order to throw further light on the subject, the following work was done :—

At Bhadrak, 50 *annularis* ♀ ♀ showing signs of delayed or suspended sexual activity were put into a cage and allowed time to digest their blood meal. Of these, 22 died during the experimental period. As each of the remaining 28 mosquitoes completed digestion, a fresh human blood meal was offered to it, and it was readily taken, irrespective of the state of ovarian development. Eight of them did not show signs of any such development even after three feeds. Three developed the ovaries completely after three feeds and laid eggs in the cage. The remaining seventeen either did not complete maturation of the ovaries even after three feeds or laid only 8 to 10 eggs each at the end of 10 to 12 days.

Similar work was done at Dongargarh in respect of *A. culicifacies*. Thirty female *culicifacies* showing signs of gonotrophic disturbance were put in a cage and allowed to digest their blood meal. Six mosquitoes died during the course of the experiment. After digesting one more feed, one mosquito laid four eggs. The remaining 23 mosquitoes were fed altogether on three occasions. Of them, fourteen laid about the normal number of eggs after the third feed, while the remaining nine either did not develop their ovaries at all or showed incomplete development.

In both the cases, the experiments were made in November 1945 when mosquitoes are observed to complete digestion in an average of 72 hours.

Table I shows the ovarian stages of *A. annularis* from the Bhadrak area at the time of dissection for malaria parasites.

In gonotrophic concordance, all the mosquitoes shown in Table I, except those in ovarian stage I, should be in ovarian stage V at the time of dissection, which was made 48 to 72 hours after capture and when the last blood meal was completely digested. It cannot be said that failure of ovarian development beyond stage II is due to lack of feeding. A very large proportion of mosquitoes collected

from daytime resting places are found fed, while unfed specimens in abdominal stage I constitute the exception rather than the rule. The dissections shown in Table IX of Senior White *et al.* (1945) consisted entirely of fed specimens, but the mosquitoes dissected were found in all stages of ovarian development, though the proportion of stage V specimens was always high.

TABLE I.*

Ovarian stages of A. annularis *(house and cowshed collections combined) from the Bhadrak area.*

Month.	Number dissected.	Percentage found in ovarian stage.				
		I.	II.	III.	IV.	V.
1944.						
September ...	128	3	33	...	1	63
October ...	158	...	1	1	...	98
November ...	85	2	5	...	...	93
December ...	18	...	17	...	...	83

Note.—The solitary gut infection found in the above dissections was in ovarian stage III.

A mosquito found in ovarian stage I on dissection after digestion is an unfertilized female caught after feeding but before mating, which has been shown to occur in *A. culicifacies* in South India (Russell and Rao, 1942) and in *A. sundaicus* in Orissa (Rao *et al.*, 1942). Mosquitoes found in stage II are either developing the ovaries initially or have already oviposited at least once. If they have fed after oviposition, as the vast majority are observed to do in nature, and yet do not show signs of further ovarian development, suspension of sexual activity may be presumed. Those found in stages III and IV after digestion indicate that ovarian development is dependent on repeated feeding. The mosquitoes in ovarian stage V are, in a majority of cases, behaving normally, but among them there must be, if the above argument is correct, some which have completed ovarian development as a result of repeated feeding.

The above facts indicate that a certain amount of sexual inactivity occurs in *A. annularis* at Bhadrak and in *A. culicifacies* at Dongargarh. The condition observed in these two species cannot, in every case, be described as gonotrophic dissociation because, in true gonotrophic dissociation, there can be no ovarian development. If this takes place simultaneously with digestion, the

* These examinations were made in the B. N. Railway Malaria Laboratory by Major R. Senior White. Similar observations were made in respect of Anopheles of the *fluviatilis* group from the Singhbhum Hills (Senior White *et al.*, 1945).

condition is known as gonotrophic concordance. If, on the other hand, ovarian development does not keep pace with nutrition, but is dependent on repeated feeding, it appears to be neither gonotrophic dissociation nor gonotrophic concordance but a condition half-way between the two. This will be described as *gonotrophic discordance.*

It has been pointed out to the writer by Majors Lumsden and Robertson of No. 9 Malaria Field Laboratory through Major Senior White that, if gonotrophic dissociation occurs, there must at that time be some accumulation of fat. Therefore, a certain number of *A. annularis* from Bhadrak and *A. culicifacies* from Dongargarh, not being less than 200 on any occasion, were examined for fat estimation each month from August to December 1945. As no collection was made for this purpose at Dongargarh in December 1945, the omission was made good by a collection in January 1946. The estimation was made by means of the Soxhlet apparatus by Messrs. S. K. Majumdar and S. C. Mukherji of the B. N. Railway Public Health Laboratory, whose assistance is gratefully acknowledged. The results are shown in Tables II and III. That there is a definite increase of fat in both the species after August is well brought out by these figures, which are also in accordance with those made in respect of *atroparvus* and *messeae* in Europe by Hackett *et al.* (1932).

That those *annularis* and *culicifacies* which are in a state of suspended sexual activity take a fresh feed in the laboratory after the last meal is digested irrespective of whether ovarian development is completed and oviposition has taken place or not has already been shown. If such re-feeding occurs in nature, it has an important bearing on the transmission of malaria. James (1926) holds the view that repeated feeding increases the chances of infection. Mitzmain (1917) found that 40 per cent of mosquitoes became infected after two daily feeds, 70 per cent after five daily feeds and 100 per cent after seven such feeds, and said that the chances of a mosquito becoming infected thus increase with the number of feeds of infective blood it is able to obtain. This does not necessarily mean that the re-feeding referred to has taken place only as a result of suspended sexual activity, though it is not usual for a mosquito to complete digestion and oviposit within twenty-four hours. But female mosquitoes which are sexually active have to undertake frequent flights in search of breeding places, which may be as far as half a mile away from the feeding focus. Apart from the hazards incidental to maternity and outdoor existence, such mainly zoophilous mosquitoes as *A. annularis* and *A. culicifacies** are likely to 'waste' their infections on cattle on their return flights by the process of stabular deviation. They may not also be able to feed on man at the proper time for want of sufficient breadth of contact. 'Only those Anopheles which live constantly in houses are in a favourable position to become infected, as they are the only ones which, by their habit of frequently feeding on human carriers, are likely to feed during the short periods when the parasites of the carriers rise in numbers' (Swellengrebel and de Buck, *loc. cit.*). This is possible in the case of those Anopheles which have suspended their sexual activity either completely or partially and are thus fixed in houses for prolonged periods.

---

*The anthropophilic index of *A. annularis* is 2·2 per cent and that of *A. culicifacies* about 3 per cent on the average, though the latter species in certain areas shows a much more marked preference for human blood.

TABLE II.

Determination of fat in A. annularis *from Bhadrak.*

Date.	Number of specimens analysed.	Average weight of 1 mosquito in mgm.	Average weight of solids other than fat in 1 mosquito in mgm.	Average weight of water in 1 mosquito in mgm.	Average weight of fat in 1 mosquito in mgm.	Percentage of fat to dry weight.	Percentage of fat increase over August.
27- 8-1945 ...	270	1·020	0·349	0·317	0·354	34·7	...
24- 9-1945 ...	420	1·040	0·360	0·318	0·362	35·4	2·3
30-10-1945 ...	500	1·046	0·358	0·320	0·368	35·2	3·9
21-11-1945 ...	270	1·048	0·352	0·322	0·374	35·8	6·2
29-11-1945 ...	270	1·046	0·343	0·325	0·378		
29-12-1945 ...	250	1·048	0·338	0·328	0·382	36·5	7·9

TABLE III.

Determination of fat in A. culicifacies *from Dongargarh.*

Date.	Number of specimens analysed.	Average weight of 1 mosquito in mgm.	Average weight of solids other than fat in 1 mosquito in mgm.	Average weight of water in 1 mosquito in mgm.	Average weight of fat in 1 mosquito in mgm.	Percentage of fat to dry weight.	Percentage of fat increase over August.
26- 8-1945 ...	400	1·009	0·380	0·304	0·325	32·2	...
30- 9-1945 ...	200	1·010	0·370	0·310	0·330	32·7	1·5
30-10-1945 ...	200	1·010	0·368	0·310	0·332	32·9	2·2
23-11-1945 ...	200	1·012	0·360	0·316	0·336	33·4	3·4
24- 1-1945 ...	200	1·015	0·365	0·316	0·334	32·9	2·8

Table IV, which is prepared from the figures published by Senior White *et al.* (1943) for the Orissa coastal plain lends support to this view.

TABLE IV.

Months in all years in which dissections were made.	Number dissected.	G+.	Gl+.	Oocyst rate per cent.	Sporozoite rate per cent.
January to August ...	2,604	...	...	...	...
September ...	1,369	10	1	0·73	0·07
October	2,244	3	2	0·13	0·09
November ...	1,981	3	5	0·15	0·26
December ...	985	1	1	0·10	0·10

G+ = Gut infected. Gl+ = Salivary glands infected.

The sporozoite rate increases to such an extent after September that in November it is four times that of the September figure.

Now, though transmission commences in this area in September, the maximum incidence occurs in October and November (Senior White *et al.*, 1943), when gonotrophic dissociation is not much in evidence according to Table I. It is true that the percentage of fat increase during these months over August is more marked than in September (Table II), but most of the ovaries, unlike in September, are in ovarian stage V. This must then be the result, not of genotrophic dissociation, but of gonotrophic discordance in which ovaries develop to the full extent, but only after a prolonged period and as a result of repeated feeding. Thus, in India, gonotrophic discordance may be of as great importance as gonotrophic dissociation is in the Netherlands.

The following points arise out of these observations :—

(*a*) There is a certain amount of gonotrophic dissociation as well as gonotrophic discordance among certain Anopheles in India, but there is no suspension of sexual activity in any species *en masse*.

(*b*) During the late rainy season and in the autumn, a certain number of *A. annularis* and *A. culicifacies* in the areas under study enter into a state of gonotrophic dissociation.

(c) In certain others of the same species, ovarian development takes much longer than the normal period and is dependent on repeated feeding; during this period, there is no urge to leave the feeding place for oviposition.

(d) In any case, all mosquitoes continue to feed whether sexual activity is, or is not, suspended or impaired.

(e) During this period, *A. annularis* and *A. culicifacies* accumulate what appears to be transient fat to the same extent as *atroparvus* does in Holland.

(f) Repeated re-feeding, specially during the period of gonotrophic discordance, appears to increase the chances of infection.

If this is correct, the majority of mosquitoes which remain sexually active do not, as a rule, carry malaria but help in keeping up the population at a high level, whereas the minority in which such activity is suspended or delayed may alone be responsible for transmitting malaria.

This hypothesis was tested in the autumn of 1945 at Bhadrak and Dongargarh by spraying with pyrethrum all houses in the railway settlements once in ten days from 1st September to the end of October. This interval was decided upon in pursuance of the idea that no mosquito would be capable of entering into a condition connoting gonotrophic disturbance within the first ten days of its life. The spraying was done in addition to routine anti-larval treatment in order to deal with those of the vectors which have emerged from the breeding places in spite of anti-larval measures and become fixed in houses through suspension of sexual activity. The results as judged from the malaria incidence in that year, as compared with the previous two years when spraying was not done, are promising and suggest that the above hypothesis may have foundation in fact. They also offer an explanation, however imperfect, as to how the two mainly zoophilous species, viz. *A. annularis* and *A. culicifacies*, manage to transmit malaria on a large scale during certain months and maintain highly endemic conditions in certain areas.

The author wishes to make it clear that the work presented in this paper is purely preliminary in its nature and scope, and that much further work must be done before it can be established as proved. Being concerned mainly with routine malaria control measures, he is not in a position to continue the investigations, and this paper is offered for publication so that other workers more fortunately placed than himself may study the question further and arrive at definite conclusions.

ACKNOWLEDGMENT.

The writer is deeply grateful to Major R. Senior White, Malariologist, B. N. Railway, for his guidance and advice generously offered throughout this study.

REFERENCES.

Afridi, M. K., Majid, A., and Shah, I. A. (1940). *J. Mal. Inst. Ind.*, **3**, pp. 23–51.

Hackett, L. W., Martin, E., and Missiroli, A. (1932). *Amer. J. Hyg.*, **16**, pp. 137–162.

JAMES, S. P. (1926) ...	*Trans. Roy. Soc. Trop. Med. Hyg.*, **20**, pp. 143–157.
MITZMAIN, M. B. (1917) ...	*U.S.A. Pub. Hlth. Repts.*, **32**, pp. 1081–1083.
RAO, V. V., ROY, B. B., and RAO, P. JAGANNADHA (1942).	*J. Mal. Inst. Ind.*, **4**, pp. 405–408.
RUSSELL, P. F., and RAO, T. R. (1942).	*Amer. J. Trop. Med.*, **22**, pp. 535–558.
SENIOR WHITE, R., ADHIKARI, A. K., RAMAKRISHNA, V., and ROY, B. B. (1943).	*J. Mal. Inst. Ind.*, **5**, pp. 159–186.
SENIOR WHITE, R., GHOSH, A. R., and RAO, V. V. (1945).	*Ibid.*, **6**, pp. 129–215.
STRICKLAND, C. (1938) ...	*Ann. Rpt. Calcutta School of Trop. Med. and Hyg. for* 1937.
SWELLENGREBEL, N. H., and DE BUCK, A. (1938).	*Malaria in the Netherlands.*
ZHUKOV, N. M., and KRASIKOVA, V. I. (1942).	*Med. Parasitol.*, **11**, pp. 35–38. Abst. *Rev App. Ent.*, **32**, p. 165.

DE-WEEDING TANKS AND PONDS IN ANTIMALARIA OPERATIONS.

BY

V. VENKAT RAO. F.R.S.T.M. & H., M.R.San.I.,

AND

V. RAMAKRISHNA, B.Sc. (HONS.), F.R.E.S.
(*Malaria Section, Medical Department, B. N. Railway.*)

[September 29, 1946.]

THERE are several areas in India where vector Anopheles breed in still waters in association with aquatic vegetation. Application of chemical larvicides to those waters would be so costly as to be beyond the economic limit of the average village. In such cases, naturalistic measures 'offer great hope for the control of rural malaria in selected areas and can suitably be carried out by the peasants themselves' (Hackett *et al.*, 1938).

The main naturalistic measure applicable to overgrown still waters is de-weeding, which appears to be the best method, though not always the easiest or immediately cheapest.

De-weeding can be carried out in several ways, viz. (*a*) by manual and mechanical labour, (*b*) introduction of silt, (*c*) periodical drying, (*d*) salinification, and (*e*) growth of vegetable crops on dry tank beds.

De-weeding by manual and mechanical labour.—This is a costly process, but remains the only method available when immediate action is necessary, and when an epidemic is threatened or has just broken out. This is done by the employment of manual labourers on a temporary basis. The labourers root out the plants and remove them to the shore in shallow waters. The process is both different and difficult in deep waters. Here, the men have to reach the deeper parts of the tanks by means of rafts, but even then rooting out becomes impracticable. In such cases, a barbed wire held firmly by the labourers, either standing on opposite banks or sitting on rafts in the water, is lowered deep into the vegetation and dragged side ways a number of times in order to cut the plants at as great a distance

51 (A)

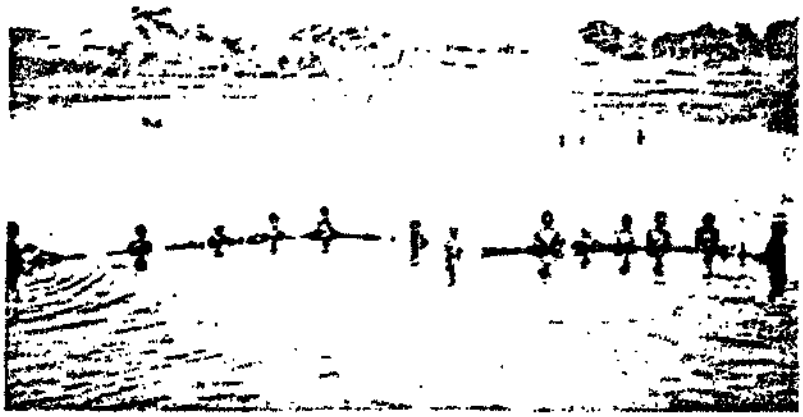


Figure 1.

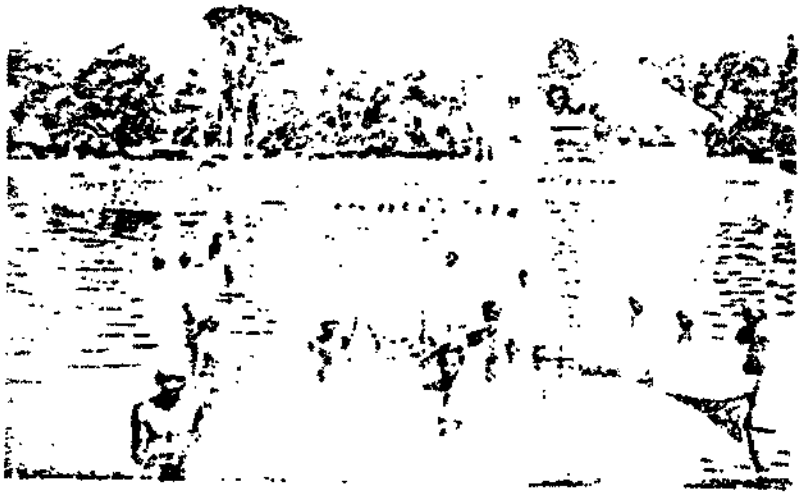
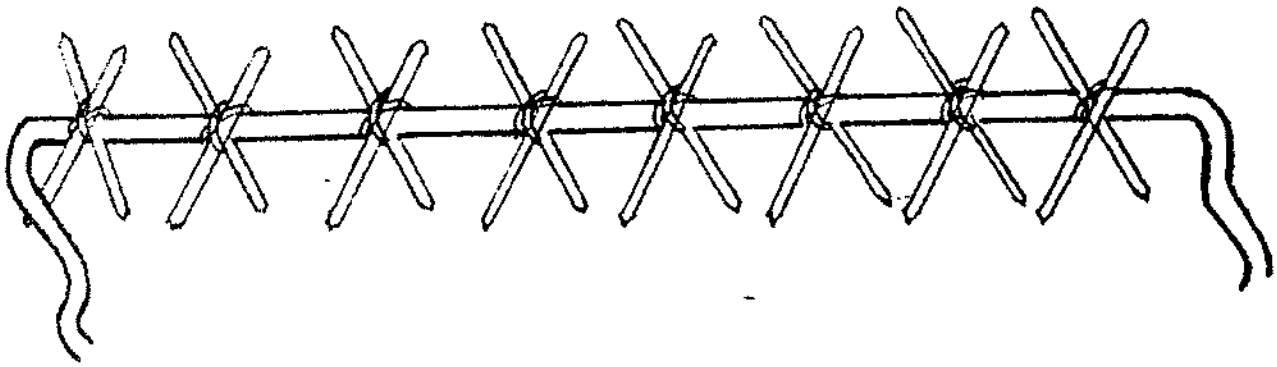


Figure 2.

Figure 3.

as possible from the surface of the water. The cut pieces of the plants now float on the water surface. These are collected on to the rafts or dragged to the bank by means of a long fishing net. Plate VI, figures 1 and 2 show both the processes, the men behind using the barbed wire for cutting the plants and those in front dragging them to the bank with a net. In the case of some types of vegetation like Pistia and Cladophora, the nets only are used without barbed wire, which is, however, necessary for vegetation like Hydrilla, Ceratophyllum, Nymphea, Nelumbium, etc. The cut plants are then removed well away from the water by means of what are locally called (bamboo) *dolas* because, if left near the water edge, they take root there and extend into the interior of the tank. Figure 3 of Plate VI shows two women labourers in the foreground removing vegetation away from the water edge by means of *dolas*. All cut pieces are thus removed from the water surface, which should be left absolutely clean, because if odd bits of plants, specially Hydrilla, Ceratophyllum and Najas, are left on the water surface, they reproduce vegetatively and establish themselves again in a short time.

During the recent war, when barbed wire was in short supply, a contrivance which was called the 'barbed rope' was used instead (Text-figure 1). This is made from a strong coir rope available locally, to which two bamboo pegs (each about 18 inches long) are fixed crosswise and fastened by means of strong knots at each one-foot interval. The barbed rope is used in the same way as the barbed

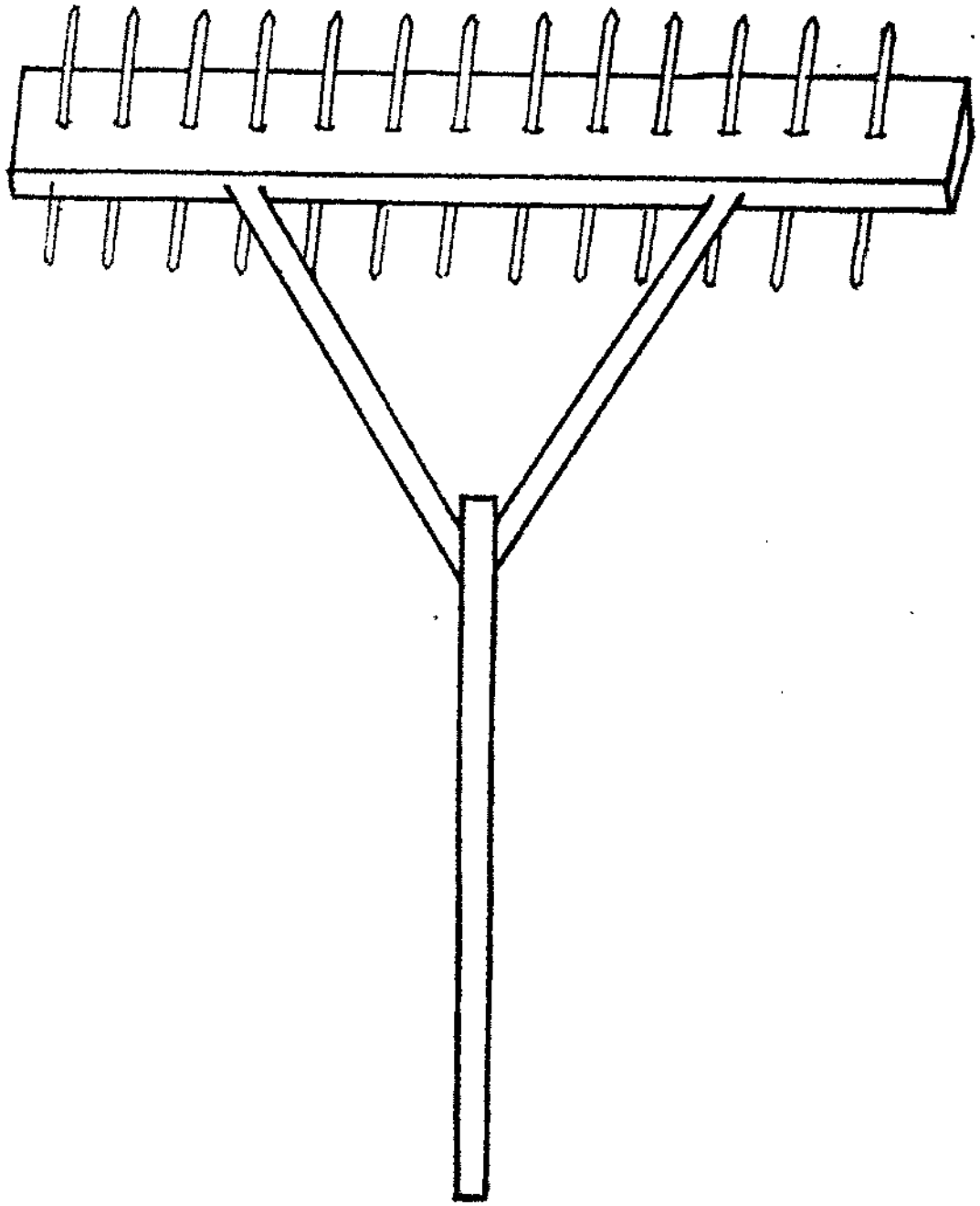


TEXT-FIGURE 1.—Barbed rope.

wire, but it possesses such advantages over the barbed wire that it has now virtually replaced the latter in our routine operations. The barbed rope is lighter, saves labour and, owing to the bamboo pegs being longer and fixed crosswise, can cut and gather more vegetation in each round than can a barbed wire.

There is usually a large amount of vegetation at the edges of a tank, which are far too shallow for the barbed rope and fishing net to be used to any advantage. In such cases, the vegetation has to be rooted out and completely removed. Hand picking would be time-consuming and, therefore, certain mechanical contrivances are used. At first, we use what we call a 'bamboo rake' (Text-figure 2) which consists of a wooden plank, about 4 feet long and 4 inches wide, to which bamboo spikes, sharpened at both ends, are fixed at intervals of 3 to 4 inches. A

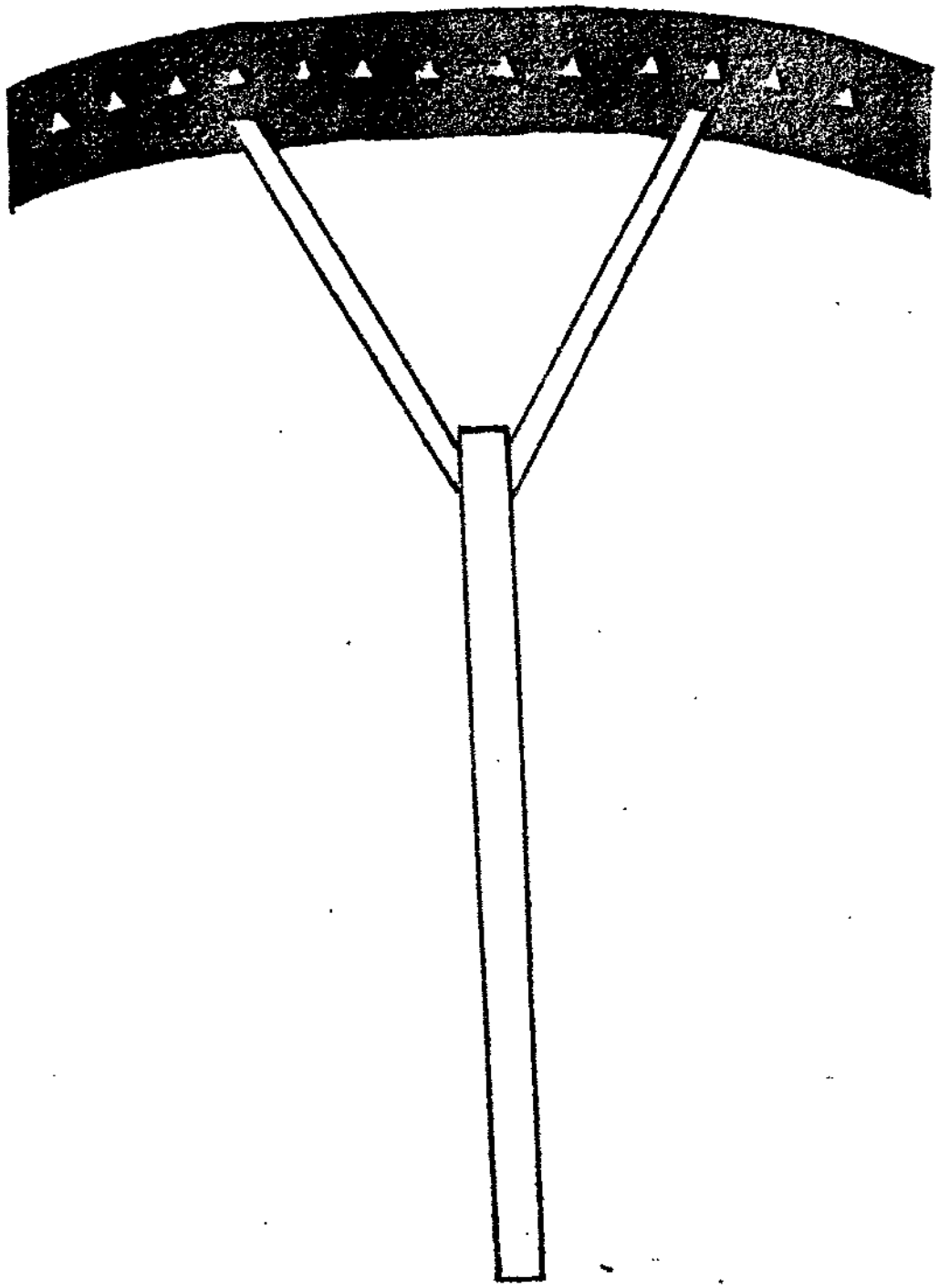
bamboo handle is attached at the centre. The labourers drag this in shallow water towards the edge, so that the vegetation may be cut and gathered there. Odd pieces of vegetation, which escape through the spaces between the spikes, are then collected by another contrivance which we have called the



TEXT-FIGURE 2.—Bamboo rake.

'scraper' (Text-figure 3) and brought to the shore. The scraper is made of a semi-circular galvanized iron sheet (any old piece of a sheet will do for this purpose), about 5 feet in length and 5 inches in width, fastened to a bamboo handle. Holes are drilled into the sheet at intervals of about 3 inches, in order

that water may escape through them while vegetation is dragged along the edge. The scraper can also root out delicate plants and remove broken pieces of vegetation sticking in the mud. One feature about these contrivances is that they are all made or are available locally.



TEXT-FIGURE 3.—Scraper.

It has been stated that de-weeding by these means may be a costly affair. An idea of the cost involved when labour is paid can be obtained by a reference to

Table I relating to Ichapuram, a small town on the North Vizagapatam Coast, which was freshly invaded by *A. sundaicus* towards the end of 1943, causing a severe outbreak of malaria, and where de-weeding had to be carried out urgently. Only those tanks in which larvæ of *sundaicus* were found were de-weeded.

When the preliminary de-weeding is completed, the tanks have to be maintained in a constantly clean condition by as frequent attention as necessary. Re-growth of vegetation in newly de-weeded tanks occurs very quickly and constitutes a problem to the malariologist. Some plants like Hydrilla, Ceratophyllum and Najas grow much faster than others, such as Pistia, Nymphea and Nelumbium. Maintenance is carried out by a permanent labour force, whose duty it is to attend to each tank once in eight to ten days and remove such growth as has already appeared at the surface, or is likely to break the surface within the next day or two. At Ichapuram Town, the maintenance gang consisted, for the first two years, of ten labourers, costing about Rs. 1,400 annually. Owing to the war and the consequent rise in the cost of living, dearness allowances at varying rates were subsequently allowed, bringing the total cost to about Rs. 2,800 per annum, which works out at Rs. 32-14-0 per acre per annum. These figures do not include cost of supervision.

The cost of the first de-weeding of similar waters on the Orissa Coastal Plain was Rs. 12-6-4 per acre before the war. Subsequent costs, with regular repetitions, are on an ever-decreasing scale (Senior White *et al.*, 1943).

Table II shows the flora and anopheline fauna of all tanks in the town before de-weeding and Table III shows the changes brought about in the fauna as a result of de-weeding. These tables do not indicate the density of larvæ before and after de-weeding; they only show whether certain species were present or not. It is thus necessary to state that de-weeding has eliminated *A. sundaicus* altogether, while the density of *A. annularis* and *A. pallidus* has been greatly reduced. *A. hyrcanus* was also eliminated, whereas *A. subpictus* and *A. vagus* showed a considerable increase in numbers. Therefore, de-weeding either completely eliminates or greatly decreases vector breeding, but may result in an increase in the breeding of harmless species.

It is thus clear that, in spite of its cost, de-weeding is a very efficacious naturalistic measure in the control of *A. annularis* and *A. sundaicus*. This method is not, however, without its disadvantages.

Most of the tanks in the villages and smaller towns in the Chilka Lake and North Vizagapatam areas are used indiscriminately by the people for drinking, washing and other domestic purposes. It has not been found possible to earmark certain tanks for drinking and others for other purposes. As long as there is dense vegetation in the tanks, the water is generally clear and appears to the villagers to be suitable for drinking. When, however, the major vegetation is removed, the water ceases to be clear, becomes rather 'turbid' and appears to be unfit even for domestic purposes. The people of the villages were not slow to observe the change and, though they did not actively obstruct the de-weeding measures, they vigorously protested against them in several instances. It was true that, as a result of de-weeding, there was discoloration of the water in some tanks and

*Microcystis aeruginosa** appeared in considerable quantities at the surface. In order to ascertain if the quality of the water deteriorated and was rendered less fit for use by de-weeding, samples of water from an overgrown tank and from a de-weeded tank in Berhampore (Orissa) were sent for chemical analysis. The results are set out in Table IV†.

On account of de-weeding the water was rendered 'very dirty and full of algæ' (Microcystis spp.), the odour was 'very putrescent', and there was a marked increase in the ammonia figures, specially from the de-weeded tank, which is ascribed to 'proteolysis of the very large amount of algæ' found in the water. In short, the water was rendered unfit for drinking.

This was clearly as discouraging as it was unexpected. An attempt was, therefore, made to study the bionomics of Microcystis, with a view to concert measures to control its growth in de-weeded tanks. The results of the study are shown in Table V.

Microcystis appears to be a delicate alga, unable successfully to establish itself either in association with, or competing against, major aquatic plants like Hydrilla and Najas. When, however, the major plants are removed, Microcystis rapidly grows and entirely covers the water surface in certain tanks. The rotting of pieces of other vegetation left in the tanks after de-weeding appears to accelerate its growth. It has been observed that Microcystis grows more rapidly in the dry months than during rains, a porous soil being more favourable than hard or clayey soils. Depth of water does not appear to affect it much, as it exists in both deep and shallow waters. Microcystis does not tolerate disturbance to the water in which it grows. If the tank is usually fed by irrigation or other channels and if its water is occasionally drained away for irrigation, Microcystis does not grow well in it. The most favourable condition for its growth appears to be organic pollution, which is present in most open tanks.

The presence of Microcystis is invariably correlated with the absence of anopheline breeding, specially of the vector species. Though this is what the malaria worker desires, he cannot, and in our opinion should not, ignore the other public health aspects involved in the question. As long as the people are allowed to make use of all tanks for all purposes, the waters should be kept up at as high a sanitary level as possible and, in any case, they should not be rendered more impure than they already are.

Microcystis can be controlled by adding 5 to 10 lbs. of copper sulphate for every million gallons of water. This is stated to inhibit this alga completely, while discouraging to an appreciable extent the growth of other vegetation. The treatment has to be repeated as long as Microcystis persists in regrowing.

Apart from the cost involved in this method, the authors were averse to the use of a chemical substance against the results of naturalistic measures. Instead of de-weeding major plants and then using copper sulphate to control minor vegetation, paris green might as well be used to control anopheline breeding itself.

---

* Identification confirmed by Dr. K. Biswas of the Royal Botanical Gardens, Calcutta.

† This and other chemical analyses mentioned in this paper were made by Mr. S. C. Mukherji of the B. N. Railway Public Health Laboratory, to whom the authors wish to express their thanks.

It has already been stated that Microcystis is a delicate alga which cannot compete with any hardier plant. Its control must thus consist of the introduction of other major or hardier anti-anopheline plants. Such are the various species of Lemna, especially *minor* and the ferns *Salvinia* and *Azolla* (Hackett *et al., loc. cit.*) or bottom growing plants like *Ottelia alismoides.*

In certain shallow tanks at Bhadrak (Orissa plain), Microcystis grows, not as the result of de-weeding, but spontaneously during the autumnal months. As soon as it establishes itself, *Lemna minor* grows and rapidly eliminates Microcystis. It is, therefore, assumed that introduction of *Lemna minor* controls the growth of Microcystis and the following experiment was made at Naupada (North Vizagapatam Coast).

Microcystis appeared in two de-weeded tanks, referred to in our malaria control plans as Tanks 1 and 2 respectively. *Lemna minor* was introduced into Tank 1 from a pukka well of the same locality where it is always present in considerable quantities. Tank 2 was left untreated for comparison. *Lemna minor* was soon found to thrive very well in Tank 1 and effectively to check Microcystis. But it was a very short-lived affair, as it gradually disappeared in Tank 1 and Microcystis returned to it. Microcystis was present in Tank 2 throughout the period.

The waters of the pukka well and the two tanks mentioned above were chemically analysed in the B. N. Railway Public Health Laboratory to see if any chemical factors were involved in the growth of *Lemna minor.* The results are shown in Table VI.

The water of Tank 2 appears intermediate in all values between those of the pukka well and Tank 1, except that the pH is slightly lower. However, the analysis does not show any significant chemical differences in the three waters likely to encourage or limit the growth of *Lemna minor.*

Azolla and Wolffia are other anti-anopheline plants which can be used in the control of Microcystis and which can grow along with *Lemna minor.* But, as these plants are also observed to thrive, like Microcystis, generally in polluted waters, their value in clear water tanks appears to be very limited.

Ottelia alismoides is a common submerged annual rooted aquatic herb of shallow, stagnant waters occurring throughout India (Biswas, 1936). It grows mostly at the bottom in abundance, but its flowers come to the surface in stalks for pollination. Being a submerged plant, it has not been associated with anopheline breeding. In order to ascertain its potentiality in controlling Microcystis, the following experiments were made :—

A cemented sump, about 4′×4′×4′, was constructed at Naupada. The bottom, which was also cemented, was filled to a height of one foot with earth taken from a tank bed and *Hydrilla verticillata* was planted on it. This plant grew rapidly and almost covered the water surface, when it was removed by hand. In less than a fortnight, Microcystis developed at the surface, proving experimentally what was already observed in the field. Then, *Ottelia alismoides* was thickly planted at the bottom. In about a month, this took root and began to thrive. Microcystis disappeared and the water again became clear. After a few days Hydrilla

reappeared in small quantities but, after one cleaning, it did not again recur. It, therefore, appears that Ottelia, when once established, can effectively control Microcystis and also limit the development of other major plants like Hydrilla. Care must, however, be taken not to interfere with the flower shoots at the surface, as otherwise the plant cannot propagate itself.

Ottelia was then planted in two de-weeded tanks, one at Berhampore and the other at Gangadharpur (Orissa). The plant is thriving well and Microcystis has completely disappeared, though its effect on limiting the growth of other major plants is still under study. However, the growth of Ottelia appears to be more marked in very shallow tanks which are likely to dry up every summer than in deeper tanks.

Introduction of silt.—Most aquatic vegetation grows in deep clear water tanks and ponds, into which subsoil seepages have access. If these waters are rendered turbid by the introduction of silt-laden flood waters, aquatic vegetation cannot thrive, as the particles of silt absorb and radiate the heat from the sun's rays and thereby increase the water temperature which inhibits the growth of vegetation (Welch, 1935). Certain observations made at Bhadrak (Orissa) and at Ulubaria (Lower Bengal) confirmed the view that this method is applicable to conditions in the area under review. Tank No. 6 of Ichapuram (North Vizagapatam Coast) was selected for this experiment. On survey in 1943, the flora and anopheline fauna of the tank were as follows :—

Flora.	*Fauna.*
Hydrilla verticillata	*A. hyrcanus*
Najas spp.	*A. barbirostris*
Ceratophyllum demersum	*A. subpictus*
Scirpus grassus	*A. vagus*
Eleocharis spp.	*A. culicifacies*
Eichhornia speciosa	*A. annularis*
Spirogyra	*A. pallidus*
Cladophora	

The extent of the tank is 5·3 acres. Very turbid water from the Bahuda River, about half a mile away, was introduced into this tank at the beginning of the rainy season in July 1944 and again in August 1944. The fact that the water had to traverse a distance of nearly half a mile before reaching the tank should be emphasized, as part of the silt would be lost by being deposited in transit. The result was not very satisfactory, as all the above-mentioned species of aquatic plants were again seen to be thriving by the end of September. The tank was again filled with turbid flood water from the same river during the rainy season of 1945, and this time the result was much more satisfactory. In January 1946, only sparse vegetation was found in the tank, *Eichhornia speciosa* (a very hardy plant) being also badly affected. Silting, therefore, appears to exert a rather slow but sure influence on the growth of vegetation and, though unsuitable in emergencies, can be relied upon as a long-term measure in de-weeding still waters.

Periodical drying.—Hackett *et al.* (*loc. cit.*) have shown how Welch controlled vegetation of fish ponds in Java, specially Enteromorpha, by periodical drying.

This method cannot be followed in a number of tanks in the area covered by this paper. In Orissa, the vast majority of the tanks are not constructed for the irrigation of ricefields. They are dug deep into the ground, either to provide drinking water and fish or for furnishing the earth required for building houses. There is no means of draining them by ordinary means for want of proper levels. Even if drainage were possible, it cannot be carried out, as there is no means of refilling them with fresh water. Drying as a routine measure is, therefore, out of the question in such areas.

An attempt was, however, made at Ichapuram to dry up a tank during the summer, in order to see if this procedure would help in curtailing the amount of vegetation in the rainy season and winter. Tank No. 4 was dried up in February 1945 by draining the water into the Bahuda River. The tank was kept dry for over 4 months. Its vegetation on survey was Hydrilla, *Scirpus grassus*, Spirogyra and Cladophora. In 1944, it took 110 man-days in 13 rounds for maintenance. In 1945, after drying, 93 man-days were spent in 18 rounds for the same purpose. The species and amount of vegetation remained practically as it was in the previous year. Annual drying in the summer months is of no use in respect of 'deep' tanks.

Things are somewhat different on the North Vizagapatam Coast south of Calingapatam. Here the annual rainfall is much less and more uncertain than in Orissa, being on an average about 35 inches against 60 inches, and flood water has to be conserved in tanks for irrigating ricefields in periods of drought. These are necessarily 'high level' tanks in order that the water may easily gravitate into the fields below. They are filled with flood water during the rains and are periodically but partially drained for irrigation. They are mostly dry for about half the year. The large majority of the tanks in the Vizagapatam District south of Calingapatam belong to this category, and are so devoid of vegetation that Covell and Pritam Singh (1942) described them as being entirely free from weeds. Each village, however, has one or two tanks of a different type reserved for drinking purposes. These tanks should necessarily contain clear water throughout the year and are, therefore, dug deep into the ground as in Orissa, and vegetation grows almost as thickly in them as in the latter area. Two tanks near Sigadam railway station (south of Calingapatam), situated within a few yards of each other, were studied in order to ascertain why vegetation thrived in one but was entirely absent in the other. One of them is an irrigation tank, its bottom being at ground level, which is devoid of subsoil seepages and contains only flood water. This tank is dry from January to May. The other is a drinking water tank, dug into the ground, containing water about 15 feet deep at the time of examination. This contains water throughout the year. The former had no vegetation at all, while the latter had a thick growth of the following plants :—

Hydrilla up to 3 feet from the edge.
Nymphea from 3 feet to the middle.

The silt condition of the tanks was as follows according to the chemist's report :—

	(Gravimetric) Suspended solids (parts per 100,000)	(Chlorimetric) Turbidity (per million)
Irrigation tank ..	[illegible]	50·00
Drinking water tank ...	[illegible]	7·50

These results explain the absence of aquatic vegetation in the majority of the tanks south of Calingapatam ; three factors, viz. the presence of turbid flood water, varying levels, and annual drying for prolonged periods, have the combined effect of limiting the extent and variety of the vegetation growing in these waters.

Salinification.—*A. annularis* is normally a fresh water breeder, but is sometimes found breeding in saline waters as well. Covell and Pritam Singh (*loc. cit.*) found a few larvæ of this species in the Chilka Lake, when its salinity was 600 parts per 100,000. The present authors subsequently observed profuse breeding in the lake when its salinity was much the same. The optimum salinity for *A. sundaicus* is 600 to 800 parts per 100,000 (Senior White and Adhikari, 1939 : Covell and Pritam Singh, *loc. cit.*), though this species can tolerate salinity up to about 1,300. Salinification should, therefore, proceed beyond the latter limit in order to deal effectively with these two species. If sea-water were introduced into the foreshore ponds, anopheline breeding would be immediately checked, by raising the salinity of the breeding places beyond the tolerance limit of the species concerned and also by destroying the vegetation. This procedure is, however, not easy to adopt in controlling *sundaicus* breeding in large bodies of water like the Chilka Lake. Expert engineering help is required to keep the mouth of the lake constantly open for the ingress of sea-water. Also, the lake water is sometimes used for irrigating certain varieties of paddy, which will be adversely affected by raising its salinity though the loss so sustained can be compensated by augmentation of fish supply.

Growing crops in dry tank beds.—It has already been said that annual drying of tanks during the summer months is not capable of controlling vegetation during the succeeding rainy season and winter. But promising results have been obtained by growing crops in the tank beds when they become dry as the following experiment indicates :—

Tank No. 3 of Ichapuram is a large one, over 30 acres in extent, which is used both for irrigation and domestic purposes. Normally, it supports a very large amount of aquatic vegetation. A sum of Rs. 317 was spent on its first cleaning and quite a heavy expenditure was incurred on its maintenance during the first year. The flora and anopheline fauna found in it on survey are shown in Table II. This tank is mainly fed by flood water, which is supplemented by a fair amount of subsoil seepages. It does not usually dry up in summer but, at that time, there are no seepages in it, owing to the lowered subsoil water level. The water that stood in it in January 1945 was drained away by bailing out with hand bailers. When sufficiently dry, the tank bed was ploughed and cucumber

seeds planted at convenient intervals. The small plants were potwatered up to the end of March, when the plants began to thrive without further watering. In spite of difficulties in preserving the plants from the depredations of men and cattle, they grew well and, during May, yielded what may be described as a medium crop. If surface drains had been dug in the tank bed to absorb the moisture and aërate the top layers of the soil, the crop would perhaps have been better. The cost of the yield cannot be correctly estimated, as it was not sold but had to be given away free of cost to the men engaged to guard it. But its effects on the growth of vegetation in the subsequent season are very marked and are set out in Table VII.

Microcystis has not appeared in this tank subsequent to raising the crop. This improvement is evidently brought about by the crop absorbing all plant food available in the soil, leaving very little for aquatic plants to feed on in the succeeding rainy and winter months.

Instead of cucumber, any other vegetable or dry food crop may be grown with similar effects. The crop should, however, be such as can be harvested by the end of May at the latest, as otherwise it would be completely destroyed by the accumulation of water in the early monsoon period.

The authors lay particular emphasis on this method because the raising of food crops and vegetables is shown, not only to provide a useful occupation to the cultivator during the dry months, but also subsequently to inhibit the growth of aquatic plants which favour the breeding of dangerous anophelines. This is one more example of good agriculture being in itself an antimalaria measure (Venkat Rao, 1942).

SUMMARY.

(1) Some methods of hand and mechanical cleaning of aquatic plants are described and their effects discussed.

(2) Attempts made to control the growth of aquatic plants by other naturalistic methods such as silting and salinification indicate that, in the long run, they are as efficacious as hand-cleaning and are considerably cheaper.

(3) The best method is shown to be the raising of a vegetable crop on dry tank beds during the summer months which, by absorbing all available plant food, renders the soil sterile for the rest of the year.

REFERENCES.

BISWAS, K. (1936) ... ... *Handbook of Common Water and Marsh Plants of India and Burma*, Government Press, Delhi.

COVELL, G., and PRITAM SINGH (1942). *J. Mal. Inst. Ind.*, **4**, pp. 457–593.

HACKETT, L. W., RUSSELL, P. F., SCHARFF, J. W., and SENIOR WHITE, R. (1938). *Qly. Bull. Hlth. Orgn., L. of N.*, **7**, pp. 1016–1064.

RAO, V. V. (1942) ... ... *Ind. Med. Gaz.*, **77**, pp. 214–219.

SENIOR WHITE, R., and ADHIKARI, A. K. (1939). *J. Mal. Ins. Ind.*, **2**, pp. 395–423.
SENIOR WHITE, R., ADHIKARI, A. K., RAMAKRISHNA, V., and ROY, B. B. (1943). *Ibid.*, **5**, pp. 159–186.
WELCH (1935) ... ... *Limnology.*

TABLE I.

Cost of first cleaning of village tanks at Ichaparam, North Vizagapatam Coast.

Tank number.	Extent in acres.	Number of labourers employed.	Rate per head.	Amount.		Cost per acre.	
				Rs.	A.	Rs.	A.
3	30·24	634	0–8–0	317	0	10	8
4, 5*a* & 5*b*	19·63	90	0–8–0	45	0	2	5
7	1·70	32	0–8–0	16	0	9	6
8	3·69	136	0–8–0	68	0	18	6
11	4·00	28	0–8–0	14	0	3	8
14	1·50	32	0–8–0	16	0	8	2
15	21·60	557	0–8–0	278	8	12	14
24	2·00	38	0–8–0	19	0	9	8
25	0·50	10	0–8–0	5	0	10	0
TOTAL ...	84·86	1,557	...	778	8	9	3

TABLE II.

Flora and anopheline fauna of tanks and ponds in Ichapuram Town (North Vizagapatam District).

Breeding place number.	Flora.															Anopheline fauna.									Remarks.
	Hydrilla.	*Najas.*	*Ceratophyllum.*	*Lemna, Wolffia and Azolla.*	*Pistia.*	*Scirpus grassus.*	*Eleocharis.*	*Eichhornia.*	*Jussiæa*	*Neptunia.*	*Anabæna.*	*Lyngbya.*	*Oscillatoria.*	*Spirogyra.*	*Cladophora.*	*A. hyrcanus.*	*A. barbirostris.*	*A. sulcifacies.*	*A. aconitus.*	*A. annularis.*	*A. pallidus.*	*A. subpictus.*	*A. vagus.*	*A. sundaicus.*	
3	+	+	+	–	–	+	+	–	–	–	+	+	+	+	+	+	–	–	–	+	+	+	+	+	
4	+	–	–	–	–	+	–	–	–	–	–	–	–	+	+	+	–	–	–	+	+	+	+	+	
5a & b	+	+	–	–	–	–	–	–	–	–	–	–	–	+	+	+	–	–	–	+	+	+	+	+	
6	+	+	+	–	–	+	+	+	–	–	–	–	–	+	+	+	+	+	–	+	+	+	+	–	
7	+	+	+	–	–	–	–	–	–	–	+	–	–	+	+	+	+	–	–	+	+	+	+	+	
8	+	+	+	–	–	–	–	–	–	–	+	–	+	+	+	–	–	–	–	+	+	+	+	+	
9	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	+	+	+	+	–	
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	
11	+	–	–	–	.	–	–	–	–	–	+	–	+	+	–	–	–	–	–	+	+	+	+	+	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
13	–	–	–	+	+	–	–	–	+	+	+	–	–	+	+	+	+	–	–	+	+	+	+	–	
14	–	–	–	–	+	–	–	–	.	–	.	–	–	.	–	+	+	–	–	+	+	+	+	–	
15	+	–	+	+	+	–	–	–	–	–	–	–	–	+	–	+	+	–	+	+	+	+	+	–	
24	+	+	+	–	–	–	–	–	–	+	–	–	+	+	+	–	–	–	–	+	+	+	+	+	
25	+	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	+	+	+	+	+	
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	+	

TABLE III.

Anopheline fauna in tanks before and after cleaning at Ichapuram (North Vizagapatam District).

Tank number.	Before cleaning.							After cleaning.							Remarks.
	A. hyrcanus.	*A. barbirostris.*	*A. annularis.*	*A. pallidus.*	*A. subpictus.*	*A. vagus.*	*A. sundaicus.*	*A. hyrcanus.*	*A. barbirostris.*	*A. annularis.*	*A. pallidus.*	*A. subpictus.*	*A. vagus.*	*A. sundaicus.*	
3	+	—	+	+	+	+	—	—	—	—	—	—	—	—	
4	—	—	+	—	—	—	—	—	—	—	+	—	—	+	(One larva of *sundaicus* once only soon after cleaning.)
5a & b	+	—	+	—	+	+	+	—	—	—	—	+	+	+	Do.
7	+	—	+	+	+	+	+	—	—	—	—	+	+	—	
8	—	—	+	+	+	+	+	—	—	—	—	+	+	—	
11	—	—	+	+	+	+	+	—	—	—	—	+	+	—	
24	—	—	+	+	+	+	+	—	—	—	—	+	+	—	
25	—	—	+	+	+	—	+	—	—	—	—	—	—	—	

TABLE IV.

Chemical analysis of waters from a de-weeded tank and an overgrown tank at Berhampore (Orissa).

SAMPLE I. Water from Tank No. 13 which was cleaned and maintained clean. (The water in this tank was very clear prior to our de-weeding.)

Appearance	... Very dirty and full of algæ.
Odour	... Very putrescent.
pH	... 7·4
Nitrate	... Traces.
Nitrite	... *Nil.*
Free and saline NH_3	... 0·9 parts per 100,000
Albuminoid NH_3 ...	... 1·8 " " "
O_2 absorbed from $KMnO_4$	... 2·16 " " "

SAMPLE II. Water from Tank No. 4 which is full of vegetation and which was not de-weeded.

Appearance	... Clear—no algæ.
Odour	... Slightly putrescent.
pH	... 8·0
Nitrate	... Traces.
Nitrite	... *Nil.*
Free and saline NH_3	... 0·09 parts per 100,000.
Albuminoid NH_3 ...	... 0·06 " " "
O_2 absorbed from $KMnO_4$	... 0·26 " " "

TABLE V.

Condition of de-weeded tanks at Berhampore with reference to Microcystis.

Tank number.	Clay.	Shade.	Open.	Pollution.	Microcystis.
1	+	+	—	—	+
10	+	—	+	—	—
11	+	+	+	—	—
12	+	—	+	—	—
13	+	+	+	+	+
14	+	+	+	—	+
15	+	+	+	—	+
16	+	+	+	+	+
17	+	+	—	+	+
18	+	+	—	+	+
25	+	—	+	—	—
26	—	+	+	—	—
29	+	—	—	—	+
30	+	—	+	—	+
34	—	—	—	—	+
39	+	—	+	—	—
40	—	—	—	—	—
21	—	—	—	—	—
6	—	—	—	—	—

Notes.

Of 14 clay	tanks	9	had	Microcystis	(64	per cent)
Of 5 moorum	,,	1	,,	,,	(20	,,)
Of 9 shady	,,	7	,,	,,	(78	,,)
Of 10 open	,,	3	,,	,,	(30	,,)
Of 11 irrigation	,,	5	,,	,,	(45	,,)
Of 8 closed	,,	5	,,	,,	(63	,,)
Of 4 polluted	,,	4	,,	,,	(100	,,)
Of 15 non-polluted	,,	3	,,	,,	(20	,,)

TABLE VI.

Water samples from Naupada (North Vizagapatam District).

	Sample I. Water from a well where Lemna grows and thrives perennially.	Sample II. Water from Tank No. 2 by the side of Tank No. 1 where there has been no Lemna.	Sample III. Containing water from Tank No. 1 where Lemna has been introduced.
Colour	Clear.	Turbid.	Turbid.
Free ammonia parts per 100,000 ...	0·005	0·003	0·004
Organic ammonia parts per 100,000	0·01	0·025	0·031
Phosphate parts per 100,000 ...	Minute traces less than 0·01	Minute traces less than 0·01	*Nil*
Nitrite parts per 100,000 ..	0·014	Traces	0·016
Nitrate	Traces	*Nil*	*Nil*
pH	8	7·6	8·2
Iron	*Nil*	*Nil*	*Nil*

TABLE VII.

Year.	Number of cleaning rounds.	Number of man-days spent.
1944	44	1 455
1945	34	242

FURTHER OBSERVATIONS ON DRY LEAF PACKING FOR THE CONTROL OF MOSQUITO BREEDING.

BY

S. NAGENDRA, B.Sc.

(*Antimalaria Assistant, Pachmarhi.*)

[October 2, 1946.]

INTRODUCTION.

In the preliminary observations, an abstract of which has appeared before (Nagendra, 1945), it was stated that two of the limitations of dry leaf packing were that it was practicable only in areas where the fall of leaves was sufficiently profuse and that its use was limited to the period March to mid-June.

A further study of this method of mosquito control has been undertaken, firstly, to determine in detail the comparative efficiency of this method over canalization and, secondly, to assess its possibilities under different conditions.

EXPERIMENT.

Six streams, which will be referred to as A, B, C, D, E and F, flowing in different areas of Pachmarhi Town were selected. Control of mosquito breeding was carried out by subjecting measured lengths of these streams to dry leaf packing and canalization, respectively. Prior to starting the routine periodical canalization larval collections were attempted for about half an hour each in both the portions by a trained insect collector. These collections were subsequently examined by the author. Experimental conditions of the six streams, such as thickness of the surrounding forests, nature of bed, width of the streams (during the non-rainy seasons), were not uniformly similar in all cases. Hence, details regarding these, as well as some brief explanations relating to the actual experiment, are given below :

Stream A.—A perennial stream, approximately two to three feet wide, flows in a nullah which is mostly sandy and pebble-bedded. It takes off from near the veterinary dispensary in the civil lines, flows for the most part in a fairly dense forest and feeds a swimming pool called the 'Twynham pool'. Approximately 600 feet length of the stream was packed with dry leaves on November 28, 1945.

As sufficient leaves were not available close by the streams, more were collected from the surrounding hillocks to ensure proper packing. A length of nearly 850 feet beyond the dry leaf packed area was controlled by canalization. Regular larval collections were attempted just before starting the canalization work, in both the portions. The results of larval collections are given in Table I.

Stream B.—A perennial stream, mostly pebble-bedded, starts from near Government House and feeds a swimming pool called the 'Bee dam' after flowing through a densely wooded forest. The width of the stream is variable, from two to four feet. A length of nearly 600 feet was packed with dry leaves on December 28, 1945, and about an equal length was controlled by regular canalization. Larval collections were made in both the portions regularly and the results of these are shown in Table II.

It is to be noted that oiling of streams A and B is prohibited, as it would interfere with the swimming pools.

Stream C.—This stream is one to two feet wide and flows in a nullah which is mostly pebble and rocky-bedded in a fairly dense forest, terminating in a gorge difficult of access. It originates near the 'Babu lines' and is subsequently joined by two side streams, one from the civil hospital and the other from a nearby hillock. Approximately 2,000 feet of the stream (including the two side streams) was packed with a covering of dry leaves on December 30, 1945, and the rest of the stream, roughly 250 feet, was controlled by canalization and oiling. The results of larval collections made in both the areas are given in Table III.

It was observed that the stream began gradually to dry up from the middle of April onwards. Just before the commencement of the monsoon the entire length under canalization and nearly half the dry leaf packed portion had dried up.

Stream D.—A perennial stream, one to one and a half feet wide, the bed of which is composed of hard non-rocky soil, takes off from near the 'Caves' and flows in a fairly dense jungle with a comparatively fast current. Approximately 400 feet of the stream was packed with dry leaves on January 1, 1946, and about 700 feet beyond this was controlled by canalization and oiling. Larval collections were made as before, and the results are shown in Table IV.

Stream E.—This is formed by the junction of two side streams, roughly one to one and a half feet wide, its bed being composed mostly of soft rocks. The two streams flow in fairly dense forests in nullahs which also serve as outlets for the washings of the military hospital and the military dairy farm, respectively. Roughly 1,800 feet length of the streams was packed with dry leaves on April 1, 1946, and about 1,200 feet length was controlled by canalization and oiling. Regular larval collections were made as before, and the results of these collections are given in Table V.

It was observed that by the end of May 1946 considerable portions of the stream, both under packing and canalization, had become dry.

Stream F.—A small side stream, about one to one and a half feet in width, flows in a thinly wooded region beyond the British Families Camp. Approximately 400 feet was packed with dry leaves on April 1, 1946, and about 150 feet below this

as controlled by canalization and oiling. The results of larval collections made in both the portions are given in Table VI. Practically the entire length under canalization had become dry by the middle of May.

METEOROLOGICAL DATA.

The monsoon (S.W.) generally sets in about the third week of June in this station, but in 1946 it started unusually early. Figures of rainfall for the period November 1945 to June 19, 1946, are given in Table VII. The rainfall did not have any adverse effect on the packings of leaves until June 10. After this date, they began to get washed away and on June 20, there was no trace whatever of any packing left in any area. The absence of breeding in streams A, B, C and D during the winter months, particularly December, January and February, can be ascribed mostly to the low temperatures prevailing in the station. It is an interesting feature that in this semi-hill station the maximum mosquito breeding, anopheline as well as culicine, occurs during the summer months of April, May and June, which are also months of peak malaria incidence. Figures of temperature and humidity are given in Table VIII for general interest.

DISCUSSION.

From a study of Tables I to V it is noticed that the larval collections in the canalized portions of streams under experiment greatly exceeded those in the dry leaf packed areas. This conclusively shows the greater efficiency of dry leaf packing over canalization.

It was observed in stream A that the packing was not as satisfactory as it was in streams B, C, D and E. This was due to the fact that the leaves which were used in the former case were old and decayed. Fresh dry leaves, which are lighter and thus can rest and cover the streams more efficiently than the heavier and decayed ones, were not available in sufficient quantity. It was observed that in portions the stream had gone beyond the packing margins and further, some isolated pools could be seen in the packed area. Larvæ, anopheline or culicine, could only be caught in such exposed portions of the packed lengths, and not in the rest of the stream which was completely under cover.

In stream A, dry leaves were used as such without any support. Renewal of packing at portions became necessary for the reasons explained above, and was done ten times during the course of the experiment. But in streams B, C and E twigs and small branches were put across, on top of which the dry leaves were heaped. In the case of the narrow stream D, intervening twigs and branches were not found necessary, as the initial covering, assisted by the natural fall of leaves, was more than sufficient to maintain a satisfactory packing throughout. The use of twigs and branches for the support of leaves in the dry leaf packing method bears resemblance to the retaining stakes which were employed by Senior White (1936) in his experiment on 'Herbage cover'.

An interesting point was observed in the case of stream E. On May 8, 1946, when the routine larval collection was to be made, it was seen that portions of the packing had been burnt away due to the 'forest fires' which, it was found out

later, resulted from the carelessness of the hospital menial staff. Amidst such burnt portions, pools of water were seen in which breeding was noticed. Thus in regions where forest fires are common (during summer) dry leaf packing requires careful watching.

The initial packing in the case of stream F in the thinly wooded region was not satisfactory owing to the scarcity of leaves. Renewal of packing with the leaves available in the immediate vicinity was done twice, but with disappointing results. Subsequently, a large quantity of dry leaves from the surrounding jungle was brought in, and thus proper packing was ensured. Excellent results of larval catches were recorded after this measure. This experiment shows that even in thinly wooded regions, control of streams, and perhaps seepages and irrigation channels also by dry leaf packing, could be undertaken if leaves in sufficient quantity are made available. The importance of some form of storage of leaves to protect them from rain and decay, and their subsequent transport to the place of requirement, is apparent under such conditions.

LARVAL COLLECTIONS.

On the whole, culicine breeding was considerably greater than anopheline breeding in the packed areas, as can be seen from a perusal of Tables I to VI. Presumably, this was due to the pollution of waters by the rotting of leaves.

The following species of anophelines were encountered in the catches from the packed areas: *A. theobaldi*, *A. subpictus*, *A. maculatus*, *A. culicifacies* and *A. fluviatilis* (in order of prevalence). Identification of all the anopheline larvæ reported from the canalized and dry leaf packed areas might have yielded some interesting results, but this was unfortunately not carried out.

CONCLUSIONS.

(*a*) *Results of experiments.*—(*i*) The greater efficiency of dry leaf packing over canalization has been conclusively proved, as can be seen from a study of larval catches in Tables I to V.

(*ii*) In contrast to the original statement (Nagendra, 1945) it has now been shown that the applicability of this method need not be confined to the period March to mid-June. Highly satisfactory results have also been obtained during the winter months.

(*iii*) The experiment in the case of stream F has shown that, even in regions where there is not sufficient natural fall of leaves, this method could be a success, if an adequate supply of leaves were made available. For such thinly wooded (or non-wooded) regions, the storage of fresh dry leaves in sufficient quantity and their transport to the places of requirement are two problems that have to be solved. It is realized that in the absence of further data the success of this measure cannot be guaranteed in thickly populated areas, as packings of leaves would be exposed to interference by human beings, cattle and other domestic animals.

(*b*) *General.*—As the underlying principle of dry leaf packing is the creation of a mechanical barrier against oviposition by mosquitoes, it follows that, whether

it be dry leaves or green leaves, or coconut fronds or wood shavings from saw-mills, anything which can act on the above principle may be employed for the control of mosquito breeding. The governing factor is the availability of such material in sufficient quantity.

Even if, for any reason, it is not possible to produce a sufficiently thick barrier against ovipositing mosquitoes, the quality of shade given by coverings of dry leaves may be found useful in 'species control' of carriers which are known to prefer sunlit breeding places, such as *A. minimus* (Manson, 1939), *A. philippinensis* (Iyengar, 1944) or *A. superpictus* (Mulligan and Baily, 1936; Covell, 1944). It is considered that dry leaf packing may also prove advantageous as such, or as supplementary to the prevailing method of growing shade giving plants (Rao and Ramoo, 1942), even in the control of a vector like *A. culicifacies*.

It is hoped that other workers will initiate experiments on these lines and publish their findings, so that the possibilities and limitations may be better understood. It is also thought that dry leaf packing, on account of its cheapness and simplicity may, under favourable conditions, provide a possible solution to the difficulty in the control of rural malaria on account of the prohibitive costs of the usual anti-larval measures in vogue.

SUMMARY.

1. The greater efficiency of dry leaf packing over canalization in the control of forest streams has been established as a result of detailed observations of regular larval catches.

2. Encouraging results have been obtained in the case of a stream in a thinly wooded region with dry leaf packing.

3. This method has been found to be applicable not only in summer but during the winter months as well. The only period during which this method is impracticable is the monsoon.

4. It is considered that dry leaf packing may have potentialities in the control of vectors which are known to prefer sunlit breeding places. Depending on local conditions, it may be employed alone or supplementary to the method of growing shade giving plants.

REFERENCES.

COVELL, G. (1944) ... ... *J. Mal. Inst. Ind.*, **5**, pp. 399–434.
IYENGAR, M. O. T. (1944) ... *Ibid.*, **5**, pp. 435–447.
MANSON, D. (1939) ... ... *Ibid.*, **2**, pp. 85–93.
MULLIGAN, H. W., and BAILY, J. D. (1936). *Rec. Mal. Surv. Ind.*, **6**, pp. 289–385.
NAGENDRA, S. (1945) ... *J. Mal. Inst. Ind.*, **6**, p. 251.
RAO, R. BHASKAR, and RAMOO, H. (1942). *Ibid.*, **4**, pp. 409–415.
SENIOR WHITE, R. (1936) ... *Rec. Mal. Surv. Ind.*, **6**, pp. 439–445.

TABLE I.

Results of larval collections.

(STREAM A.)

Date of packing—November 28, 1945.

Date.	CANALIZED PORTION.				DRY LEAF PACKED PORTION.			
	ANOPHELINE.		CULICINE.		ANOPHELINE.		CULICINE.	
	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.
From 5-12-45 to 1-4-46	...	...	...	...	...	...	...	...
8-4-46	...	24	...	...	...	...	...	17
16-4-46	...	17	...	More than 50	...	8	...	...
23-4-46	More than 50	10	...	...	...	...	...	1
1-5-46	More than 50	...	...	...	...	...	...	...
8-5-46	...	6+1P	...	...	...	...	...	...
15-5-46	...	...	...	...	...	...	...	...
22-5-46	...	...	...	...	...	...	...	...
29-5-46	...	...	...	...	...	...	...	...
5-6-46	...	...	...	...	...	...	...	...
TOTAL ...	More than 100	57+1P	...	More than 50	...	8	...	21

P = pupæ.

TABLE II.

Results of larval collections.

(STREAM B.)

Date of packing—December 28, 1945.

Date.	CANALIZED PORTION.				DRY LEAF PACKED PORTION.			
	ANOPHELINE.		CULICINE.		ANOPHELINE.		CULICINE.	
	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.
From 4-1-46 to 17-4-46	...	...	...	...	...	...	...	...
24-4-46	...	20	...	...	...	...	...	...
1-5-46	...	11+3P	...	...	...	...	...	...
8-5-46	13	8	...	...	...	...	...	...
15-5-46	...	...	...	...	...	...	...	...
22-5-46	...	...	...	...	...	...	...	...
29-5-46	...	1+3P	...	...	...	...	...	...
5-6-46	...	...	...	...	...	...	...	...
TOTAL ...	13	43+6P	...	...	...	...	...	...

P = pupae.

TABLE III.

Result of larval collections.

(STREAM C.)

Date of packing—December 30, 1945.

Date.	CANALIZED PORTION.				DRY LEAF PACKED PORTION.			
	ANOPHELINE.		CULICINE.		ANOPHELINE.		CULICINE.	
	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.
From 6-1-46 to 1-4-46	...	...	...	...	...	...	...	...
8-4-46	4	...	...	...	...	...	...	...
16-4-46	...	...	...	...	...	...	...	...
23-4-46	...	4	5	8	...	...	...	...
1-5-46	...	...	...	...	...	...	...	...
8-5-46	...	...	...	...	...	...	...	...
15-5-46	...	...	...	...	...	...	...	...
22-5-46	...	...	...	...	...	...	...	...
29-5-46	...	...	...	...	...	...	...	...
5-6-46	...	...	...	...	...	...	...	...
TOTAL ...	4	4	5	8	...	...	...	...

TABLE IV.

Results of larval collections.

(STREAM D.)

Date of packing—January 8, 1946.

Date.	CANALIZED PORTION.				DRY LEAF PACKED PORTION.			
	ANOPHELINE.		CULICINE.		ANOPHELINE.		CULICINE.	
	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.
From 15-1-46 to 1-4-46	...	...	...	...	...	...	...	...
8-4-46	...	25	...	...	...	...	...	...
18-4-46	...	20	...	...	...		...	...
24-4-46	More than 50	3	More than 50	...	3	...	...	...
2-5-46	More than 50	32	...	...	6		...	...
8-5-46	...	...	...	...	...	...	...	...
15-5-46	2	8	...	...	...		...	...
22-5-46	6	More than 50	...	...	...	...		...
29-5-46	10	6	...	...	...	...	...	...
5-6-46	4	15+2P	...	...	...	...	...	...
TOTAL ...	More than 122	More than 2P+159	More than 50	...	9	...	...	...

P = pupae.

TABLE V.

Results of larval collections.

(STREAM E.)

Date of packing—April 1, 1946.

Date.	CANALIZED PORTION.				DRY LEAF PACKED PORTION.			
	ANOPHELINE.		CULICINE.		ANOPHELINE.		CULICINE.	
	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.
8-4-46 ...	...	...	...	...	...	2	...	...
17-4-46 ...	8	10	...	...	...	...	..	3
24-4-46 ...	...	...	...	...	...	...		..
1-5-46 ...	More than 50	10	...	...	...	..	.	
8-5-46 ...	More than 50	29	...	...	...	13 + 4P	..	.
15-5-46 ...	4	14 + 2P	...	...	...	..	...	1
21-5-46 ...	More than 50	More than 50 + 4P	...	...	...	...	...	5
28-5-46 ...	More than 50	30 + 2P	...	...	...	...	...	12 + 2P
4-6-46 ...	...	22 + 1P	...	...	...	...	...	..
TOTAL ...	More than 212	More than 156 + 9P	...	...	...	15 + 4P	...	24 + 2P

P = pupæ.

TABLE VI.

Results of larval collections.

(STREAM F.)

Date of packing—April 1, 1946.

Date.	CANALIZED PORTION.				DRY LEAF PACKED PORTION.			
	ANOPHELINE.		CULICINE.		ANOPHELINE.		CULICINE.	
	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.	I and II stages.	III and IV stages.
8-4-46 ...	...	10	...	...	5	8	...	...
17-4-46 ...	...	12+4P	...	...	...	22+10P	...	28+8P
24-4-46 ...	...	6	...	...	...	12	...	11
1-5-46 ...	...	2	...	...	...	...	...	...
8-5-46 ...	15	7	...	...	...	...	...	...
15-5-46 ...	3	14	...	...	...	...	...	...
21-5-46 ...	...	...	...	...	...	...	...	...
28-5-46 ...	...	...	...	...	...	...	...	...
4-6-46 ...	...	...	...	...	...	...	...	...
TOTAL ...	18	51+4P	...	...	5	32+10P	...	39+8P

P = pupae.

TABLE VII.

Figures of daily rainfall in inches for the period November 1945 to June 19, 1946.

Months and dates.	1945.	1946.	Monthly average for 12 years (1933–1944).	Months and dates.	1946.	Monthly average for 12 years (1933–1944).
November	*Nil*	...	0·48	May	...	0·85
December	*Nil*	...	0·13	6	0·48	...
January	...	*Nil*	0·16	21	R.T.	...
February	...	...	1·61	30	R.T.	...
16	...	0·20	...	June	...	...
17	...	0·06	...	4	R.T.	...
18	...	0·04	...	5	R.T.	...
23	...	R.T.	...	6	R.T.	...
24	...	R.T.	...	8	R.T.	...
March	...	...	0·87	9	0·76	...
12	...	0·04	...	10	1·33	...
19	...	R.T.	...	12	0·28	...
20	...	0·01	...	13	0·34	...
April	...	...	0·63	15	1·28	...
12	...	R.T.	...	16	0·02	...
13	...	0·05	...	18	0·80	...
14	...	0·03	...	19	3·51	...
16	...	0·02	...	...	...	...
20	...	0·02	...	...	...	...
24	...	0·01	...	...	...	...

R.T. = traces of rain below one cent.

TABLE VIII.

Figures of temperature and humidity recorded at Pachmarhi, for the period November 1945 to June 1946.

Period.	Temperature.				Humidity.		
	Mean monthly maximum. °F.	Mean monthly minimum. °F.	Highest recorded maximum. °F.	Lowest recorded minimum. °F.	Mean monthly morning figures, per cent.	Mean monthly evening figures, per cent.
1945						
November ...	74·0	46·0	76	41	69	45
December ...	70·6	42·7	76	33	69	45
1946						
January ...	73·0	45·0	81	31	68	33
February ...	79·0	52·0	83	34	58	32
March ...	85·5	59·1	94	49	38	24
April ...	93·3	70·0	98	60	34	21
May ...	95·0	75·7	100	69	42	23
June ...	83·0	71·0	99	67	75	67

Indian Journal of Malariology, 1, 1, March 1947.

MALARIA ON THE NORTH MADRAS COAST.*

Part I.

BY

R. SENIOR WHITE,

V. RAMAKRISHNA,

AND

V. VENKAT RAO.

(Malaria Section, Medical Department, Bengal-Nagpur Railway.)

[October 10, 1946.]

THIS area of peninsular India had the reputation, until some ten years ago, of complete freedom from malaria. However, in 1938, Sundaresan, investigating a report of malaria in the coastal village of Naupada, captured a single specimen of *A. sundaicus*, as mentioned in Senior White and Adhikari (1939, p. 422) and later more fully recorded by Sundaresan and Rao (1943), who adduced evidence that the species may have been present in the area in 1937. Whilst the malaria of the Chilka Lake was under investigation between 1939 and 1942 by the Malaria Institute of India (Covell and Pritam Singh, 1942), some journeys were undertaken to investigate how far southward from the lake *A. sundaicus* had penetrated. A number of scattered foci, all strictly coastal, were discovered, the furthest being Bhavanipadu, 81 miles south of the lake, and little more than a hundred miles north of the port of Vizagapatam. Actually, this was not the furthest south, even at that time, as Table II shows. The work of the Malaria Institute was continued by the Madras Public Health Department, which appointed a regional malariologist under whom were investigation units, with one of which the second author, seconded from railway service, served for twelve months in 1942-43.

* The former Madras district of Ganjam, now transferred to Orissa, is in part included. The area dealt with extends from the Rishikuliya River on the north to the Vamsadahra River on the south.

Though keenly alive to the threat to the working of the railway which the various findings closer to the coast presented, the malaria department of the Bengal-Nagpur Railway was not actively interested until early in 1943, when a violent outbreak of malaria occurred at Naupada Junction, about two miles west of the site of the original discovery of Sundaresan. The vector was shown to be *A. sundaicus*, and it was realized that for at least a hundred miles south of the Chilka Lake the hitherto completely healthy east coast section was at risk.

The country affected is a narrow coastal plain, not usually exceeding ten miles in width, lying between the outermost hills of the Eastern Ghats Range and the Bay of Bengal. Unlike the Orissa coastal plain to the north, the flat land here is broken by isolated hills, bare or sparsely scrub covered, from which no streams arise. Only two rivers traverse the plain, the Bahuda and the Mahendratanaya. Both arise from the eastern face of the ghats, not from their forested inner ranges, and hence are seasonal in their flow, unlike the two rivers considered as limiting the area, the Rishikuliya and the Vamsadahra, which are perennial.

The actual coast is not a continuous sea face. South of the Rishikuliya is the fresh water 'tampara' or lagoon of Chatrapur described by Covell and Pritam Singh (*loc. cit.*) and treated physiographically by Strickland (1939). South of this tampara, at intervals, are a series of such, stretched along the coast from the vicinity of the small port and seaside resort of Gopalpur to Naupada, where a large tampara has an exit to the sea and extends southwards, inland, for several miles to the vicinity of Kotabommali Station.

From the Rishikuliya River to Kotabommali the railway, more or less closely paralleled by the Grand Trunk Road, follows the coast at a distance of three to seven miles; but at Kotabommali the railway turns inland, not to approach the coast again until it reaches Vizagapatam.

Ensuent on the Naupada Junction epidemic of February 1943, the railway malaria department was actively engaged, not only in combating outbreaks as these occurred, but also in surveying in anticipation of such throughout the whole length considered to be at risk from *A. sundaicus*. Periodic surveys were carried out for twenty miles south of Kotabommali as far as Chicacole Road Station.

There was close collaboration with the regional malariologist throughout, and the majority of the foci tabulated in Tables I and II are the result of the work of the Madras Public Health Department, and it is therefore greatly to be regretted that the present first author's proposal for a joint paper incorporating all that department's results together with our own has not been accepted. Thus the findings of this department alone on a narrow cross-section of the country have been described.

Table I shows, by years, the *sundaicus* foci as found, the name of each village being followed, so far as information is available, by the spleen rate at the time of examination, though these rates may not always be the maxima attained in the case of any individual outbreak. It cannot always be claimed that the month of the outbreak, shown in roman figures preceding the name, or even the year, is strictly accurate.

Table II represents an attempt to reduce to grapho-tabular form our spot map of all the findings known to us, the year of attack being placed in brackets above the village name. From these tables we see that :—

In **1938,** there was one known focus, east of the railway, Naupada Village.

In **1939,** a group of coastal villages around Baruva was found infested.

In **1940,** this group-infestation spread slightly northwards, and an entirely separate focus was found at Gopalpur. The 1938 focus at Naupada spread down the coast outside the tampara, and northward to Buragam and Devanalthada. Buragam is west of the railway.

In **1941,** the Gopalpur focus extended inland to Dura. Another widely separated focus was found at Sonapurampeta, east of the town of Ichchapuram.

In **1942,** the Malaria Institute's finding at Bhavanapadu indicated another extension of the Naupada focus, which was already spreading in 1940. Another separated focus was found at Pittavanipeta, which established a fresh southward record for the insect.

1943 is seen from Table I to mark the greatest outspread of *sundaicus* distribution. The line of the railway was crossed in several places. As an extension of the Naupada focus it reached to Bejjipalli, five miles west of the railway and eight miles from the coast. It created a fresh focus east of the line at Patatekkali. In the north the Gopalpur focus of 1940 extended, as had been forecast by Covell and Pritam Singh (*loc. cit.*), to the town of Berhampur. In the winter of 1943 there was a completely fresh infestation of at least eight villages east of Jhadupudi railway station, and one just west of the railway. The Baruva focus of 1939 spread to Sompeta Town. The isolated 1941 focus at Sonapurampeta spread westward, south of the nearby tampara, to cause a violent epidemic in the town of Ichchapuram, and to create a rather isolated focus west of the railway at Mandapalli. In the far south the insect extended miles to Kottarevu on the coast.

In **1944,** this Kottarevu focus spread further south coastwise, until it reached and crossed the Vamsadahra at Calingapatam, where it had not been found in an earlier search by Sundaresan and Rao (*loc. cit.*). Here it appears to have encountered some limiting factor, possibly the change in the nature of the local tanks and their flora as described by Covell and Pritam Singh (*loc. cit.*). The focus initiating from Baruva in 1939 reached the railway at Sompeta station. Here the foothills are in close proximity, thus inhibiting further extension westward. The focus at Tharlakota, discovered this year, appears to be completely isolated. It is not related to any pre-existing coastal focus, and will be discussed in more detail later.

In **1945,** the original Naupada focus again spread northwards to coalesce with the isolated Patatekkali focus of 1943, thus creating a solid block of infestation between some fifteen miles along the railway and the corresponding length of coast. In the extreme north of the whole area an infestation at Banginibodi (*alias* Banginipada), nine miles north-west of Berhampur and eighteen miles from the sea, appears to be quite isolated. The isolated Tharlakota focus of 1944 definitely extended eastward to Palasa Station, though it is possible that the vicinity of the station was actually invaded in 1944. The solitary female found at Golantra

station in April may have been only an importation. This station loads much local produce (betel, etc.) brought in by cart, and the infested Gangi tampara near Dura is within four miles.

For **1946** (to September), no new focus has been reported. *A. sundaicus* has actually disappeared from many of the infested areas recorded above, naturally in many cases, in some, it is believed, as the result of control measures. It appears only to be maintaining itself locally in the Mulapeta group of villages and near Uppalam Village which form part of the original Naupada tampara focus, situated about six miles east of the railway. But just as the species disappeared from the Hooghly right bank focus of 1931 between 1940 and 1944, only to reappear in the latter year, so it may (as stated by Covell and Pritam Singh, *loc. cit.*, p. 469) reappear on this coast after an indeterminable period, and again cause widespread malaria.

From the foregoing it would seem certain that the gradual invasion of the North Madras Coast has not all originated from a single focus. There would seem to have been three such foci:

(*a*) *Gopalpur*, extending with time west across Berhampur Town to Banginibodi (1940–45). This infestation is separated by a free strip about ten miles wide south of Golantra from

(*b*) *Barara*, which extended to Ichchapuram and Jhadupudi (1939–44). This belt is separated by a gap of some sixteen miles south of Uppalam from

(*c*) *Naupada tampara area*, extended between 1938 and 1945 north and south along the coast from Patatekkali to Pittavanipeta, and west of the railway to Tekkali Town. The Kottarevu focus extending to the mouth of the Vamsadahra (1943-44) would appear to be an extension of this, though not continuous.

This argument is admittedly very difficult to follow merely from a study of Table II alone. Detailed understanding demands reference to Ordnance Survey Sheets 74A and 74B. Unfortunately these are on the scale of 4 miles to the inch and all the villages named are not marked on them.

It must not be thought, from the foregoing, that *A. sundaicus* is the only malaria vector of this coastal belt. Covell and Pritam Singh (*loc. cit.*, p. 482) found high spleen rates where there was no indication of the presence of *sundaicus*, and south of its known distribution. They attributed these high rates either to *culicifacies* or to *stephensi*. The extent to which the latter is a vector around Vizagapatam was not known until the work of Senior White and Rao (1943), and the authors feel confident that the rates found by Pritam Singh south of the Languliya River are due to this species. What is surprising, however, was the findings of March 1943 in the villages around Palasa Station (which was being surveyed for *sundaicus* on the strength of the capture of one ♀ in that station*) of *stephensi* infected to a high degree. Now around Vizagapatam, *stephensi* is associated with

* The captures of one ♀ at Palasa, and one ♂ at Kotabommali in March 1943, are thought to be instances of train importation from the then still uncontrolled Naupada Junction focus. Real invasion of these two stations by *sundaicus* i.e. the establishment of breeding, is believed to have occurred later.

epidemic rather than endemic malaria, and the same may be the case on this coast. There can be no question, with *stephensi*, of 'invasion': it is a species natural to the Indian fauna. The reason why on this coast outbreaks due to *stephensi* should be associated with outbreaks due to *sundaicus* is quite obscure, but there are records of malaria outbreaks prior to the *sundaicus* 'invasion', though they were never of sufficient virulence to destroy the general reputation for healthiness the coast enjoyed. The spleen rates east of Palasa Station, shown in Table III, in the 20–30 per cent group, can only, both on catches and dissections, be due to *stephensi*. Any locality where this mosquito has been found must therefore be considered 'at risk', and we have distinguished the following belts of *stephensi* distribution :—

(*a*) Vizagapatam to Kantakapalli (rail miles 548 to 525). The east-west distribution is quite unknown. The belt probably extends south of Vizagapatam, as the malaria officer of the M. & S. M. Railway informs us that several of his stations just south of Vizagapatam are malarious.

(*b*) Vizianagram to Chipurupalle (rail miles 508 to 489). This belt stretches eastward to the coast at Konada. There is a history of an outbreak in Chipurupalle Taluq in 1938, vector unknown, which might indicate the existence of an infested block between the railway and the coast. An outbreak at Garividi (rail mile 493), in 1945, during which *stephensi* was found in small numbers, occurred in this belt.

(*c*) Kotabommali to Palasa, through Nandigam (rail miles 445 to 420). In this putative belt *stephensi* has however not been found at Pundi or at Tekkali. The belt reaches the edge of the true land, not the new coastal alluvium, at Bendi (*vide* Table III).

While investigating for *sundaicus* at Jhadupudi, considerably further north, a solitary specimen of *A. stephensi* was captured. The Banginibodi outbreak of 1945 was reported too late for other than post-epidemic findings. Searches on eleven occasions between August and January 1946 produced neither vector until December, when single specimens of both *sundaicus* and *stephensi* were taken, the latter with the glands infected. A second *sundaicus* was taken in January. Though these findings established the existence of *sundaicus* eighteen miles from the sea, they do not indicate which of the two vectors caused the original outbreak.

Table III sets out the spleen rates found during the course of our surveys, not the Public Health Department findings shown in Table I together with our own. In the case of railway operated controls, rates found subsequently are also given. Localities protected by railway operated controls are shown in heavy type. Even though *sundaicus* may have apparently disappeared, these controls remain in force, since it is cheaper to maintain than to re-initiate large areas of tank cleaning. At Kotabommali, however, the clean-weeding of the single tank and the borrowpits involved was abandoned, for reasons to be given later, after *sundaicus* had not been found for eighteen months.

The dissections made during the course of these investigations are shown in Tables IV–XI, which will now be discussed.

[illegible] Table IV.—In thirteen months' dissections no vector has been [illegible]. This is the one place on the section where the hills actually extend to the railway, and where therefore it had always been suspected that *fluviatilis* might be a carrier. In March 1943, the nala flowing between the station and Gohanna Village was breeding both *fluviatilis* and *varuna*, but whatever species had caused the high colony spleen rate found in that month was not in evidence when dissections were commenced, and until another outbreak affects the locality, the vector must remain unknown.

Ichchapuram. Table V.—Lodda Putti. This village is one of those frequently encountered along this coast where, before the war, the males immigrated to Burma in numbers, and the village lived largely on their earnings. A year after the evacuation of that country, not only had these remittances ceased, but the survivors had returned to their village naturally expecting sustenance, which was not sufficiently available from the limited area of cultivable land. Malnutrition among the children examined was very evident, and the majority were badly infected with scabies. The spleen rate in Table III shows full epidemic conditions established, and though breeding was obviously on the decline, the *sundaicus* infection rate was inordinately high. The local registrar supplied figures representing a mortality of 43·2 per mille over the preceding two-and-a-half months.

TABLE V.

Ichchapuram area.

Date.	Locality.	*sundaicus.*			*culicifacies.*			*aconitus.*			*annularis.*		
		Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1943													
Mar. ...	Lodda Putti Village.	4	0	1	25	0	0	15	0	0	32	0	0
Nov. ...	Town and Colony.	41	1	3	...	...	...	...	...	...	...	...	...
Dec. ..	Do.	103	7	15	...	...	...	...	...	...	...	...	...
TOTALS		148	8	19	...	...	...	...	...	...	...	...	...
Infection rate, per cent		...	5·4	12·8	...	...	...	...	...	...	...	...	...

G+ = gut infected. Gl+ = salivary glands infected.

Ichchapuram Town.—This outbreak was not unexpected, routine catches in the railway area having been made each week since the previous April. Until November 19, these had produced no vector species, but the catch of November 26 yielded 1 ♂ and 6 ♀ *sundaicus*, and an intensive catch made shortly after this

finding gave dissection results as per the table above, with a sporozoite rate already at 7·3 per cent. Actually the outbreak appears to have started on the opposite side of the town early in November, i.e. about a fortnight before the railway area was found infested. By the seventh day following the report of the second author as district inspector, pyrethrum spraying had been sanctioned and instituted, and antilarval control was introduced on each breeding place as this was located. Thus no collections for dissection could be made after December, which month shows full epidemic transmission rates in being. From Table III it will be seen that the outbreak was checked before the spleen rates approached those of Lodda Putti. This history of an outbreak and its very rapid control shows what can be accomplished when an organization is forewarned for action.

Jhadupudi. Table VI.—Trouble at this station was anticipated when the Public Health Department gave notice of the outbreak at Silagam Village, four miles distant (*vide* Table I). Three visits to Silagam by the staff in November produced eleven *sundaicus*, one with a gut infection. The Public Health Department found a spleen rate of 64·7 per cent and commenced quinine distribution, whilst the railway instituted a 'catching' watch on the station and the adjacent village of Basavakotturu. One *sundaicus* was collected on November 21, followed by a single specimen of *stephensi*, as recorded earlier, on December 6, but the routine dissection catches shown in the table were all negative, in fact, before control measures could be instituted both vector species had disappeared. Further indication that the infection period was very short is provided by the spleen rates found in January after the outbreak had subsided, though according to the local registrar Belgam Village, only three-quarter mile east of the station, had a 'fever' mortality of 27 per mille during November and December. The 0–5 and over 50 age groups suffered the most.

TABLE VI.

Jhadupudi Station area.

(All dissections negative.)

Date.	*culicifacies.*	*varuna.*	*aconitus.*	*annularis.*
1944				
January 27 ...	...	3	...	15
February 8 ...	1	..	11	11
February 22 ...	2	...	1	19
March 7 ...	...	1	6	21
April 18 ...	5	...	...	3
May 9 ...	...	...	...	5
TOTALS ...	8	4	18	74

Sompeta. Table VII.—The usual weekly catching revealed the presence of *sundaicus* at Kanchili Village, immediately south of the station, from December 29, 1943. Breeding was located in two tanks, and the spleen rate shows that the village was already considerably affected. The spleen rate of Purushotpur, nearby and just across the railway, as taken in March 1943, suggests that this focus may have been present a year earlier than it was detected, though a catch in that month in Kanchili had produced no *sundaicus*. No outbreak in the station occurred. Antilarval measures here remain in force.

TABLE VII.

Kanchili Village.

(All dissections negative.)

Date.	*sundaicus.*	*culicifacies.*	*fluviatilis.*	*varuna.*	*aconitus.*	*annularis.*
1943						
March ...	...	3	1	...	...	20
December (2) ...	1	1	...	...	46	21
1944						
January (2) ...	...	1	...	3	25	32
February (2)	...	5	...	...	23	29
March (2) ...	...	...	...	...	3	5
April	...	...	...	...	1	6
May (2) ...	...	1	...	...	...	11
TOTALS ...	1	11	1	3	98	124

Palasa. Table VIII.—The discovery that *stephensi* is a vector in this area has been already described, as has also the subsequent attempts by *sundaicus* to invade the station neighbourhood. Table III shows that the railway colony was never seriously affected, but the failure of *stephensi* control on the nalas to reduce the spleen rate of Ambusoli Village suggests that very low density breeding of *sundaicus* existed, without discovery, through 1944, probably in the village tank, which was not then clean-weeded.

TABLE VIII.

Palasa Railway Colony and 5 neighbouring villages.

Date.	*culicifacies.*			*stephensi.*			*annularis.*		
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1943									
March	95	0	0	20	0	2	37	0	0
Infection rate, per cent	...	0	0	...	0	10	...	0	0

G+ = gut infected. Gl+ = salivary glands infected.

The discovery of the **Tharlakota** *sundaicus* focus described previously was followed by dissections for twenty months (Table IX). The weeding of the infested tanks by the Public Health Department appears to have completely eliminated *sundaicus* from the locality, even though the work was not of the meticulous standard in force on the railway. Prior to de-weeding, the infestation had proceeded unchecked from May to December; during this period the 233 specimens of *sundaicus* taken had a gross infection rate of 4·7 per cent. The first action taken was mass quininization from January to June. During this period the gross infection rate in 755 specimens was 1·7 per cent. Thus whilst quinine would certainly appear to have affected the infection rate in the vector, larval control eliminated the vector and all possibility of further transmission.

The finding of this quite isolated *sundaicus* focus presents an interesting problem as to its origin. Tharlakota had a local reputation for malariousness, which led us to make the catches which resulted in the ultimate discovery of *sundaicus*, instead of *stephensi* as was expected. Specimens of *fluviatilis* were collected, as would be expected near a hill-foot, but no other finding of interest was reported until the discovery of heavy *sundaicus* breeding in April, five months after the catches were commenced, followed by the capture of adults in Palasa Town, two miles nearer the railway, in May. The heavy Tharlakota catches of the ensuent fifteen months followed. The spleen rate of August 1943 may represent either epidemic or endemic conditions, the infection rate in the vector suggesting the latter.

As de-weeding so rapidly eliminated *sundaicus*, it is thought that its foothold locally must have been precarious. From whence did it enter? The nearest point on the coast, Mutturu, spleen rate 13 per cent, is not infested, and the species was not found along the road from the railway to the coast at Neol Revu, the low

spleen rate of which shows that *sundaicus* had not been present, at least in recent years. In March 1943, we took *stephensi* along the road to the coast at Garudukandy, but not at Bendi.

The authors can only suggest that the Tharlakota focus was established by a few specimens, caught up in one of the local cyclonic storms of autumn, from one of the heavily infested coastal areas north-east and south-east of Tharlakota, and dropped there undamaged when the storm impacted on the first ranges of the hills just above the village. Weak cyclones fail to jump the hills, and by therefore depositing all their moisture content on the narrow coastal plain cause the catastrophic floods which periodically wash out the railway through this area. Strong cyclones cross the hills, and pass into Central India. If sufficient staff were available, the tracks of cyclones across the plain might well be worth following up epidemiologically.

Naupada Junction. Table X.—Owing to the immediate institution of control measures after discovery of the invasion, only one dissection catch could be made. It shows an infection rate in *sundaicus* typical of the values found in first outbreaks due to this species.

TABLE X.

Naupada Railway Colony and Rallapeta Village.

Date.	*sundaicus.*			*culicifacies.*			*annularis.*		
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1943									
February ...	24	0	3	3	0	0	14	0	0
Infection rate, per cent	...	0	12·5	...	0	0	...	0	0

G+ = gut infected. Gl+ = salivary glands infected.

Kotabommali. Oddibada Village. Table XI.—Again only one catch could be made before control measures were instituted. *A. stephensi* also occurs here, though no specimens were obtained for the dissection catch. The nala flowing past the station on the east is interesting in that it bred *stephensi* when flowing and *sundaicus* after its reduction to pools in the hot weather of 1943. With the elimination of other foci of breeding, this phenomenon was not encountered subsequently. As mentioned previously, weeding in the one tank and the borrow-pits here was abandoned, in the belief that this infestation was probably rail-borne from Naupada Junction or carried by wind from the coast across the tampara,

and is due to the former, had been isolated by control of the Nagapattinam area. Observations continue regularly, and control can at any time rapidly be introduced.

TABLE XI.

Oddibuda Village.

Date	*sundaicus.* Number dissected.	*sundaicus.* G+.	*sundaicus.* Gl+.	*culicifacies.* Number dissected.	*culicifacies.* G+.	*culicifacies.* Gl+.	*annularis.* Number dissected.	*annularis.* G+.	*annularis.* Gl+.
1943									
June ...	13	1	0	...	...	...	...	...	...
1944									
January ...			...	2	0	0	31	0	0
February (2) ...	...	...	...	2	0	0	30	0	0
March (2) ...	...	...	...	13	0	0	19	0	0
April (2) ...	...	...	...	6	0	0	2	0	0
May (2) ...	...	...	...	3	0	0	3	0	0
TOTALS ...	13	1	0	26	0	0	85	0	0
Infection rate, per cent	7	7·7	0	...	0	0	...	0	0

G+ = gut infected. Gl+ = salivary glands infected.

Part II.

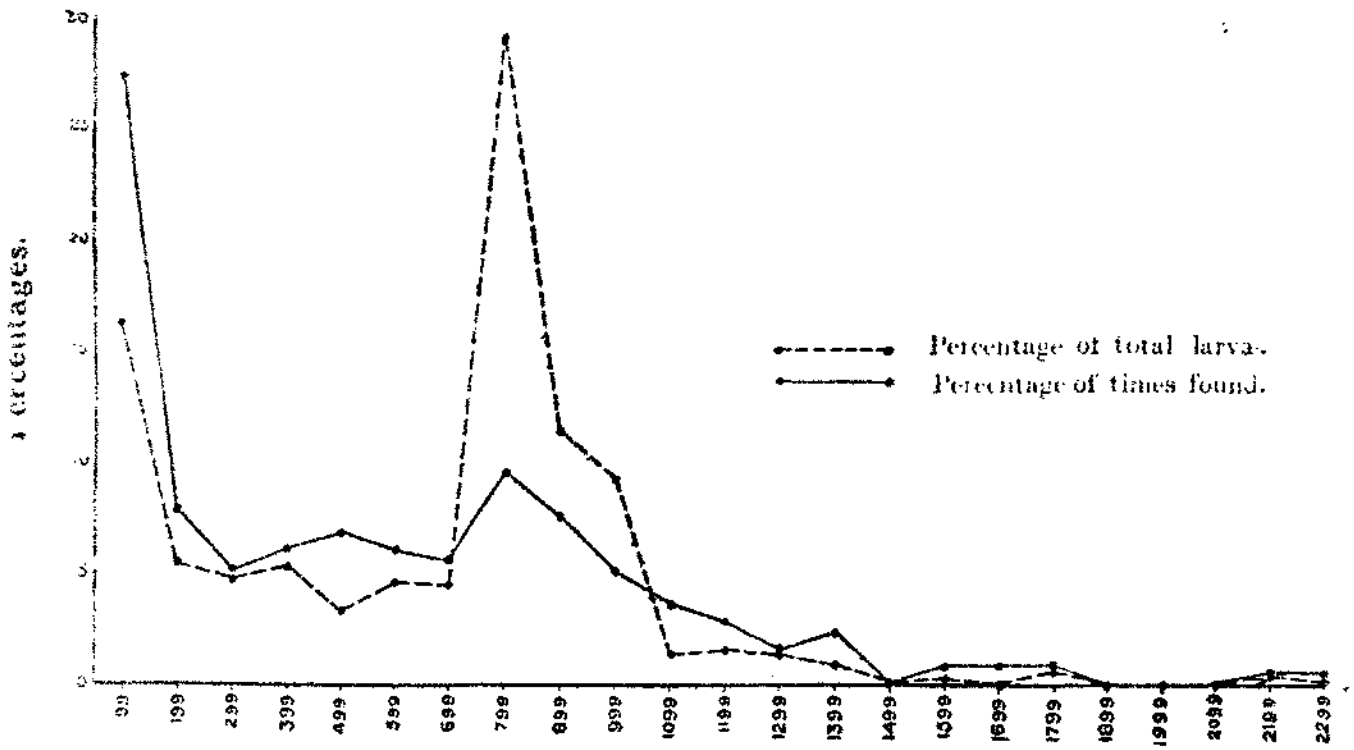
ON THE POSSIBLE EXISTENCE OF SEPARATE BIOLOGICAL RACES IN *A. SUNDAICUS.*

THIS possibility was first advanced by Taylor (1943) referring to a statement by Dr. B. A. R. Gater that there was a lack of direct correlation between *A. sundaicus* and malarial incidence in Singapore. Owing to the war, Dr. Gater was presumably unable to pursue the subject further.

In Graph 1 are presented the salinity findings of Senior White and Adhikari (*loc. cit.*) and of Covell and Pritam Singh (*loc. cit.*) combined. Of the total examinations positive for *sundaicus* it is seen that 27·6 per cent were from waters of a salinity lower than 100 parts per 100,000. These findings, however, comprised only 16·5 per cent of the total larvæ taken. For the remaining 72·4 per cent of positive collections, the distribution of findings is fairly even up to 1,000 parts per 100,000, but in respect of the remaining 83·5 per cent of the total larval captures, no less than 29 per cent were found at 700–800 parts per 100,000. Thus whilst 100 is the optimum for oviposition, productivity at this value is very much lower than at 700–800, and it is seen that in waters between 700 and 1,000, no less than 50 per cent of the total larval production occurs. The curves for positive findings and for larval numbers are thus both bimodal, but do not follow one another. In other words, larvæ are more likely to be found in fresh than in saline water, but the output from saline water findings is much the higher.

GRAPH 1.

A. sundaicus : salinity relationships : larvæ.



Salinity per 100,000.

This evidence appears to us definitely suggestive of the possible existence of two races of *sundaicus*, such as Christophers (1933) has proved for *subpictus* (in that case distinguishable on morphological characters), one of which tolerates a much higher degree of salinity than *sundaicus* usually appears to do. Though there is no inherent improbability in the hypothesis, it has to be remembered that other species, *stephensi* and *annularis* in particular, are found from time to time

in saline waters without there being any suggestion that specimens so breeding belong to a separate race.

South of the Chilka Lake the *sundaicus* invaded area now comprises localities both coastal and inland; but the dates shown in Tables I and II show that the first findings were coastal and that the species did not move inland to any extent until 1943, i.e. for six or seven years after its discovery on this coast. This may suggest increasing adaptation to fresh waters of a mono-racial species, or the gradual segregation of such a species into two races.

The question is of great epidemiological importance, if the third author's hypothesis that the fresh water race is a much more efficient vector than the saline has any validity.

Now in Table XII all the dissections made by Senior White and Adhikari (*loc. cit.*) and by Covell and Pritam Singh (*loc. cit.*) are set out by years, and this very clearly brings out the fluctuations in virulence which are such a feature of *sundaicus* transmission. Another aspect of such transmission is the almost fantastically high infection rates found when *sundaicus* has newly invaded a locality, as exemplified in Table V and by Iyengar's (1931) findings at the commencement of the invasion of deltaic Bengal. These phenomena prevent any deductions being made from comparisons between coastal and inland findings, as the latter are in many cases those found during first outbreaks

In support of the two-race hypothesis, however, the following evidence is adduced :—

Following the lead of Covell and Pritam Singh (*loc. cit.*), the control of breeding in the Chilka Lake had been attempted by de weeding, in the vicinity of the affected stations, with varying success until 1944, when, though much larger sums were expended than had been estimated, the weed growth in Nairi Bay, a mile from Gangadharpur station, defeated all our efforts to keep pace with the re-growth. As a result, perhaps too much attention was devoted to the lake and not enough to the fresh water breeding places nearer the station. After this failure it was decided to let the lake go, and concentrate on the fresh water breeding places, using both de-weeding and paris green to ensure their absolute sterility. The results for the two periods were :—

A. sundaicus : Gangadharpur.

Period.	Number dissected.	G—.	Gl.	Oö.R. per cent.	Sp.R. per cent.	
Mar.–Dec. 1944	734	9	2	1·2	0·3	General de-weeding.
Jan. 1945–June 1946	495	1	0	0·2	0	Inland breeding only controlled.

G— = gut infected. Gl. = salivary glands infected.
Oö.R. = oöcyst rate. Sp.R. = sporozoite rate.

Thus whilst partial control of the whole locality was ineffective, strict attention to breeding places within a three-quarter-mile distance, whilst failing to eliminate

sundaicus population, rendered it innocuous. This innocuous population was entirely lake (i.e. saline) bred. The result may be due to the elimination of a race, but it may equally be due to the absolute control of primary foci.

At Kallikota, where the station is closer to the lake than any other on the coast, control of the lake has never been possible owing to the vast sheets of weeds which fill the channel around Gopakuda Island, and cover that part of the lake cut off by the causeway carrying the railway south of the station. Control measures at Kallikota Station, therefore, had to be confined to daily pyrethrum spraying, which was not particularly successful. The third author's proposal to adopt larval control, and confine it to in-shore breeding places was therefore given a trial, using in this instance paris green only, without any de-weeding. The results for the two periods were :—

A. sundaicus : Kallikota Station.

Period.	Number dissected.	G+.	Gl+.	Oö.R. per cent.	Sp.R. per cent.	
Jan. 1944–Aug. 1945	1,636	26	15	1·6	0·9	Pyrethrum spraying.
Aug. 1945–June 1946	97	0	0	0	0	In-shore breeding control.

G+ = gut infected. Gl+ = salivary glands infected.
Oö.R. = oöcyst rate. Sp.R. = sporozoite rate.

This is at first glance a much more striking result than at Gangadharpur, but, since there was no control of lake breeding, the reduction in numbers can mean no more than that in 1945-46 *sundaicus* underwent one of the periods of recession which occur even in hyperendemic localities such as this. On the other hand, even on the small numbers of the second period, had the infection rates of the first period continued, positive dissections should have been found. Probably density was too low to maintain efficient breadth of contact between mosquito and man. Actually, therefore, the results are much less suggestive than those from Gangadharpur.

Now Christophers (*loc. cit.*) was able to show definite morphological differences between the two races of *A. subpictus*. In pursuit of such differences between fresh and saline water *sundaicus*, twenty of the former and thirty-two of the latter were closely examined, using the criteria tabulated by King (1932), in distinguishing between *ludlowi, littoralis* and *sundaicus*. The salt water specimens used were collected at Gangadharpur after it was certain that all fresh water was under full control, while the fresh water specimens were obtained from Tharlakota, where no saline waters exist. Between the two small series, there were some apparent differences in the phallosome, but much more material must be studied before any reliance can be placed on such. Both forms, however, showed a departure from King's *sundaicus*, in that the stem of the anterior forked cell was as long as the cell itself.

In general support of their hypothesis, the authors would advance that Huxley (1942) has shown that in certain insects divisibility into races is possible only on

their disease-carrying capacity, and that Covell (1944) has stated the same for Anopheles.

A simple test of this hypothesis would be possible on the very malarious islands on the eastern side of the Chilka. If malaria there is due solely to fresh water breeding, it could be easily eliminated by control of the very restricted fresh water sources of production. The present authors have not been in a position to carry out such an experiment, and their hypothesis is therefore advanced and such a method of trial suggested, in the hope that others may be sufficiently interested to pursue the matter further. If the hypothesis is correct, the financial import requires no stressing.

SUMMARY.

1. The invasion by *A. sundaicus* of the North Madras coastal area, lying between the Eastern Ghats and the Bay of Bengal, is described.

2. Invasion appears to have occurred between 1938 and 1945, and to have originated from three isolated coastal foci. No explanation for the existence of these foci is attempted.

3. In certain parts of the area, *A. stephensi* is shown to be the vector, and not *A. sundaicus*. In certain places both species have been found.

4. The initiation of malaria control programmes by the Bengal-Nagpur Railway Medical Department, and the results achieved by them are briefly described.

5. Some evidence is adduced that in *A. sundaicus* there may be two biological races, one of which may be of greater importance than the other in the transmission of malaria.

REFERENCES.

CHRISTOPHERS, S. R. (1933) ... '*Fauna of British India Diptera* **4**, *Anophelini*'. Taylor and Francis, London.

COVELL, G. (1944) ... ... Notes on the distribution, breeding places, adult habits and relation to malaria of the anopheline mosquitoes of India and the Far East. *J. Mal. Inst. Ind.*, **5**, pp. 399–434.

COVELL, G., and PRITAM SINGH (1942). Malaria in the coastal belt of Orissa. *Ibid.*, **4**, pp. 457–593.

HUXLEY, J. (1942) ... ... '*Evolution.*' G. Allen & Unwin, Ltd.

IYENGAR, M. O. T. (1931) . The distribution of *Anopheles indiawii* in Bengal and its importance in malarial epidemiology. *Ind. J. Med. Res.*, **19**, pp. 499–524.

KING, W. V. (1932) ... *Phil. J. Sci.*, **46**, p. 751.

SENIOR WHITE, R., and ADHIKARI, A. K. (1939). On malaria transmission around the Chilka Lake. *J. Mal. Inst. Ind.*, **2**, pp. 395–423.

SENIOR WHITE, R., and RAO, V. V. (1943). On malaria transmission around Vizagapatam. *Ibid.*, **5**, pp. 187–205.

STRICKLAND, C. (1939) ... A study in physiography in relation to malaria in the Orissa coastal tracts. *Rivis. di Mal.*, **18**, pp. 38–44.

SUNDARESAN, B., and RAO, M. A. (1943). The distribution of *A. sundaicus* in Vizagapatam District. *J. Mal. Inst. Ind.*, **5**, pp. 107–112.

TAYLOR, F. H. (1943) ... '*Intermediary hosts of malaria in the Netherlands Indies.*' School of Public Health and Tropical Medicine, Service Pubn. No. 5.

TABLE

North Madras Coast.

Spleen rates found in Arabic figures. Railway stations

1938.	1939.	1940.	1941.	1942.
[illegible] VII. 31.	Baruva Tu. 16	Manikyapuram	III. Dura	I. Bhavanapadu 62
	Isakalapalem 94	Ontooru	X. Sonapurampeta	Pittavanipeta 69
	Ramayyapatnam	Goilagandi 73		Chinnavuru
	Vadapalem 31	Buragam 24		
	Kottooru	Mulapeta 95		
	Uppalam 61	I. Devanalthada 52		
		Vishnuchakram		
		Lingudu		
		Sunapalli		
		Rajapuram		
		VI. Gopalpur		

I.

A. sundaicus *invasion dates.*

in heavy type. Month if known in Roman figures.

1943.	1944.	1945.
I. Loddapatti 72	I. Khojiria	II. Langipilli
I. Sompeta Tn.	I. **Sompeta R. S.**	I. S. Jagannadhapuram
II. **Naupada R. S.** 39	I. Kanchili 36	I. Marripadu
II. Ballapeta 42	I. Kambalapeta	I. Komaralthada
III. Talagam 6	I. Revuampalam 60	I. Seetanagram
III. Nandigam 49	I. Akkuvaram	II. **Palasa R. S.** Area 10
III. Lakhidaspuram 20	IV. Calingapatam Tn.	IV. **Golantra R. S.**
III. Dimilada 96	IV. Bandarupet	XII. Banginibodi
III. Kottarevu 91	IV. Tharlakota 72	
IV. Oddibada 43	V. Palasa Tn. 14	
IV. Bejjipalli 32	VIII. **Berhampur R. S.**	
IV. Patafekkali 40		
IV. Pothumaidupeta		
VI. Kotabommali R. S.		
VIII. Berhampur Tn.		
XI. **Ichchapuram Tn.** 43		
XI. Silagam		
XI. Sanyasiputtukku		
XI. Basavakotturu 21		
XI. **Jhadupudi R. S.**		
XI. Kaviti		
XI. Kapaskuddi		
XII. Thulasigam		
XII. Kotari		
XII. Edupur		
XII. Kesapur		
XII. Nelavanka		
XII. Mandapalli		
Kollipadu 45		
Sirupuvanipet		
Akasalakkavaram		
Kurmanadhapuram		
Tekkali Tn.		

TABLE

North Madras Coast. A. sundaicus.
(Affected railway stations

West.					
				Mile.	Railway Station.
(1945) Bangnibodi				361	Chatrapur
				369	Jagannadhapuram
(1940) Ampua					
(1943) Berhampur Town				374	(1944) **Berhampur**
				381	(1945) **Golantra**
(1943) Mandapalli					
				389	(1943) **Ichchapuram**
(1944) Khojiria					
		(1943) Basavakotturu		396	(1943) **Jhadupudi**
				400	(1944) **Sompeta**
				406	Baruva
				412	Mandasa Rd.
(1944) Thatlakota	(1944) Palasa Tn.			420	(1945) **Palasa**
				424	Bendikonda
(1943) Bejjipalli	(1943) Lakhidaspuram	(1943) Nandigam		428	Pundi
	(1943) Dimilada				
(1943) Kurmanadhapuram			(1940) Buragam		
(1943) Tekkali Tn.			(1943) Talagam	436	(1943) **Naupada**
				439	Dandugopalapuram
			(1943) Oddibada	445	(1943) **Kotabommali**
				453	Tilaru
				459	Urlam
				465	Chicacole Road

II

Approximate locations and years of incasion.

in heavy type.)

East.				
(1941) Dura	(194[illegible]) Gopalpur			
(1943) Laddajatti	(1943) Kotam	(1943) Tulasigam	(1943) Edupur	(1941) Somapurampeta
(1943) Belgam	(1943) Silagam	(1943) Sanyasipurunka		(1943) Kesapur
(1943) Kavita	(1943) Kajaskuddi	(1943) Nelavanka		
(1944) Kanchili	(1940) Mallikyapuram	(1940) Chiteeru		
(1943) Sompeta Tn.	(1939) Isakalapalem	(1939) Ramayyapatnam		
(1940) Gollagandi	(1939) Baruva Tn.	(1939) Vadapalem	(1939) Kotteeru	
(1939) Uppalam				
(1943) Paratekkali	(1945) S. Jagannadhapuram			
(1945) Manpadu	(1945) Komaralthada	(1940) Devanalthoda	(1940) Bhavanapadu	
(1943) Rallapeta	(1945) Seethanagram	(1938) Naupada Vill.		
(1940) Mulapeta	(1940) Vishnuchakram	(1940) Lingudu	(1940) Sunapalli	(1940) Rajaparam
(1943) Pothunaidupeta	(1943) Sirupuvanipet	(1943) Akkasalakavaram		
(1943) Kallipadu	(1942) Chinnavuru	(1942) Pattavanipeta		
(1943) Kottareva	(1944) Akhuvaram	(1944) Kambalapeta		
(1944) Revuampalam	(1944) Calingapatam	(1944) Bandarupet		

TABLE III.

Spleen rates—Chatrapur to Kotabommali.

(Localities put under control in heavy type.)

Date.	Station.	Locality.	Number examined.	Spleen rate per cent.	Average enlarged spleen.
Apr. 1937 ...	Chatrapur	Town (A)	63	36·5	1·5
Mar. 1943 ...	Golantra	Ry. Colony	15	40·0	2·5
Mar. 1943 ...	,,	Jikkibada	19	10·5	1·5
Mar. 1943 ...	,,	Golantra	66	9·0	2·0
Nov. 1943 ...	**Ichchapuram**	**Ry. Colony (B)**	35	0	0
Mar. 1944 ...	,,	,,	41	43·9	1·5
Sept. 1944 ..	,,	,, (C)	52	9·6	1·2
Mar. 1943 ...	,,	**Town (D)**	?	8	?
Dec. 1943 ...	,,	,, (E)	?	43	?
Mar. 1943 ...	m. 391	Loddaputti	114	71·9	2·5
Jan. 1944 ...	**Jhadupudi**	**Basavakotturu**	38	21·0	1·6
Jan. 1944 ...	,,	Belgam	54	20·5	1·6
Mar. 1943 ...	**Sompeta**	**Ramachandrapur**	42	2·4	2·0
Jan. 1944 ..	,,	,,	45	0	0
Mar. 1943 ...	,,	**Purushotpur**	40	15·0	1·0
Jan. 1944 ...	,,	,,	51	5·9	1·0
Jan. 1944 ...	,,	**Kanchili**	28	35·7	1·9
Jan. 1944 ...	,,	Gola Kanchili	68	2·9	2·0
Jan. 1944 ...	,,	Boradupadu	23	4·3	1·0

(A) cf. Covell and Pritam Singh, Table IX. (B) (C) Ry. S. A. S. (D) (E) Govt. Public Health Inspector,

TABLE III—*contd.*

Date.	Station.	Locality.	Number examined.	Spleen rate per cent.	Average enlarged spleen.
Feb. 1943 ...	Palasa	Ry. Colony	134	1·5	2·0
Mar. 1944 ...	,,	,,	151	2·0	1·7
Mar. 1945 ...	,,	,,	162	1·2	2·5
Mar. 1943 ...	,,	Ambusoli	53	9·4	1·8
Mar. 1944 ...	,,	,,	78	10·3	1·4
Mar. 1943 ...	,,	Kasihugga	157	1·3	2·0
Mar. 1944 ...	,,	,,	175	2·8	1·2
Mar. 1943 ...	,,	Talabhadra	44	4·1	1·0
Mar. 1943 ...	,,	Nilapuram	50	12·0	1·2
Mar. 1943 ...	,,	Passerapadu	50	22·0	1·5
Mar. 1944 ...	,,	,,	41	21·9	1·3
Aug. 1944 ...	...	Palasa Town	59	3·4	1·5
Aug. 1944 ...	...	Tharlakota	33	72·0	3·0
Mar. 1943 ...	m. 122	Guruduhandy	40	22·5	1·8
Mar. 1943 ...	...	Bendi	55	29·1	1·9
Jan. 1942 ...	...	Wajrafkotooru (F)	85	12	...
Mar. 1943 ...	...	,,	34	5·9	3·0
Jan. 1942 ...	...	Neol Revu (G)	138	7	...
Mar. 1943 ...	...	,,	106	10·4	1·5

(F) Covell and Pritam Singh, Table XX. (G) Ditto.

TABLE III—*concld.*

Date.	Station.	Locality.	Number examined.	Spleen rate per cent.	Average enlarged spleen.
Feb. 1943 ...	**Naupada**	**Ry. Colony**	35	37·1	1·8
Mar. 1943 ...	"	" (H)	48	39·5	1·5
Jul. 1943 ...	"	" (I)	52	25·0	2·2
Mar. 1944 ...	"	"	43	14·0	2·7
Mar. 1945 ...	"	"	51	3·9	1·5
Feb. 1943 ...	"	**Rallapeta**	63	25·4	1·9
Mar. 1943 ...	"	" (I)	65	41·5	1·9
Mar. 1944 ...	"	"	109	4·6	1·4
Mar. 1945 ...	"	"	121	1·6	2·5
Feb. 1943 ...	"	Talagam	87	5·6	1·6
Jan. 1942 ...	"	**Naupada Village** (J)	200	13	...
Mar. 1943 ..	"	"	151	30·7	1·6
Mar. 1944 ...	"	"	218	15·2	2·1
Mar. 1945 ...	"	"	298	12·8	1·7
Jul. 1943 ...	**Kotabommali**	**Oddibada**	100	43·0	2·5
Mar. 1945 ...	"	"	103	4·8	1·4

(H) Control plus quinine. (I) Control only. (J) Covell and Pritam Singh, Table XX (1942).

TABLE IV.

Golamra Village dissections.

(All dissections negative.)

Date.	*culicifacies.*	*fluviatilis.*	*varuna.*	*aconitus.*	*jamesi.*	*annularis.*	*pallidus.*
1943							
December (2) ...	3	...	4	31	...	29	...
1944							
January (2) ...	29	...	10	13	1	35	...
February (2) ...	22	1	8	18	7	42	...
March (2) ...	17	...	...	13	5	30	...
April (2) ..	23	...	...	3	...	21	...
May (1) ...	...	...	...	...	...	13	...
June (2) ...	...	...	...	...	...	29	...
July (2) ...	16	...	1	...	...	17	...
August (2) ...	37	...	...	...	...	20	2
September (2) ...	22	...	1	...	...	35	...
October (1) ...	...	...	...	...	...	16	...
November (2) ...	10	...	2	8	...	27	6
December (1) ...	13	...	2	...	...	15	...*
1945							
January (1) ...	...	...	...	...	...	30	...
TOTALS ...	201	1	28	86	13	368	8

* *A. tessellatus* 2.

TABLE IX.

Palasu—Tharlakota Village.

Date.	*sundaicus.*			*culicifacies.*			*fluviatilis.*			*varuna.*			*aconitus.*			*tessellatus.*			*annularis.*						
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.				
1944																									
May ...	10	0	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	15	0	0				
June 13 ...	46	0	0	1	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
July 13 ...	12	0	2	24	0	0	...	...	...	...	...	...	...	...	...	...	...	...	9	0	0				
July 26 ...	12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Received dead			
August 4 ...	30	0	1	48	0	0	...	...	...	1	0	0	...	...	...	...	...	...	...	...	...				
August 10 ...	...	...	...	29	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
August 23 ...	...	...	...	8	0	0	...	...	...	...	...	...	...	...	...	...	...	...	2	0	0				
September 13	...	...	...	14	0	0	...	...	...	...	...	...	...	...	...	...	...	...	5	0	0				
September 27	1	0	0	1	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
October 13 ...	3	0	1	1	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
October 27 ...	1	0	0	1	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*Pallidus.*			
November 13	5	0	0	5	0	0	...	...	...	2	0	0	...	...	...	5	0	0	2	0	0	5	0	0	
November 26	39	0	0	3	0	0	...	...	...	...	...	...	1	0	0	...	...	...	8	0	0	1	0	0	
December 14	47	2	1	...	...	...	...	...	...	...	...	...	1	0	0	...	...	...	6	0	0				
December 28	39	2	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	31	0	0				

G+ = gut infected. Gl+ = salivary glands infected.

TABLE IX—*contd.*

Date.	*sundaicus.*			*culicifacies.*			*fluviatilis.*			*varuna.*			*aconitus.*			*tessellatus.*			*annularis.*			
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	
1945																						
January 14 ...	32	1	0	...	...	...	1	0	0	...	...	...	...	...	...	...	...	...	6	0	0	Quinine.
January 29 ...	51	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	0	0	
February 12 ...	34	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	0	0	
February 28 ...	130	0	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
March 13 ...	59	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	2	...	...	Received dead.
March 20 ...	63	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
March 30 ...	97	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	0	
April 15 ...	99	1	0	2	0	0	...	...	...	...	...	...	...	...	...	...	...	...	4	0	0	
April 28 ...	72	2	0	1	0	0	...	...	...	...	...	...	...	...	...	...	...	...	3	0	0	
May 12 ...	66	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
May 26 ...	55	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	12	0	0	
June 14 ...	33	0	0	2	0	0	...	...	...	...	...	...	...	...	...	...	...	...	1	0	0	
June 30 ...	13	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
July 14 ...	10	1	1	15	0	0	...	...	...	...	...	...	...	...	...	...	...	...	4	0	0	

G+ = gut infected. Gl+ = salivary glands infected.

TABLE IX—*concld.*

Date.	*sundaicus.*			*culicifacies.*			*fluviatilis.*			*varuna.*			*aconitus.*			*tessellatus.*			*annularis.*					
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.			
1945																								
July 31 ...	...	...	...	25	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Tanks weeded.		
August 14 ...	...	...	...	24	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			
August 30 ...	...	...	...	35	0	0	...	...	...	...	...	...	...	...	...	1	0	0	1	0	0			
September 15	...	...	...	12	0	0	1	0	0	...	...	...	...	...	...	2	0	0	...	...	...			
September 30	...	...	...	20	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			
October 15 ...	...	...	...	21	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*Pallidus.* 1	0	0
October 28 ...	...	...	...	4	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			
November 14	...	...	...	5	0	0	...	...	...	...	...	...	...	...	...	...	...	...	2	0	0			
November 29*	...	...	...	8	0	0	...	...	...	1	0	0	...	...	...	...	...	...	13	0	0	1	0	0
December 16	...	...	...	1	0	0	1	0	0	1	0	0	...	...	...	...	...	...	4	0	0			
December 29	...	...	...	1	0	0	...	...	...	...	...	...	...	...	...	...	...	...	15	0	0			
TOTALS ...	1,059	13	12	311	0	0	3	0	0	5	0	0	2	0	0	9	0	0	152	0	0	8	0	0
Infection rate, per cent. †	...	1·3	1·2	...	0	0	...	0	0	...	0	0	...	0	0	...	0	0	...	0	0	...	0	0

**A. ramsayi* 1 caught 29–11–45. Dissection negative.

G+ = gut infected.

† Deducting 71 *sundaicus* arrived dead and not dissected for calculation.

Gl+ = salivary glands infected.

Page 107

TABLE XII.

Dissections—Orissa coast—Senior White and Adhikari (1939) and Covell and Pritam Singh (1942) combined.

From S. W.	Village.	Apr.–Dec. 1937.				Jan.–Mar. 1938.				May–Dec. 1939.				Jan.–Dec. 1940.			
		No.	G+.	Gl+.	I. R.	No.	G+.	Gl+.	I. R.	No.	G+.	Gl+.	I. R.	No.	G+.	Gl+.	I. R.
½	Soran ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0	Bolabandh ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1	Ichapur ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0	Sona Nairi ...	...	...	...	...	...	...	...	...	...	...	...	...	95	0	0	0
1–1¼	Chatrapur ...	144	0	0	0	68	0	0	0	...	...	...	...	...	...	...	...
0–¾	Balugan ...	6	0	0	0	16	0	0	0	...	...	...	...	2	0	0	0
0	Kespur ...	124	5	2	5·7	53	0	0	0	1	0	0	0	2,875	11	8	0·7
2	Kallikota ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
0	Konaka ...	155	4	2	3·9	45	0	0	0	3	0	0	0	206	1	0	0·5
0	Sabilia Rambha	31	1	1	6·4	17	0	0	0	144	2	0	1·4	835	4	5	1·1
0	Dubrakudi ...	...	...	...	...	...	...	...	...	...	...	...	...	207	1	0	0·5
0	Proyagi ...	...	...	...	...	...	...	...	...	...	...	...	...	287	1	1	0·7
2	Tolo Humma ...	...	...	...	...	...	...	...	...	...	...	...	...	129	0	1	0·8
1	Ganjam Area ...	...	...	...	...	...	...	...	...	...	...	...	...	38	0	0	0
1	Chatrapur ...	...	...	...	...	...	...	...	...	2	0	0	0	14	1	0	7·3
1	Haripur-B ...	...	...	...	...	...	...	...	...	...	...	...	...	30	0	0	0
	TOTALS ...	460	10	5	3·3	199	0	0	0	150	2	0	1·3	4,718	19	15	0·7
	(Locs.) I. R. ...	(5)	2·2	1·1	...	(5)	0	0	...	(4)	1·3	0	...	(11)	0·4	0·3	...

TABLE XII—*concld.*

From S. W.	Village.	Jan.–Dec. 1941.				Jan.–Mar. 1942.				TOTALS.			
		No.	G+.	Gl+.	I. R.	No.	G+.	Gl+.	I. R.	No.	G+.	Gl+.	I. R.
½	Soran ...	67	0	2	3·0	...	...	...	...	67	0	2	3·0
0	Bolabandh ...	111	1	0	0·9	316	0	0	0	427	1	0	0·2
1	Ichapur ...	164	1	3	2·4	24	0	0	0	188	1	3	2·1
0	Sona Nairi ...	1,858	1	2	0·2	386	0	2	0·5	2,339	1	4	0·2
1–1¼	Chatrapur ...	...	...	...	...	...	...	...	...	212	0	0	0
0–¾	Balugan ...	11	0	0	0	1	0	0	0	36	0	0	0
0	Kespur ...	516	8	2	1·6	59	0	1	1·7	3,628	22	13	1·0
2	Kallikota ...	25	0	1	4·0	20	0	0	0	45	0	1	...
0	Konaka ...	66	0	0	0	...	...	...	...	475	5	2	1·5
0	Sabilia Rambha	168	1	1	1·2	...	...	...	...	1,195	8	7	1·3
0	Dubrakudi ...	23	0	0	0	1	0	0	0	231	1	0	0·4
0	Proyagi ...	20	0	0	0	8	0	0	0	315	1	1	0·5
2	Tolo Humma	37	0	0	0	...	...	...	...	166	0	1	0·6
1	Ganjam Area	960	1	14	1·6	426	0	2	0·5	1,424	1	16	1·2
1	Chatrapur ...	95	0	5	5·3	4	0	0	0	115	1	5	5·2
1	Haripur-B ...	37	0	1	2·7	36	0	0	0	103	0	1	1·0
	TOTALS ...	3,158	11	31	1·3	1,281	0	5	0·4	9,966	42	56	1·0
	(Locs.) I. R. ...	(15)	0·3	1·0	...	(11)	0	0·4	...	...	0·4	...	0·8

Note.—G+ = gut infected. I. R. = infection rate, per cent.
Gl+ = salivary glands infected. No. = number dissected.

APPENDIX.

The following dissections, by the second author, were analysed after the manuscript was completed. They are not germane to the main argument, but furnish additional data on certain of the species of the area from localities and for periods not covered by Tables IV–IX. All dissections were negative except where noted.

	sundaicus.	*culicifacies.*	*fluviatilis.*	*varuna.*	*aconitus.*	*stephensi.*	*annularis.*	*pallidus.*	
Berhampur Town Dec. 1943–Nov. 1945.	3*	5	...	8	3	...	110	1	* 1 Gl+ (Feb. 1944).
Ichchapuram Town Jan. 1944–May 1944.	31	12	...	23	...	...	71*	4	* 2 G+ (Dec. 1943) (supplements Table V).
Mandasa Village Dec. 1943–Apr. 1944.	...	13	...	1	12	...	65	4	
Palasa Station area Dec. 1943–Feb. 1945.	1	29	1	3	15	5	202	6	
Bendi Feb. 1944–Mar. 1944.	...	4	...	7	...	...	23	...	
Themburu Nov. 1943–Jan. 1945.	...	23	34	18	89	1	222	1	A foothill area.

G+ = gut infected. Gl+ = salivary glands infected.

Indian Journal of Malariology, 1, 1, March 1947.

ON THE ANTHROPOPHILIC INDICES OF SOME ANOPHELES FOUND IN EAST CENTRAL INDIA.

BY

R. SENIOR WHITE, F.R.S.E.

[October 10, 1946.]

DURING the past seven years the Malaria Institute of India has carried out, on behalf of the Malaria Section of the Medical Department of the Bengal-Nagpur Railway, 8,456 precipitin tests which have yielded a positive reaction. Though in obtaining the test material every care to make smears only from specimens in which the stomach contents were fresh was enjoined upon the inspectors in the different districts, the number of 'negative' tests has none the less been considerable. This may, however, be at least in part the result of the Institute using human and bovine anti-sera only, which would result in negative reactions with fresh blood from other animals, for of 166 specimens of nine species submitted to the five anti-sera used by Rice and Barber (1935) and reported on in Senior White (1938) five specimens in four species gave positive results for goat, which under the Institute's technique would have been returned as negative. Like every other malaria worker in India, however, the author would gratefully express his indebtedness to the Institute for providing a centralized service for this special technique at a time when the Italian anti-sera, on which the Rockefeller Foundation workers depended, had ceased to be available.

The impending retirement of the author has called a halt to this work, and though much material sent up from the author's section perforce remains at the Institute awaiting test, it seems worth while to put on record an abstract of all the results so far returned, irrespective of whether some of these have not already been published to illustrate points in previous papers. The day will surely come when the whole of the results found at the Institute will be collected into a paper such as the invaluable series compiled by Covell (1927, 1931) in which all the dissection results for India have from time to time been summarized; but pending that day the results for East Central India alone appear worthy of discussion. These are given in Tables I and II.

It will at once be apparent that comparisons of the values found for the three heads under which such are classified for each species from any one locality are

reduced in value, owing to the differences in the numbers tested under each head. On the other hand, results for the same species, taken in the same resting places in different localities, are of great interest, as they reveal differences in the feeding tropisms of the same 'species' which point to the existence of biological 'races' within the systematic unit in different areas.

The species for which the largest numbers of results are available, set out in Table I, have juxtaposed to the anthropophilic indices the results of dissections made in the *same localities* as those where the smears tested were obtained. For these dissections gross 'infection rates', i.e. gut plus gland positives, are shown, as for the purpose of the present argument it is immaterial in what stage an infection is found (since either stage is evidence of human feeding), and affords a comparison with an anthropophilic index. Admittedly the changing gametocyte rate is a potent factor regulating the infection rate, and may have seasonal as well as daily fluctuations, whereas there is little evidence for any seasonal change in trophic habits in this country other than the 'gonotrophic discordance' hypothesis recently advanced by Rao (1947).

My tabulation under the one head, out of doors, of specimens taken in truly feral surroundings, such as among undergrowth and in holes in banks, with specimens taken in empty houses, is perhaps not legitimate, for an odour of man, appreciable to a mosquito, may cling to such houses for some time, though the evidence presented in Rao's observations quoted in Senior White (1937, p. 59) is to the contrary. When 'out of doors' connotes empty houses a remark is made in the last column, and there are no records in which the two types of foodless resting place are commingled. On the other hand, specimens taken resting under culverts are classed as truly feral, for such places are to the mosquito probably only large-size 'holes'.

The species listed in Table I can now be discussed.

A. culicifacies.

In SINGHBHUM, the anthropophilic index is four times as high in houses as in cattlesheds, and there would therefore appear to be in this area some attraction to man, but insufficiently so to make the species an effective vector, as gland infections have never been found. KOREA shows the same phenomenon, a house anthropophilic index five times that found in cattlesheds, but in this area there is epidemiological evidence that *culicifacies* is responsible for transmission during the three monsoon months, in spite of no gland infections having been found in a very large series of dissections (Senior White, 1946).

In the JEYPORE HILLS (Chatikona Summit), on the contrary, the anthropophilic index is the same in houses and in cattlesheds. When the relative proportions of the species taken in the two kinds of shelter are considered (Senior White, Ghosh and Rao, 1945), this appears quite incomprehensible. With such a high anthropophilic index there would appear to be every reason for any species to be an effective vector, yet only a few gut infections have ever been found, and the results of control measures, ignoring it, are conclusive evidence to the contrary.

Around VIZAGAPATAM, the anthropophilic index found is not altogether natural, being affected by trap-hut catches, in which alone infections were found.

The cattleshed anthropophilic index is quite high, though an adequate number of dissections have shown no infections.

Considering the species as a whole, the results tabulated appear so contradictory that the hypothesis that the name '*culicifacies*' covers a whole series of crypto-species (or biological races) is greatly strengthened.

A. fluviatilis.

In SINGHBHUM, the anthropophilic index in houses is high, and dissections show it to be the major vector. Collections from cattlesheds suggest the existence of a second race with a preference for bovine blood. In the JEYPORE HILLS, two localities show such different results that they have been separately tabulated. At Chatikona Summit there is a very strongly anthropophilic race, a minute proportion of which strays into cattlesheds, and very occasionally feeds there. Bandiguda, twenty miles further north, in very similar country, on the other hand presents quite conflicting results. The house anthropophilic index is very low for the species, and that in cattlesheds indicates that this population is again mainly an overflow from houses. However, the December catches, included in these totals, showed a rise in house anthropophilic index to 53 per cent, the only evidence of a seasonal variation. The spleen rate of this village, 90·6 per cent, is as high as in the villages around Chatikona Summit, where the vector anthropophilic index is four times as high. Evidently, in these comparatively well-investigated hills there is a multiplicity of problems still to be solved.

In the HAZARIBAGH RANGES, transmission on the eastern slopes below Ranchi is still most incompletely understood, and the Ramgarh records are too small in numbers for useful discussion. If *fluviatilis* is the major vector locally, at the infection rates found in the not far distant Singhbhum Hills even 219 dissections should have shown positives. On the other hand, if the local rates are no higher than those found in Korea, at the western end of these ranges (Senior White, 1946), the numbers are too small to make a positive finding probable. Above all the areas of East Central India these Hazaribagh Ranges demand further, and intensive, investigation.

A. varuna.

In SINGHBHUM, the house anthropophilic index is rather lower than in *fluviatilis* from the same area. The cattleshed anthropophilic index again suggests the existence of a second race with bovine preferences. In this species there is sufficient out-of-doors material to discuss. The anthropophilic index and the infection rates appear contradictory. Now that Posoita, where the results tabulated were obtained (Senior White, Ghosh and Rao, *loc. cit.*), is under D.D.T. protection, an opportunity is presented to whoever may succeed the author to investigate this out-of-doors resting with the sure knowledge that so-caught specimens have not visited houses. In the JEYPORE HILLS (Chatikona Summit) *varuna* from all three types of resting place agrees absolutely with *fluviatilis*.

In the EASTERN SATPURAS the anthropophilic index of the house population is much lower, though the infection rate is very high, whilst the cattleshed value

suggests the existence of a separate race, as in Singhbhum. In the VIZAGAPATAM area the anthropophilic index is again high in houses and low in cattlesheds, but the numbers captured, both for precipitin tests and for dissection, indicate that here the species is primarily a bovine feeder, with an anthropophilic race as numerically small as is the boviphilic race in the Jeypore Hills. There seems little doubt that around Vizagapatam we are not dealing with the same species as in the hills, but until the statistician to whom the numerous egg measurements recorded have been referred completes his analysis, it will not be clear as to whether there are two, or even four races distinguishable on egg measurements, which his first analysis suggested. In this area it would appear that it is only the low proportion of the anthropophilic race in the total *varuna* population that prevents the 'species' being dangerous.

A. minimus.

In SINGHBHUM, this species in houses shows the same behaviour as *fluviatilis*, but it is much rarer than that species in cattlesheds, the small numbers taken making the apparent difference in the cattleshed anthropophilic index untrustworthy. In the JEYPORE HILLS *minimus* results agree in all respects with the local races of the other two species of the group.

Taking this group as a whole for Singhbhum and Chatikona, it is found—

	House A. I. per cent.	Cattleshed A. I. per cent.
Singhbhum ...	68·0	8·9
Chatikona ...	84·1	64·4

A. I. = anthropophilic index.

but the relative proportion of adults taken in houses and in cattlesheds in the two areas is entirely different.

A. annularis.

Whilst this species is the major vector of the ORISSA COASTAL PLAIN it is of no significance at Dongargarh in the EASTERN SATPURAS. In both areas the anthropophilic index is so low that *prima facie* it appears inconceivable that the species should play any part in malaria causation. However, in both areas, the house infection rates are higher than those of the non-vectorial races of *culicifacies* discussed above. The dates of the 'man +' findings are important. These are :—

Orissa ... July, 3 ; October 13 to November 19, 7.

Dongargarh ... All eleven between October 18 and January 3.

Thus at Dongargarh *annularis* is found biting man when the cold weather has set in and the extrinsic cycle of the malaria parasites has been nearly if not yet quite inhibited. In Orissa, however, infective specimens have only been found between September and November, which period is the height of the local transmission season. At Dongargarh *annularis* has never been found infective and once only, at the close of a *culicifacies*-caused epidemic, has an oöcyst infection been found. Another matter of great significance is the spatial distribution of the 'man +' specimens. In Orissa, 99 per cent of these came from houses, whereas at Dongargarh only 27 per cent did so. In Orissa the house anthropophilic index, low as it is, is eighteen-fold that found in cattlesheds, whereas at Dongargarh the values are equal.

Rao (*loc. cit.*) has adduced evidence to show that in Orissa there appears in *annularis* to be 'gonotrophic discordance' leading to temporary house fixation until the number of blood meals requisite to mature the ovary has been taken, which of course results in increased opportunities for acquiring and perhaps even for maturing an infection, whereas at Dongargarh a house-fed specimen is as likely as not to enter a cattleshed to digest. If there then follows gonotrophic discordance, it is not known what may be the result of successive meals from different animals on a developing gut infection. Even if development is not affected, should the mosquito remain feeding on cattle, whilst the ovaries gradually mature, and its stay be long enough to extend to gland invasion, then the sporozoites formed may be wasted.

Remaining species.

Table II summarizes the much less complete information on the remaining species which have been submitted to test. This is generally too scanty to be worth more than brief remarks on certain species only. At Chatikona Summit a considerable proportion of the *aconitus* captured in cowsheds have fed on man, whereas with *jeyporiensis* the man-fed proportion of the cattleshed captures is very much lower, both species in houses having much the same anthropophilic index.

The anthropophilic index found for *stephensi* around Vizagapatam cannot represent the maximum values that must occur in epidemics caused by this species: the 10 per cent sporozoite rate shown in Table VIII of Senior White, Ramakrishna and Rao (1947) must surely be the result of an anthropophilic index higher than 15 per cent.

In the mildly endemic tracts of the Central Provinces, Kenrick (1911) considered *pallidus* to be a vector of importance. The author's figures from Dongargarh show an equal anthropophilic index in houses and in cowsheds, with a *nil* infection rate in house captures (Senior White, 1946). It is doubtful whether it ever plays any part in transmission in the town, whatever may prove to be its vectorial status in other parts of the province.

A. sundaicus.—The two anthropophilic index values tabulated are from not very distantly separated inland villages in the North Madras coastal belt. The value found at Dimilada was at a period subsequent to the original invasion

epidemic outburst, and is not high; when this mosquito is showing epidemic infection rates such as are shown in Table V of Senior White, Ramakrishna and Rao (*loc. cit.*), or as were found by Iyengar (1931) in the original Bengal invasion, it must be inferred that the anthropophilic index must be in the vicinity of one hundred per cent. The index found at Tharlakota is very low. It was recorded during the period of the dissection collections summarized in Table IX of Senior White, Ramakrishna and Rao (*loc. cit.*), when the infection rate was more conformable to endemic than to epidemic conditions. The figure found is very valuable, as illustrating how a quite appreciable infection rate can exist in the face of a very low anthropophilic index.

DISCUSSION.

Throughout this paper repeated references have been made to the existence of crypto-species, or biological races, in explanation of the differences in tropisms and in vectorial capacity found in certain of the 'systematic' species as between different areas. The matter is not exactly on a par with the elucidation of malaria distribution in Europe resulting from Falleroni's discovery of races in *A. maculipennis* distinguishable by differing egg patterns. Except in the case of *A. varuna* there is no suggestion that even differences in egg measurements will serve to distinguish races, as was done in *A. stephensi* by Sweet and Rao (1937).

In the face of complete lack of visible differences in *culicifacies* to account for its non-vectorial status in the Jeypore Hills, the author first advanced the hypothesis of different races in this species (Senior White, 1937). The matter was taken up by Sweet and Rao (1938), who failed to find any statistically significant differences in egg measurements in this species from four localities, including the Jeypore Hills. Later Pal (1945) pursued the same subject in respect of larval and adult differences without success, but being convinced that in *culicifacies* races do exist, informed the author recently, that he was about to study the chromosomal make-up in different areas. Only a worker able to devote his whole time to it can undertake such a study, and if real differences do exist, as seems probable from the evidence presented in Senior White (1940) and in the present paper, and such are found to consist of differences in genes, then the investigation of such races must pass from field biologists to the purely laboratory investigator, the function of the field biologist being to produce evidence such as has already been adduced for the apparent existence of races. That differences in anthropophilic index alone will not account for varying vectorial capacity such as exists in *culicifacies* is amply demonstrated by the species being the vector at Delhi and Pattukottai on anthropophilic indices of no more than 1·9 and 2·6 per cent respectively, and being of no vectorial importance at Chatikona on a house anthropophilic index of 25·7 per cent (Senior White, Ghosh and Rao, *loc. cit.*).

A. fluviatilis presents a different problem. It is not apparently a vector in Turkestan and Northern Iraq, and until recently was believed not to be a vector in India north of the Ganges, though during the war it came under suspicion in the foothills of the western U. P., beyond the distribution of *minimus*, known to be the vector as far west as Bazpur in the U. P. Terai. In peninsular India, however, it was everywhere accepted as a vector until Viswanathan (1946) failed

to incriminate it in the Bombay Deccan, within fifty miles of the Kanara District where he has shown it to be the sole vector, and of a virulence as great as has been found for it anywhere in Southern India.

But as between the Jeypore and the Singhbhum Hills there are, as shown in Table I, most striking differences in the behaviour of *fluviatilis* when outside the house, its principal feeding place. In Singhbhum it is not seldom found in cow-sheds, and there shows an anthropophilic index very much lower than in houses. In the Jeypore Hills (Chatikona) it is exceeding sparse in cattlesheds, but has there an anthropophilic index indicative of its use thereof almost solely for resting purposes, though there is a slight, but undoubtedly significant, reduction in the cattleshed anthropophilic index which must be caused by some part of that catch having actually fed on cattle. So unexpected are the results from Bandiguda, where it maintains hyperendemic conditions on an anthropophilic index lower than that of the locally harmless *culicifacies*, that had it been possible the author would have preferred to await the second year's precipitin results, now being collected, before indulging in any speculations at all.

In the Eastern Satpuras the species is undoubtedly the principal vector (Senior White and Adhikari, 1940), though in the same hills, further west Kenrick (references in Senior White and Adhikari, *loc. cit.*) and de Burca (1946) have failed to incriminate it.* The number of *fluviatilis* dissections carried out by de Burca's co-workers are too few to justify its acquittal, even though during epidemics *culicifacies* is the causative anopheline.

If there is a single species in which hitherto there has been no suggestion of the existence of races it is *A. minimus*. Yet Table I shows a difference in trophic behaviour in cattlesheds in Singhbhum and the Jeypore Hills somewhat similar to that found in *fluviatilis*, save that in the former it enters cattlesheds to a much lesser extent.

The only other Indian species in which great differences in behaviour have been shown to exist is *A. annularis*, which has already been discussed. But there are such great differences in climate between Coastal Orissa and the Satpura Ranges of the Central Provinces that until this species has been studied in places intermediate in this respect it is not possible to decide whether the differences found are simply those due to climate, or whether they afford evidence for the existence of biological races in this species also.

The problems raised in the present paper were first discussed by Buxton (1938), the last sentence of whose paper reads: 'We might be well advised to record the facts and refrain from making further categories or definitions.' To accept this dictum, however, is not to debar oneself from speculating on what the facts so far accumulated may reveal or conceal, for without such thinking the accumulation of facts becomes mere mechanical labour, and such accumulating should therefore be undertaken with a preconsidered goal. Had it been realized earlier that the

---

* Jubbulpore (de Burca, *loc. cit.*, Table, p. 266) is approximately in the same longitude as the Wainganga Valley, only 100 miles further south, where Senior White and Adhikari (*loc. cit.*) have shown that *fluviatilis* is the primary vector. The reference in de Burca to 'hypomelanic forms' of *culicifacies* engenders suspicion regarding identifications.

lack of cattleshed dissections seen in Table I would have hampered, as it has, the present argument, an effort could have been made to carry out such, even though at the constant high pressure at which this laboratory has worked it would have been difficult to provide the necessary time; for the immediately practical aspect has always had to be placed in the forefront of our work, viz. to discover, as leading to strict species control, the local vector and transmission season in each area, and this demanded that primary attention be paid to house collections.

The author therefore bequeaths the filling of the *lacunæ* thus indicated to his successor as Malariologist of the Bengal Nagpur Railway.

SUMMARY AND CONCLUSIONS.

1. Evidence is presented, in respect of five species of Anopheles, to show that their anthropophilic index has wide differences in different localities, and according to whether they are caught in houses or in cattlesheds. The import of the differences found is discussed.

2. Of these five species, only *A. varuna* has so far shown any indication of being separable into unrecognizable races by measurements. It is however thought that the evidence adduced indicates the existence of biological races in at least *culicifacies*, *fluviatilis* and *minimus* in addition, though at present no separatory characters, systematic or statistical, have been found.

REFERENCES.

BUXTON, P. (1935) ... Anopheles and the species problem. *Proc. Zool. Soc.*, Ser. C., **108**, pp. 57–60.

CHRISTOPHERS, S. R. (1933) ... *Fauna of British India, Diptera*, **4**, *Anophelini*, Taylor and Francis, London, p. 208.

COVELL, G. (1927) ... A critical review of the data recorded regarding the transmission of malaria by the different species of Anopheles. *Ind. Med. Res. Memoir No.* 5.

Idem (1931) ... The present state of our knowledge regarding the transmission of malaria by the different species of anopheline mosquitoes. *Rec. Mal. Surv. Ind.*, **2**, pp. 1–48.

DE BURCA, B. (1934) ... Tropical zone malaria associated with an increase in *P. falciparum* infections in the spring wave. *J. Mal. Inst. Ind.*, **6**, pp. 265–267.

IYENGAR, M. O. T. (1931) ... The distribution of *A. ludlowi* in Bengal and its importance in malarial epidemiology *Ind. Jour. Med. Res.*, **19**, pp. 499–524.

KENRICK, W. H. (1911) ... *Report upon malaria in the Central Provinces.* Govt. Press, Nagpur.

PAL, R. (1945) ... On the bionomics of *A. culicifacies* Giles. Part IV. *J. Mal. Inst. Ind.*, **6**, 2, pp. 239–241.

RAO, V. V. (1947) ... On gonotrophic discordance among certain Indian Anopheles. *Ind. J. Mal.*, **1**, pp. 43–50.

RICE, J. B., and RAMBER, M. A. (1935). Malaria studies in Greece. *J. Lab. Clin. Med.*, **20**, pp. 876–883.

SENIOR WHITE, R. (1937) ... On malaria transmission in the Jeypore Hills. Part I. *Rec. Mal. Surv. Ind.*, **7**, pp. 47–75.

Idem (1938) ... On malaria transmission in the Jeypore Hills. Part II. *J. Mal. Inst. Ind.*, **2**, pp. 129–145.

SENIOR WHITE, R. (1940) ... Studies on the behaviour of *A. culicifacies*. Part III. *Ibid.*, **3**, pp. 363–382.

Idem (1946) ... On malaria transmission in East Central India. Further data. *Ibid.*, **6**, pp. 469–488.

SENIOR WHITE, R., and ADHIKARI, A. K. (1940). On malaria transmission in the Eastern Satpura Ranges. *Ibid.*, **3**, pp. 383–411.

SENIOR WHITE, R., GHOSH, A. R., and RAO, V. V. (1945). On the adult bionomics of some Indian Anopheles. *Ibid.*, **5**, pp. 129–215.

SENIOR WHITE, R., RAMAKRISHNA, V., and RAO, V. V. (1947). Malaria on the North Madras Coast. Part I. *Ind. J. Mal.*, **1**, 1, pp. 81–109.

SENIOR WHITE, R., and RAO, V. V. (1943). On malaria transmission around Vizagapatam. *J. Mal. Inst. Ind.*, **5**, pp. 187–205.

SWEET, W. C., and RAO, B. A. (1937). Races of *A. stephensi* Liston 1901. *Ind. Med. Gaz.*, **72**, pp. 665–674.

SWEET, W. C., and RAO, B. A. (1938). Measurements of *A. culicifacies* Ova. *J. Mal. Inst. Ind.*, **1**, pp. 33–35.

[illegible] D. K. (1946) ... The seasonal prevalence of malaria trans- [illegible]

TABLE

Anthropophilic indices

Species.	Houses.					Cattlesheds.				
	No.+	M.+	A. I.	No. diss.	I. R.	No.+	M.+	A. I.	No. diss.	I. R.
culicifacies.										
Singhbhum ..	81	5	6·2	9,794	0·07	147	2	1·4	..	..
Chatikona ..	70	18	25·7	3,947	0·08	626	156	24·9	262	0
Korea	211	13	6·2	16,381	0·02	246	3	1·2	..	..
Vizagapatam District	202	26	12·8	2,261	0·09	385	33	8·6	4,590	0
Totals ..	564	62	11·0	32,383	0·05	1,404	194	13·8	4,852	0
fluviatilis.										
Singhbhum ..	321	222	69·2	10,731	5·2	362	33	9·1	..	..
Chatikona ..	357	295	82·6	2,709	8·3	14	9	64·3	10	0
Bandiguda ..	348	70	20·1	..	..	52	7	13·5	..	..
Ramgarh ..	24	9	37·5	219	0	16	2	12·5	110	0
Vizagapatam District	..	..	..	..	..	1	1	100	1	0
Totals	1,050	596	56·8	13,749	5·7	445	52	11·7	121	0
varuna.										
Singhbhum ..	124	66	53·2	964	4·3	114	7	6·1	..	..
Chatikona ..	96	78	81·2	518	8·5	22	14	63·6	2	0
E. Satpuras .	55	18	32·7	180	9·4	88	7	8·0	..	..
Vizagapatam District	94	55	58·5	762	0·1	779	71	9·1	10,567	0·01
Totals	369	217	58·8	2,424	4·2	1,003	99	9·9	10,569	0·01
minimus.										
Singhbhum ..	234	174	74·4	638	10·2	28	5	17·9	..	..
Chatikona .	124	112	90·3	341	7·0	9	6	67·7	..	..
Totals .	358	286	79·9	979	9·1	37	11	29·7	..	..
annularis.										
Chatikona ..	1	0	0	..	..	..	..	..	..	..
Orissa Plain ..	281	10	3·6	9,446	0·23	553	1	0·2	423	0
Dongargarh ..	148	3	2·0	5,181	0·25	460	8	1·7	..	..
Totals	430	13	3·0	14,627	0·24	1,013	9	0·9	423	0

* Gut and gland infections considered together.
No.+ = number positive.
M.+ = positive for man.

*and infection rates.**

OUT OF DOORS.					TOTALS.					
No.+	M.+	A. I.	No. diss.	I. R.	No.+	M.+	A. I.	No. diss.	I. R.	
9	1	2·0	2	0	278	8	2·9	9,796	0·07	'OUT'=empty houses.
2	1	33·3	..	..	708	178	25·1	4,209	0·07	
		..	..	..	457	16	3·5	16,381	0·02	
			..	..	587	59	10·1	6,851	0·03	Infections in trap hut only.
[illegible]	[illegible]	[illegible]	2	0	2,030	261	12·9	37,237	0·04	
2	1	50·0	52	0	695	259	37·3	10,783	5·2	
27	25	92·6	..	..	398	329	82·7	2,809	8·2	'OUT'=empty houses. Spleen rate (May 1943) 90·6 per cent.
..	..	..	..	..	400	77	19·2	..	..	
	..	..	..	..	40	11	27·5	329	0	
	..	..	..	..	1	1	100	1	0	
38	29	74·4	52	0	1,534	677	44·1	13,022	5·7	
347	14	4·0	17	5·9	585	87	14·9	981	4·3	
7	6	85·7	..	..	125	98	78·4	520	8·5	'OUT'=empty houses.
..	..	..	..	..	143	25	17·5	180	8·4	
	..	..	..	..	873	126	14·4	11,329	0·02	Infections in trap huts only.
354	20	5·6	17	5·0	1,726	336	13·7	13,010	0·08	
4	3	75·0	13	15·4	266	182	68·4	651	10·3	
	3	100	..	..	138	123	89·1	341	7·0	'OUT'=empty houses.
4	3	75·0	13	15·4	404	305	75·5	992	9·2	
	..	..	..	..	1	0	0	..	..	
		..	..	..	834	11	1·3	9,869	0·2	
	..	..	..	..	608	11	1·8	5,181	0·2	
	..	..	..	..	1,443	22	1·5	15,050	0·2	

A. I. = anthropophilic index, per cent.
No. diss. = number dissected.
I. R. = infection rate, per cent.

Table II.

Anthropophilic indices.

Species.	Houses.			Cattlesheds.			Out of doors.			Totals.		
	No.+	M.+	A. I.	No.+	M.+	A. I.	No.+	M.+	A. I.	No.+	M.+	A. I.
aconitus.												
Chatikona	14	4	28·6	145	21	14·5	22	3	13·7*	181	28	15·5
jeyporiensis.												
Chatikona	26	6	23·1	314	27	8·6	37	1	2·7*	377	34	9·0
stephensi.												
Vizagapatam District.	77	12	15·6	..	..	..	..	..	..	77	12	15·6
Dongargarh ..	3	0	0	..	..	..	..	..	..	3	0	0
Totals ..	80	12	15·0	..	..	..	..	..	..	80	12	15·0
maculatus.												
Singhbhum ..	..	..	..	40	0	0	..	..	..	40	0	0
theobaldi.												
Singhbhum ..	..	..	..	3	0	0	..	..	..	3	0	0
splendidus.												
Singhbhum	3	0	0	29	0	0	..	..	..	32	0	0
Chatikona ..	1	1	100	..	..	..	..	..	..	1	1	100
Totals ..	4	1	25·0	29	0	0	..	..	..	33	1	33·3
tessellatus.												
Singhbhum ..	1	0	0	13	0	0	2	0	..	16	0	0
pallidus.												
Chatikona	..	..	..	1	0	0	..	..	..	1	0	0
Dongargarh ..	88	1	1·1	325	3	0·9	..	..	..	413	4	1·0
Totals ..	88	1	1·1	326	3	0·9	..	..	..	414	4	1·0
subpictus.												
Chatikona ..	12	0	0	34	0	0	..	..	..	46	0	0
vagus.												
Chatikona ..	21	0	0	9	0	0	..	..	..	30	0	0
sundaicus.												
Tharlakota ..	72	2	2·8	..	..	..	..	..	..	72	2	2·8
Dimilada ..	18	3	16·7	..	..	..	..	..	..	18	3	16·7
Totals ..	90	5	5·6	..	..	..	..	..	..	90	5	5·6

* From empty houses.
No.+ = number positive.
M.+ = positive for man.
A. I. = anthropophilic index, per cent.

Indian Journal of Malariology, 1, 1, March 1947.

THE FREQUENCY OF DISTRIBUTION OF GAMETOCYTES OF THE INDIAN STRAINS OF MALARIA PARASITES*.

BY

B. C. BASU, D.Sc.

(*Research Officer, Imperial Veterinary Research Institute, Izatnagar, India.*)

[December 3, 1946.]

KNOWLES and Basu (1943) and Basu (1943) worked out the actual correlation between the density of malarial gametocytes in the peripheral blood and the rate of infectivity in susceptible mosquitoes. The present paper deals with the frequency of distribution of gametocytes of the Indian forms of three species of malaria parasites studied in 318 gametocyte-carriers, *viz.*, *Plasmodium falciparum*, 163 ; *P. vivax*, 84 ; and *P. malariæ*, 71. Gametocyte counts were made by Sinton's (1924) fowl-corpuscle method.

Table I shows the frequency of distribution of gametocytes of *P. vivax*. The number varied from 'scanty' (less than 40) to 3,800 per c.mm., the average being 334.

Table II shows the frequency of distribution of gametocytes of *P. malariæ*. The number of gametocytes of *P. malariæ* varied between 'scanty' and 480 per c.mm., the average being 81.

Table III represents the frequency of distribution of gametocytes of *P. falciparum*. The number of gametocytes varied between 'scanty' and 4,920 per c.mm., the average being 489.

From these tables it will be seen that the three different species of parasite show a marked variation. The frequency of distribution of the gametocytes of *P. falciparum* is greater than in the other species. *P. vivax* causes more frequent relapse with the appearance of gametocytes, and therefore may have more opportunities for spread. *P. malariæ* produces fewer sexual forms than either of the species.

* This work was carried out at the School of Tropical Medicine, Calcutta.

TABLE 1.

Frequency distribution of gametocytes of P. vivax.

Gametocytes per c.mm.	Number of carriers.	Total gametocytes.
0	2	0
+	7	7
40	10	400
80	13	1,040
120	3	360
160	9	1,440
200	10	2,000
240	6	1,440
280	1	280
320	7	2,240
360	2	720
400	3	1,200
440	0	0
480	2	960
520	1	520
560	...	...
600	...	...
920	1	920
1,120	1	1,120
1,280	1	1,280
1,360	2	2,720
1,800	1	1,800
3,800	2	7,600
TOTALS ...	84	28,047

Average gametocytes per carrier 334 per c.mm.

TABLE II.

Frequency distribution of gametocytes of P. malariæ.

Gametocytes per c.mm.	Number of carriers.	Total gametocytes.
+	13	13
40	20	800
80	18	1,440
120	8	960
160	8	1,280
200	1	200
240	1	240
280	0	...
320	1	320
480	1	480
TOTALS ...	71	5,733

Average gametocytes per carrier 81 per c.mm.

TABLE III.

Frequency distribution of gametocytes of P. falciparum.

Gametocytes per c.mm.	Number of carriers.	Total gametocytes.
+	9	9
40	4	160
80	16	1,280
120	8	960
160	16	2,560
200	8	1,600

TABLE III—*concld.*

Gametocytes per c.mm.	Number of carriers.	Total gametocytes.
240	14	3,360
280	5	1,400
320	8	2,560
360	4	1,440
400	6	2,400
440	9	3,960
480	2	960
520	5	2,600
600	3	1,800
640	6	3,840
680	6	1,360
720	1	720
800	4	3,200
840	4	3,360
1,040	1	1,040
1,120	3	3,360
1,200	4	4,800
1,280	5	6,400
1,360	1	1,360
1,400	3	4,200
1,440	1	1,440
1,600	2	3,200
1,760	1	1,760
2,160	1	2,160
2,760	2	5,520
4,920	1	4,920
TOTALS ...	163	79,689

Average gametocytes per carrier 489 per c.mm.

SUMMARY.

The frequency of distribution of gametocytes of Indian strains of three species of Plasmodium was studied in 318 gametocyte-carriers *P. vivax*, 84 ; *P. malariæ*, 71 ; and *P. falciparum*, 163.

The number of gametocytes of *P. vivax* varied between 'scanty' (less than 40) and 3,800 per c.mm., average 334 ; that of gametocytes of *P. malariæ* varied between 'scanty' and 480 per c.mm., average 81, and that of gametocytes of *P. falciparum* varied between 'scanty' and 4,920 per c.mm., average 489.

REFERENCES.

Basu, B. C. (1943) ... ... *J. Mal. Inst. Ind.*, **5**, pp. 31–51.
Knowles, R., and Basu, B. C. (1943). *Ibid.*, **5**, pp. 1–29.
Sinton, J. A. (1924) ... *Ind. J. Med. Res.*, **12**, pp. 341–346.

Indian Journal of Malariology, 1, 1, March 1947.

ABNORMAL DEVELOPMENT OF MALARIAL OÖCYSTS IN *ANOPHELES STEPHENSI*.*

BY

B. C. BASU, D.Sc.

(*Research Officer, Imperial Veterinary Research Institute, Izatnagar, India.*)

[December 3, 1946.]

In the normal development of malarial parasites in mosquitoes, the oökinetes bore through the walls of the insect's stomach, penetrating between the columnar epithelial cells until they lie in the space between the epithelium and the elastic membrane covering it. Here they become globular forms called oöcysts, which grow gradually and when mature burst, liberating the sporozoites into the hæmocœle.

Certain abnormalities in the development of malarial oöcysts, noted in serial sections of infected mosquitoes, are described in this note. The mosquitoes referred to were all laboratory-bred *Anopheles stephensi*, and were fed on gametocyte-carriers of the Indian strain of human malaria.

ABNORMALITIES.

(*i*) In some of the fed mosquitoes (especially in *Plasmodium falciparum* infections), oöcysts packed with sporozoites were found developing towards the lumen of the midgut (Plate VII). Such oöcysts would rupture into the gut, but the mosquitoes concerned could not be infective, as the sporozoites liberated would have no chance to invade the salivary glands. Thus, an infected mosquito is very different from an infective mosquito. The diagram of Wenyon *et al.* (1921) is also suggestive of this phenomenon. It would be interesting to find out if there was any particular factor responsible for this condition.

(*ii*) In some mosquitoes, infected with *P. vivax*, *P. malariæ* and *P. falciparum*, pigmentary degeneration of the oöcysts resulted in the formation of the 'black spores' of Ross, the pigment being derived from the parasite and not from the

---

*This work was carried out at the School of Tropical Medicine, Calcutta.

mosquito tissue. Knowles and Basu (1933) studied the formation and evolution of these bodies.

In the first series of experiments, 173 of the mosquitoes, fed on gametocyte-carriers of *P. vivax*, survived and were serially sectioned, stained and examined. Two showed 'black spores'. In the second series, 61 mosquitoes fed on gametocyte-carriers of *P. malariæ* survived and were sectioned, stained and examined. Four of them showed degenerated and pigmented oöcysts or 'black spores', associated with normal oöcysts. In the third series, survivals of the mosquitoes fed on gametocyte-carriers of *P. falciparum*, 354 in number, were sectioned, stained and examined. Thirteen of them showed the 'black spores', which were associated with normal oöcysts in some cases. In the fourth series, included as a comparison, batches of normal unfed *A. stephensi* were sectioned, stained and examined, but in none of them were 'black spores' found.

It may be concluded from the foregoing observations that the 'black spores' of Ross, or at least degenerated and densely pigmented oöcysts, are generally found in mosquitoes in which malaria infection is present.

In a single mosquito there may be found: (*a*) Only a few completely degenerated oöcysts towards the hinder end of the midgut. (*b*) Partially degenerated oöcysts, with or without completely degenerated ones. (*c*) Findings (*a*) or (*b*) associated with perfectly healthy oöcysts showing sporozoite formation.

The number of these bodies varied from one to sixteen in a single mosquito.

Protocols of these experiments are summarized below in a tabular form.

TABLE I.

Black spores of Ross.

(1) B. T.—Male; Hindu; 18; gametocyte count 160 per c.mm.; 92 mosquitoes fed; 56 survived; 20 showed gut +, one with black spores also; 6 days; T. 85°F.; R.H. 76 per cent.

(2) B. T.—Male; Christian; 36; gametocyte count 240 per c.mm.; 176 mosquitoes fed; 117 survived; 23 showed gut +, one with black spores also; 20 days; T. 66°F.; R.H. 72 per cent.

(3) Q.—Male; Hindu; 22; gametocyte count 40 per c.mm.; 112 mosquitoes fed; 61 survived; no gut infection; 4 showed black spores; 7 days; T. 85°F.; R.H. 76 per cent.

(4) M. T.—Male; Hindu; 27; gametocytes +; 35 mosquitoes fed; 20 survived; 12 showed gut +, one with black spores also; 13 days; T. 80°F.; R.H. 60 per cent.

(5) M. T.—Male; Hindu; 6; gametocyte count 240 per c.mm.; 52 mosquitoes fed; 17 survived; no gut infection; one showed black spores; 12 days; T. 85°F.; R.H. 76 per cent.

(6) M. T.—Male; Hindu; 6; 12 doses of atebrin + 4 of plasmoquine; gametocyte count 240 per c.mm.; 66 fed; 53 survived; no gut infection; 9 days; one gut with black spores; 11 days; T. 85°F.; R.H. 76 per cent.

M. T. = malignant tertian.
B. T. = benign tertian.
Q. = quartan.
T. = temperature.
R.H. = relative humidity.

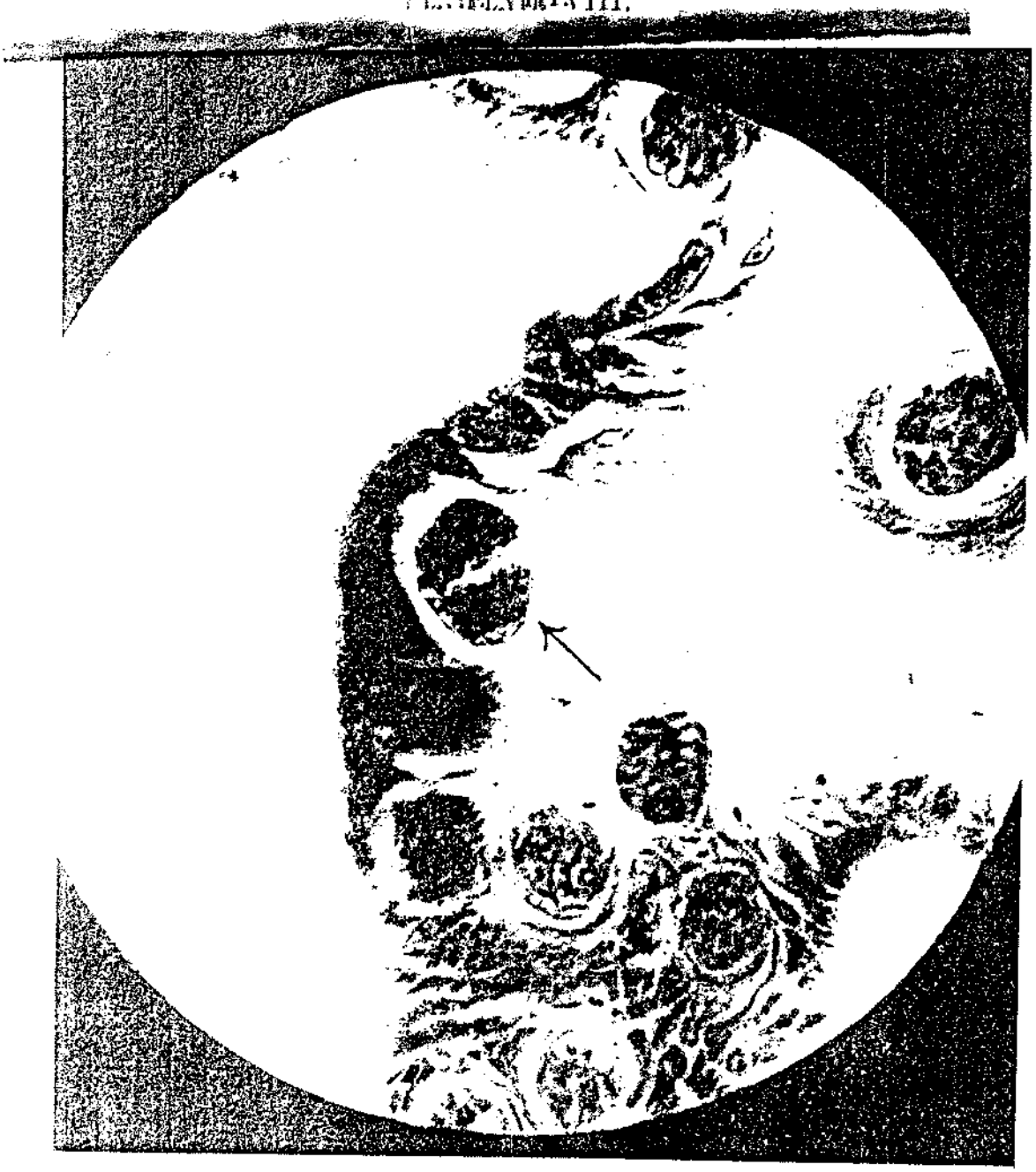
130 (1)

PLATE VII.

Photomicrograph showing malarial oöcyst developing towards the lumen of the midgut.

130 138 (2) (2)

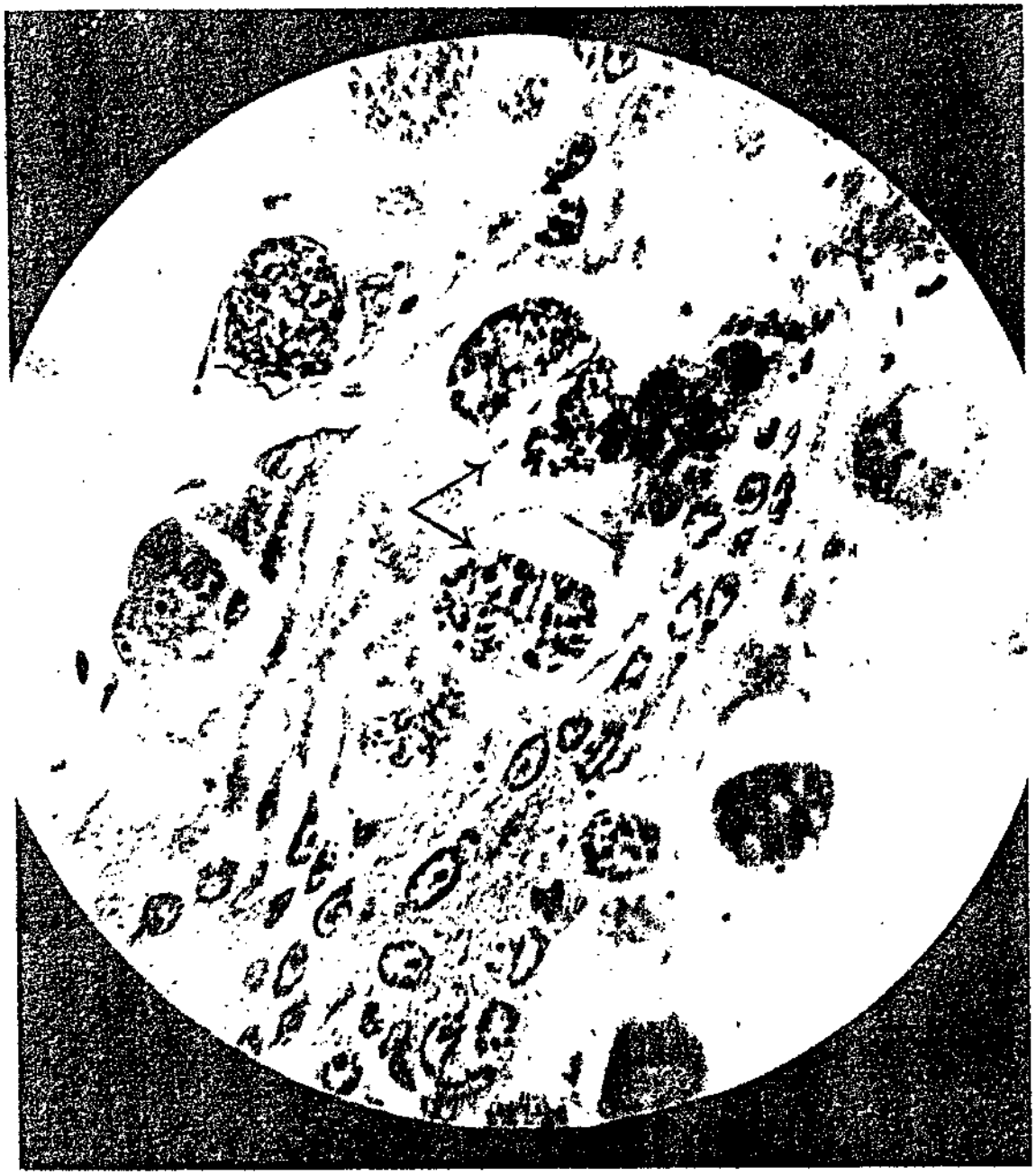
PLATE LVIII.



Photomicrograph showing malarial oöcyst with divided (?) contents.

130 (3)

PLATE IX.



Photomicrograph showing malarial oöcysts with divided (?) contents.

TABLE I—*concld.*

(7) M. T.—Male; Hindu; 6; 12 doses of atebrin; gametocyte count 280 per c.mm.; 28 fed; 15 survived; no gut infection; one gut with black spores; 11 days; T. 85°F.; R.H. 76 per cent.

(8) M. T.—Male; Hindu; 9; 12 doses of atebrin; gametocyte count 320 per c.mm.; 61 fed; 34 survived; 19 gut +, one with black spores; 9 days; T. 85°F.; R.H. 76 per cent.

(9) M. T.—Female; Christian; 14; gametocyte count 400 per c.mm.; 40 fed; 24 survived; 11 gut +; one with black spores; 14 days; T. 70°F.; R.H. 90 per cent.

(10) M. T.—Male; Hindu; 9; 12 doses of atebrin; gametocyte count 720 per c.mm.; 54 fed; 40 survived; 29 with gut +; 3 with black spores; 7 days; T. 85°F.; R.H. 76 per cent.

(11) M. T.—Male; Hindu; 9; 6 doses of atebrin; gametocyte count 800 per c.mm.; 125 fed; 72 survived; 38 with gut +; one with black spores; 11 days; T. 85°F.; R.H. 76 per cent.

(12) M. T.—Male; Hindu; 9; 3 doses of atebrin; gametocyte count 840 per c.mm.; 150 fed; 59 survived; 31 with gut +; 2 with black spores; 12 days; T. 85°F.; R.H. 76 per cent.

(13) M. T.—Male; Indian Christian; 12; 3 days cinchona febrifuge; gametocyte count 1,360 per c.mm.; 84 fed; 20 survived; 10 with gut +; one with black spores; 14 days; T. 80°F.; R.H. 90 per cent.

M. T. = malignant tertian. T. = temperature.
B. T. = benign tertian. R.H. = relative humidity.
Q. = quartan.

(*vii*) In two mosquitoes infected with *P. vivax*, it appeared as if the whole protoplasmic contents of oöcysts had divided (?) into two masses—the appearance rather recalling that which occurs in the oöcysts of *Isospora* (Coccidiida). It is probable that two zygotes had settled down so close together that they had formed a common cyst (?). The history of these two mosquitoes is that they were fed on a patient showing 480 gametocytes of *P. vivax* per c.mm. of blood and were kept in an air-conditioned cabinet at a temperature of 66°F. and relative humidity of 70 per cent, conditions which correspond to those of the average cold weather in Calcutta.

The process is certainly not one of degeneration, as the usual formation of very numerous daughter nuclei is seen in the protoplasmic masses, proceeding in the usual manner towards sporozoite formation. In both mosquitoes, fairly heavy gut infection with oöcysts was observed. In the first mosquito the measurement of 25 normal oöcysts with undivided contents varied from $16 \times 12\ \mu$ to $24 \times 20\ \mu$ with a mean at $20 \times 17\ \mu$: two oöcysts with divided (?) contents measured $20 \times 16\ \mu$ and $24 \times 20\ \mu$ respectively (Plate VIII). In the second, the measurement of seven abnormal oöcysts with divided (?) contents varied from $24 \times 18\ \mu$ to $32 \times 24\ \mu$ with a mean at $28 \times 22\ \mu$: the measurements of 26 oöcysts showing undivided contents varied from $20 \times 20\ \mu$ to $32 \times 24\ \mu$ with a mean at $26 \times 21\ \mu$ (Plate IX). These oöcysts with divided (?) contents are admittedly a rare abnormality in the sporogony cycle of malaria parasites, but their occurrence emphasizes the close relationship between these parasites and Coccidiida.

Dr. C. M. Wenyon, F.R.S., kindly examined these two slides and expressed the opinion that two zygotes may have settled down close together and that this point could only be decided by careful examination of earlier stages—a very difficult procedure.

SUMMARY.

Abnormal development of malarial oöcysts, as observed in the serial sections of laboratory-bred *Anopheles stephensi*, fed on gametocyte-carriers of Indian strains of malaria, is recorded.

(*i*) In some of the fed mosquitoes (especially in *P. falciparum* infections) oöcysts packed with sporozoites were found developing towards the lumen of the midgut. Such oöcysts apparently rupture into the gut and as the liberated sporozoites have no chance of invading the salivary glands, the mosquitoes concerned cannot be infective.

(*ii*) In some mosquitoes, infected with *P. vivax*, *P. malariæ* and *P. falciparum*, pigmentary degeneration of the oöcysts occurs, thus producing the 'black spores' of Ross.

(*iii*) In a few mosquitoes, infected with *P. vivax*, it appeared as if the protoplasmic contents of oöcysts had divided (?) into two masses—the appearance rather recalling that which occurs in the oöcysts of *Isospora* (Coccidiida). It is probable that in such cases two zygotes settle down close together.

REFERENCES.

KNOWLES, R., and BASU, B. C. (1933). *Ind. J. Med. Res.*, **20**, p. 757.

WENYON, C. M., ANDERSON, A. G., McLAY, K., HELEY, T. S., and WATERSTON, J. (1921). *Jl. R. A. M. C.*, **37**, pp. 81–109.

Indian Journal of Malariology, 1, 1, March 1947.

STUDIES ON SOME INSECTICIDES AGAINST ANOPHELINE ADULTS AND LARVÆ.

PART I.

PRELIMINARY EXPERIMENTS AT DELHI WITH DDT.*

BY

I. M. PURI, M.SC. (Punj.), PH.D. (Cantab.),

AND

RAJINDAR PAL, M.SC., PH.D. (Punj.).

(*Malaria Institute of India, Delhi.*)

[December 6, 1946.]

SEARCH for an efficient synthetic insecticide for the control of the insect carriers of disease has been in progress for a number of years. Owing to the serious shortage of pyrethrum insecticide, partly due to the failure of the pyrethrum crop in Kenya in 1942 and partly to the entry of Japan in World War II, this search has been greatly intensified during the last few years. As a result, a number of synthetic insecticides have been developed by various workers and all these have been subjected to elaborate laboratory and field tests in India as well as in other countries.

Of these synthetic insecticides, DDT (dichlor-diphenyl-trichloroethane) and 666 (benzene hexachloride) are the only two which have so far been found to compare favourably with pyrethrum extract in their insecticidal properties. DDT has the added advantage of being effective for a number of days, weeks or even months, after it has been applied. During the last three years, a great deal of experimental work has been carried out by various workers in India and in other countries by both civil and military organizations in order to find out the potentialities and limitations of this insecticide. Buxton (1945*a*) reviewed most of the

* Most of the work was financed by the Indian Research Fund Association under the Insecticide and Mosquito Repellent Enquiry.

available data on the use of DDT in relation to the problems of tropical medicine. More recently, West and Campbell (1946) have made a comprehensive contribution on the use of DDT as an insecticide, against all kinds of insect pests. Following the work of Barber (1943) on the larvicidal properties of DDT-oil solutions, Buxton (1945*b*) in West Africa, Deonier and others (1945) in U. S. A., and Ribbands (1945) in India studied the use of various preparations containing DDT against mosquito larvæ in stationary waters. A number of papers have recently been published describing the insecticidal properties of DDT against various agricultural pests and Gahan and others (1945) and Lindquist and others (1945) have studied the effect of DDT solutions, emulsions and suspensions on mosquitoes and some other insects of medical importance. Ribbands has also carried out very useful observations on the efficacy of this insecticide against the adult mosquitoes. But the results of these latter experiments have not yet been published. Senior White (1945) has compared the effect and the economic aspect of DDT and pyrethrum sprays in the control of malaria in Vizagapatam Agency tract.

A number of experiments to assess the potentialities of DDT as a mosquitocide and larvicide and to study the methods of its application have been carried out during the last three years. Although some of these experiments are of a preliminary nature, it has been considered advisable to describe them, so that the results and conclusions may be available to other workers on this subject in India. Some of these investigations were conducted at the Malaria Institute of India and in the villages around Delhi, where *Anopheles culicifacies* is the vector of malaria, while others were carried out at Siliguri and Marianbari (Bengal Terai) where *philippinensis* and *minimus* are the vector species and in the Quetta District of Baluchistan, where the main vector is *superpictus*. The present paper deals with the results of the experiments carried out at Delhi up to the end of 1945, while in subsequent publications will be recorded the results of the experiments carried out at other places.

MATERIAL.

Through the courtesy of the Medical Directorate, General Headquarters (India Command), a number of samples of DDT were received for experimental purposes. This DDT was apparently of two different qualities—one lot was white while the other appeared comparatively dirtier and had a lot of extraneous matter in it. The white variety was marked '100 per cent concentrate' and apparently was technically pure DDT, the para para content of which varies between 70–80 per cent. As the technically pure variety was not received till very recently, all experiments in 1945 were carried out with the other variety, and this was tried in oil solutions as well as in oil-in-water emulsions.

SOLUTIONS.

It has already been found by various workers that DDT is practically insoluble in water, moderately soluble in vegetable and mineral oils and readily soluble in many organic solvents. A study of the solubility of the two samples of DDT in some of the common readily available solvents in India has shown that this varies at different temperatures and differs in the case of different samples. The solubility of the two samples by weight in 100 c.c. of the solvent at different temperatures has been shown in Table I.

In the experiments with solutions* 5 per cent DDT solution in kerosene grade III, malariol or used engine oil was tried. At ordinary temperatures (27°-30 C.) DDT crystals dissolve very slowly in these solvents and it often takes 48 to 72 hours to obtain a 5 per cent concentration. The process can however be hastened by raising the temperature of the oil, either by direct heat or by placing the tin containing the oil in the sun and stirring occasionally. Another method found very advantageous was to melt DDT in a tin over a slow fire and to pour it into the solvent when it went into solution in a short time.

EMULSIONS.

Various workers have found that DDT emulsions, when applied as residual sprays, were as effective as oil solutions of DDT. In fact, Gahan and others (1945), from their comparative laboratory tests, concluded that aqueous emulsions were slightly superior to kerosene-DDT sprays. Emulsions† have a number of advantages over solutions :—

(1) They are as a rule prepared in concentrated form to be diluted to the required strength with water at the site of spraying operations. Consequently, they take up less space and their transport is relatively easier.

(2) In order to apply very small quantities of DDT (25–100 mg. of DDT per square foot) uniformly to a surface, it has been found advisable to dilute the spray to 1·25–2·5 per cent. This can be done very easily without increasing either the cost of material or the hazard of fire.

(3) Aqueous emulsions in the dilutions ready for use are always non-inflammable, some being so even in the concentrated form.

(4) Emulsion concentrate is prepared by dissolving DDT in a suitable solvent to which an emulsifying agent is added, so that the resultant fluid or paste can be diluted in all proportions with water. Water being the chief vehicle in DDT-aqueous emulsions, these are comparatively cheaper than oil solutions, depending of course on the price of the emulsifier and of the special solvent used. According to Jones *et al.* (1945), 5 per cent emulsion prepared from an emulsion concentrate developed by the U. S. A. Department of Agriculture, is more expensive than an equal amount of 5 per cent solution of DDT in fuel oil or kerosene. As, however, weaker dilutions of the emulsion concentrate are usually used, they are much cheaper than the oil solutions.

American workers recommend a DDT emulsion‡ prepared by dissolving DDT in xylene and emulsifying the solution with triton × 100. This makes a very

---

* 5 per cent DDT solution is prepared on a large scale by dissolving 8 oz. of DDT by weight in 9 lbs. 11 oz. (by volume) kerosene oil, malariol or used engine oil.

† Emulsion concentrates should be solutions containing a high percentage of DDT combined with an emulsifier which will readily mix with soft or hard water. They should not require any special apparatus in the preparation of the final emulsion and should be reasonably stable to allow of application without separation.

‡ *Xylene-triton emulsion :*

DDT	... 25 gm.	DDT	... 3 lbs.
Xylene	... 68 gm.	Xylene	... 3 litres.
Triton × 100	... 7 gm.	Triton × 100	... 6 fl. oz.

stable emulsion when diluted with water. Triton however is as yet not available in this country. Moreover, xylene, because of its high volatility, is not very satisfactory as a solvent. Besides, xylene as well as triton are both comparatively costly and it is probable that this was the emulsion referred to by Jones *et al.* At the suggestion of the Director of Scientific and Industrial Research,* Delhi, turpentine oil was tried for the first time as a solvent for DDT and for preparing an emulsion concentrate. A satisfactory emulsion was prepared by dissolving DDT in this solvent, mixing the solution with liquid soap and diluting this concentrated emulsion with the required quantity of water immediately before use.

The detailed method of preparation of DDT-turpentine emulsion is as follows :—

Dissolve 20 parts by weight of DDT in 77 parts by volume of hot turpentine oil (temperature about 45°C.) and mix with it 10 parts (by volume) of 20 per cent soap solution. Shake thoroughly to form a uniform emulsion concentrate. This concentrate contains 20 per cent DDT, and at the time of use should be diluted with water 1 part to 3 parts for a 5 per cent final emulsion, 1 part to 7 parts for a 2·5 per cent and 1 part to 15 parts for a 1·25 per cent final emulsion. While diluting the concentrated emulsion, it was found advisable first to add a small quantity of water and to stir the mixture thoroughly so as to form a uniform primary emulsion and then to add sufficient water to obtain the desired percentage of DDT in the final spray.

Twenty per cent soap solution is easily prepared by dissolving common washing soap in hot water. This soap solution congeals on cooling and has to be warmed up before use. This can, however, be avoided by using either soft soap instead of ordinary washing soap or by using dry soap powder or flakes.

The emulsion concentrate can easily be prepared in bulk in an ordinary churn made out of a 40 gallon drum of the type described by Butt (1938). With the help of this churn it takes 4 labourers and one laboratory assistant half an hour to prepare 30 gallons of emulsion concentrate. In preparing emulsion concentrate with turpentine as a solvent, care has to be taken to use refined turpentine and not the crude product. A disadvantage of this emulsion concentrate is that in concentrated form it is not stable and breaks up into two layers within a short time. It has to be thoroughly stirred before drawing it out of a drum for dilution with water.

Emulsions similar to the above can be also prepared using toluene or medium kerosene extract (M. K. E.) or toluene and turpentine combined as solvents for DDT. A stable DDT emulsion concentrate has been prepared by the Chemical Warfare Antigas Laboratory, Jubbulpore, using equal quantities of toluene and turpentine†

---

* The authors wish to express their gratitude to Dr. S. Siddique of the Scientific and Industrial Research Laboratories for his help and suggestions in the preparation of emulsions.

† *Turpentine-toluene DDT emulsion concentrate (Antigas Laboratory formula) :—*

	By weight.	By volume.
Toluene	33·35	39·03
Turpentine	33·35	38·02
Absolute alcohol	4·4	5·4
Dry soap powder	2·8	2·8 (weight).
Water	1·1	1·1
DDT	25·0	25·0 (weight).

as solvents. When preparing this emulsion concentrate, meticulous care has to be taken as to the amount of water added, since even the slightest excess of water renders the emulsion concentrate unstable. This concentrate is highly inflammable but not so when it has been diluted. Five per cent emulsion prepared from this is much more expensive than an equal amount of a 5 per cent DDT kerosene solution. Stable emulsion concentrates similar to the above can also be prepared by using turpentine, M. K. E. and toluene separately as solvents. Of the solvents available in India for the preparation of DDT emulsion concentrate, medium kerosene extract is about the cheapest, even taking into consideration the solubility of DDT in it. Stable emulsion concentrates have been prepared with M. K. E. as the solvent. These emulsions can be diluted with water without much stirring, and the diluted emulsion is stable for a much longer period than the toluene-turpentine emulsion described above. An additional advantage of the M. K. E. emulsion concentrate* over the latter is that it is not highly inflammable. Methods of preparing these emulsion-concentrates will be described in a subsequent paper (Part IV of this series).

PASTES.

A semi-solid concentrate of DDT was first prepared by the Assam Oil Company, Ltd., Digboi, and sent to the Malaria Institute of India for trial in 1945. The solvent used by them was ordinary kerosene and the paste contained 25 per cent DDT. It could be diluted with water on vigorous shaking, producing a more or less stable emulsion but a fair amount of floccular scum of butter-like consistency always floated at the surface of the diluted emulsion. This butter-like scum contained a high concentration of DDT and all efforts to emulsify it were unsuccessful. Similar semi-solid concentrates were prepared by us using turpentine, toluene and M. K. E. as solvents and containing about 40, 60, 80 per cent DDT respectively. All these, however, showed the same defect as the original paste received from Digboi.

A semi-solid concentrate containing 50 per cent DDT, which on dilution formed the least amount of butter, was prepared according to a formula supplied by Dr. S. Siddique. It, however, does not readily mix with cold water and for the primary emulsion either hot water has to be used or the paste has to be melted over a water-bath. On account of this buttering at the time of preparing dilute emulsions from these semi-solid concentrates, search for a highly concentrated emulsion was finally abandoned.

SUSPENSIONS.

Towards the end of the mosquito season (in 1945) a 20 per cent DDT suspension concentrate was prepared by wet grinding of commercial DDT crystals in the

---

* *M. K. E.-DDT emulsion concentrate :—*

DDT	50 gm.
M.K.E.	12 c.c.
Oleo-rosin soap	20 gm.
Sodium silicate	3 gm.
Water	15 c.c.

DDT should be dissolved in hot M. K. E. and the silicate in hot water. The two should be thoroughly mixed together and the oleo-rosin soap added.

presence of powdered gum acacia. In this suspension concentrate the percentage of gum acacia was as high as 10 per cent and it was felt that such a large quantity of gum might cover the DDT crystals with an impermeable film round them and act as a barrier between the DDT and the insects. Preliminary experiments, however, showed that the residual efficacy of DDT was in no way interfered with by gum acacia mixed in the spray. In further field experiments this form of preparation has shown the greatest promise. These will be dealt with in a later paper.

APPARATUS FOR THE APPLICATION OF DDT.

(1) *As larvicide.*—The quantity of DDT solution or emulsion to be applied as a larvicide to a water collection is so small that the apparatus commonly employed for oiling, etc., is of very little use. After trying a number of different methods an ordinary sprinkler top bottle or a tin with one or two fine holes was found the most satisfactory. Sawdust and sand soaked in DDT solutions were also found effective for spreading DDT on the surface of the water.

(2) *For residual effect against adult mosquitoes*: (*a*) *For indoor use.*—In order to apply about 50 mg. of DDT per square foot of surface, 1 c.c. of 5 per cent or 2 c.c. of 2·5 per cent solution or emulsion must be sprayed on the wall in such a way that it covers the whole surface uniformly. Ordinary sprayers, whether hand operated or power, used for atomizing insecticides for spray-killing of mosquitoes are not suitable for this purpose. The spray produced by them is very fine and instead of falling on the wall or the ceiling much of it is carried away by the blast and wasted so far as the residual effect of the spray is concerned. Even when the spray from a power spraying unit is made very coarse, part of the discharge is still very fine and these particles fail to fall on the walls and ceilings. The spray required for a residual treatment should be a coarse wet spray and the discharge from the sprayer should not be very heavy.

A stirrup pump fitted with a spraying lance which has a shut-off valve at one end and a specially designed nozzle at the other with a bore 1/32 inch to 1/64 inch, has been found to produce a satisfactory wet spray. As the discharge from such a nozzle is only about 12 to 20 oz. per minute, the operator can cover the surface without undue haste and is able to see that every part is properly sprayed without any waste of emulsion or solution.

It has been found that an ordinary stirrup pump fitted with a nozzle having 1/32 inch to 1/64 inch bore develops a water pressure of about 75 lbs. per square inch. As the hose usually supplied with these pumps is not able to stand such a high pressure, a relief valve, opening at pressures above 50 lbs. per square inch should be fitted either into the stirrup pump or near the attachment of the hose with the pump. This ensures against the bursting of the hose, even when the operator continues to work the pump when the nozzle becomes blocked.

It was found in our experiments that with the help of two such stirrup pumps five men were able to spray 56 huts having a total area of 50,635 square feet in 2½ hours, while 8 men operating three stirrup pumps sprayed 153 huts (total surface area of 81,197 square feet) in 3 hours. This time can be considerably shortened when spraying is done with stirrup pumps fitted with a double nozzle at the end of the lance.

A suitable wet spray for indoor residual treatment can also be produced with a knapsack hand-operated sprayer fitted with a similar nozzle, but where a room contains much furniture this equipment does not allow the workman sufficient freedom of movement. A knapsack pneumatic sprayer, in which air pressure can be built up either with a hand-pump or from a power-driven air-compressor, is to some extent better than the knapsack sprayer which has to be continuously worked.

Residual spraying can also be done with hand sprayers. The MISH continuous sprayer atomizes too finely and has to be specially modified for producing a wet spray by slightly increasing the nozzle orifice. These hand-sprayers, though useful for small rooms, are laborious and not practicable for applications on a large scale.

(*b*) *For outdoor or barrier residual spraying.*—For outdoor spraying a knapsack sprayer continuous action or of the pneumatic type, fitted with a fine bore nozzle (1/32 inch), has been found very satisfactory. The discharge rate of the type manufactured in India and fitted with such a nozzle is about one gallon in 8 minutes, and a workman moving at ordinary walking pace is able to cover about ½ acre during this time. For increasing or decreasing the dose, the pace has either to be made slower or faster or the concentration of the fluid has to be correspondingly altered. A stirrup pump can also be used, but being a two-man unit it is not as convenient to operate for outdoor work as a knapsack sprayer. For outdoor spraying a petrol-driven pressure sprayer giving a wet spray may be found very useful if it is mounted on a motor truck, and is very mobile.

DDT AS A MOSQUITO LARVICIDE ON STATIONARY WATER.

Deonier, Burrell and others (1945), in preliminary field studies on DDT as a larvicide, have shown that one per cent DDT dust when applied at the rate of 0·1 to 2·0 lbs. DDT or 10 to 200 lbs. dust per acre gives a nearly 100 per cent kill of anopheline larvæ in 24 hours, the effect lasting for four to five days only. In solutions, 5 lbs. (DDT) per acre produced a 100 per cent kill while in emulsions and suspensions 0·1 to 0·0125 ppm. gave a 97 to 100 per cent mortality. In laboratory experiments carried out in glass jars, Deonier, Maple and others (1945) found that much smaller doses produce a 100 per cent kill for about 30 days with dust. They also found that in the doses recommended, DDT in oil solutions or as dust was not toxic to warm blooded animals and fish, while in suspension form it was toxic to fish when the concentration of DDT in the water was above 0·1 ppm. Ribbands (1945) with a dose of 1 pint (20 oz.) of 5 per cent DDT solution per acre [1·2 c.c. per 10 square yards or 1 oz. (30 gm.) DDT per acre] obtained a 100 per cent mortality in the larvæ within 24 hours in experimental pits. Carrying out similar experiments in garden ditches in the Gold Coast on larvæ of *A. funestus*, Buxton (1945*b*) has recorded a reduction of 80 per cent in the larval density applying 5 per cent DDT at 0·5 c.c. per 10 square yards (8 oz. solution or 12 gm. DDT per acre), over 80 per cent when the dose was 1 c.c. per 10 square yards (1 lb. of solution or 24 gm. DDT per acre) and 95 to 100 per cent mortality with doses of 2·5 c.c. per 10 square yards (1 quart of solution or 60 gm. DDT per acre).

A number of field experiments on the larvicidal properties of DDT were carried out at Delhi to find out :—

1. The minimum lethal dose of DDT solution and emulsion for different types of breeding places.
2. The best method of applying DDT to water surface.
3. The length of residual effect, if any.

Suitable breeding places were selected for the different experiments. 10 dips were made in each breeding place and the average number of larvæ collected per dip recorded. The breeding places were then treated with measured doses of the insecticide to be tried and the pools examined at regular intervals in the same way as before treatment, by the same individual in any one experiment, and the average number of larvæ recorded per dip.

Experiment I (*dated* 24-7-1944).—Four rainwater pools (A to D) with heavy breeding of both anopheline and culicine larvæ were selected. All of them had grass and other emergent vegetation growing along the edges. Three of these were treated with 5 per cent DDT-used engine oil solution and the fourth (D) with used engine oil without any DDT in it. The solution was sprinkled on to the surface of water of only half the pond by means of a pipette. The results recorded in Table II show that such small doses (0·15 to 0·36 c.c.) of 5 per cent DDT-used engine oil solution, the spreading power of which is only about 12 dynes, have no appreciable effect on the breeding of mosquitoes (anopheline or culicine) in a pool.

Experiment II (*dated* 28-7-1944).—As practically no reduction in breeding was observed even two days after the first application of DDT solution, these pools were re-treated as before but with a higher dose. The average number of larvæ collected per dip at various intervals are recorded in Table III.

The results indicate that if the dose is increased from 4 to 6 c.c. per 10 square yards, breeding is brought under control, but the number of larvæ begins to increase after the third day. These pools were again treated at the end of the fourth day, pool D being left untreated for comparison. The results of the third treatment are summarized in Table IV.

While the last set of observations was being carried out, the water in pools A to C began to dry up rapidly and breeding was adversely affected. This is seen from the fall in the number of larvæ even in pool D. Consequently, the apparent prolonged duration of residual effect, particularly in pool C, may not be due to DDT at all.

Experiment III (*dated* 11-8-1944).—Three other rainwater pools with marginal vegetation were selected and after the intensity of breeding had been recorded as heretofore, 5 per cent DDT-used engine oil solution at the rate of 2 c.c. per 10 square yards was applied to one pool with a pipette, while sawdust soaked in the solution was sprinkled on the other. Observations were continued as before and the results are tabulated in Table V.

These observations show that the breeding became very scanty for about 24 hours only and then gradually increased, showing that the dose (2 c.c. per 10 square yards) was not sufficient to inhibit breeding completely. The effect of DDT was apparent only for two days.

Experiment IV (dated 16-8-1944).—Six cement tanks in a cement pipe factory were selected. Except for the algal flora no other vegetation was present in them. After making the usual observations, the tanks were treated with 5 per cent DDT in used engine oil, employing different methods of application. The result of dipping for larvæ at various intervals after applying DDT is tabulated in Table VI.

The prolonged residual action noticeable in pool 3, in which sawdust soaked in DDT-used engine oil was sprinkled, was probably due to small quantities of DDT solution being given out gradually by the sawdust even after the 5th day. If this assumption is correct the best method of applying DDT for prolonged residual larvicidal effect is by soaking a light porous substance in DDT-oil solution and sprinkling this over the surface of the breeding place.

From these experiments it is obvious that DDT-used engine oil solution is more effective in the absence of emergent vegetation along the margin of the pool, producing a nearly 100 per cent kill when applied at the rate of 6 c.c. per 10 square yards. The residual effect seems to last for at least 3 days, as larvæ appear only after the fourth day. The rate of increase in the intensity of breeding appears to be influenced by the method of application of DDT solution, and was slowest in the case of the pool in which sawdust soaked in DDT-oil solution had been applied. The sudden appearance of young first stage larvæ after the fourth day shows that the fine film of DDT oil solution, if present on the surface of water, does not inhibit oviposition after the third day. This observation is in conformity with similar observations made by Ribbands (1945) while working in Assam.

Experiment V (dated 14-10-1944).—The same tanks were treated nearly two months later with 2·5 per cent DDT-turpentine oil emulsion, the emulsion being applied from a sprinkler top bottle. The result of dipping for larvæ at various intervals is recorded in Table VII.

From a comparison of the results obtained from various experiments, it appears that oil-in-water emulsions of DDT (using turpentine as a solvent) are more effective than oil solutions as larvicides. When applied at the rate of 100 to 200 mg. (2 to 4 c.c. of 5 per cent emulsion) per 10 square yards there is a 100 per cent control for 5 to 8 days and partial control for about 12 days. If the dose is increased to 300 mg. (6 c.c. of 5 per cent emulsion) per 10 square yards, complete control lasts for about 9 days and partial control for over 15 days. As, however, only one set of experiments was carried out with these doses the results cannot be considered conclusive. It is intended to repeat these experiments at the earliest opportunity.

In the course of the above experiments it was observed that in the doses applied DDT had no lethal action on the other aquatic fauna except certain Micronecta, Hydrometra and Gerris. Mosquito larvæ present in all the above experiments consisted of a mixture of *A. culicifacies, A. subpictus* and *Culex fatigans.*

AERIAL SPRAYING OF DDT AS A LARVAL CONTROL MEASURE.

Spraying of DDT solutions and emulsions from the air for larval and adult control has been advocated by certain workers. With a view to study the efficacy

of this method of spraying a number of experiments were carried out. In two preliminary test flights 5 per cent solution of DDT in third grade kerosene oil was sprayed over an area of 8 square miles at the rate of about 660 gallons per square mile. The results were far from satisfactory.* A great variation was observed in the percentage of anopheline larvæ killed in different breeding places over the area sprayed. This varied from 100 per cent to below 50 per cent in some pools. The results indicated that the distribution of the spray over the area was very irregular. These results were much inferior to those recorded by Colonel J. W. Scharff in certain aerial spray experiments (unpublished) carried out in Bihar and Orissa and suggest that the spraying technique was probably defective in the Delhi experiments.

Kerosene oil, however, has been shown to have a deleterious effect on certain agricultural and vegetable crops in the area sprayed. It was therefore decided to use an oil-in-water emulsion instead of oil solutions. The only emulsion available for these experiments was a formulation in which DDT was dissolved in a mixture of toluene and turpentine.

In three separate experiments the efficacy of the toluene-turpentine-DDT emulsion was tested for its anti-larval properties when sprayed from the air. In two of the experiments a pool about half a mile long and about 150 feet wide by the side of a railway embankment was sprayed while the third was carried out in another locality over a more or less stagnant stream about 100 feet wide. In all the three experiments Hurricane aircraft fitted with two 13·5 gallon tanks, one under each wing (smoke curtain installations) operated by detonators, were employed.

In all the three experiments (VI to VIII) the aircraft, at the time of spraying, was 150 to 250 feet above the ground level and was stated to be travelling at the rate of about 150 miles per hour. With the type of spraying equipment fitted to the tanks, it took about 11 seconds to empty each tank. In the first experiment (VI) both the tanks, each containing 12·5 gallons of emulsion, were operated practically simultaneously, delivering a dose of nearly 20 c.c. of 5 per cent emulsion per 10 square yards, while in the other two (VII and VIII) only one tank was operated, spraying approximately 10 c.c. per 10 square yards.†

Experiment VI.—A long pool of water along the Delhi-Shahdara Railway line was sprayed from the air at the rate of about 20 c.c. per 10 square yards. Approximately four hours after spraying a 97 per cent reduction in the density of anopheline larvæ was observed. Twenty-four hours later, however, a large number of first instar larvæ was observed at various points in the pool and subsequently the larval density progressively increased. A number of fish were found dead in the pool. The water in the pool was, in most places, less than one foot deep so that the concentration of DDT in the water was approximately 1·4 parts per mille (1,000).

Experiment VII.—This was carried out at Okhla over a practically stagnant stream. Five per cent emulsion (toluene-turpentine) sprayed at the rate of 10 to 12 c.c. per 10 square yards.

---

* A 50 per cent reduction in the prevalence of adult mosquitoes was observed in those areas which received practically a double dose (about 2 gallons per acre) and this reduction was apparent only for one week.

† Based on observed swathe of nearly 70 yards.

Four hours after spraying a considerable number of larvæ in all instars were still present in the area sprayed and the part of the stagnant stream which was under observation as a control contained many larvæ as usual.

Twenty-four hours later, however, I to IV stage larvæ were present in fair number in half the stream sprayed. Some were present in the other half but very little breeding was found in the portion kept as control, except in the part farthest away from the sprayed area. The only explanation of this anomaly appeared to be that owing to a very heavy shower of rain which fell during the night following the day of spraying, larval drift and storm water changed the whole picture.

No dead fish were observed in this stream after spraying. In most places water was more than 3 feet deep and the concentration of DDT in the water was probably considerably below 0·1 ppm., the concentration found toxic to fish by Ginsburg (1945), and Deonier, Maple and others (1945).

Experiment VIII.—A pool near that in experiment VI and similarly situated was sprayed at the rate of about 10 c.c. per 10 square yards. Two hours after spraying, larvæ of all instars were found scattered in various parts of the pool. Twenty-four hours later I to II stage larvæ were found in some places on the windward side of the pool, while larvæ of all four instars were present in some parts on the leeward side. On this side, however, a number of dead fish were seen floating on the surface. Dead fish were also observed in various water collections over most of the area sprayed. The water in many of these was less than one foot deep and the concentration of DDT after spraying probably exceeded 0·1 ppm.

From these three experiments it is obvious that even 500 mg. DDT (20 c.c. of 5 per cent emulsion) per 10 square yards when sprayed from the air in the form of toluene-turpentine emulsion is not sufficient to produce a 100 per cent kill of anopheline larvæ. As DDT in concentrations of over 0·1 ppm. is toxic to fish, the presence of large numbers of dead fish and aquatic insects on the surface of water indicates that most of the emulsion sprayed from the air must have fallen on the pool. Previous experiments had, however, already shown that 200 to 300 mg. of DDT per 10 square yards in the form of a turpentine emulsion or oil solution produces a 100 per cent mortality among anopheline larvæ without any apparent ill-effects to the fish present in the water. Apparently DDT applied as a toluene-turpentine emulsion sprayed from the air is precipitated to the bottom, thus becoming innocuous to anopheline larvæ.

RESIDUAL TOXICITY OF DDT TO ADULT MOSQUITOES.

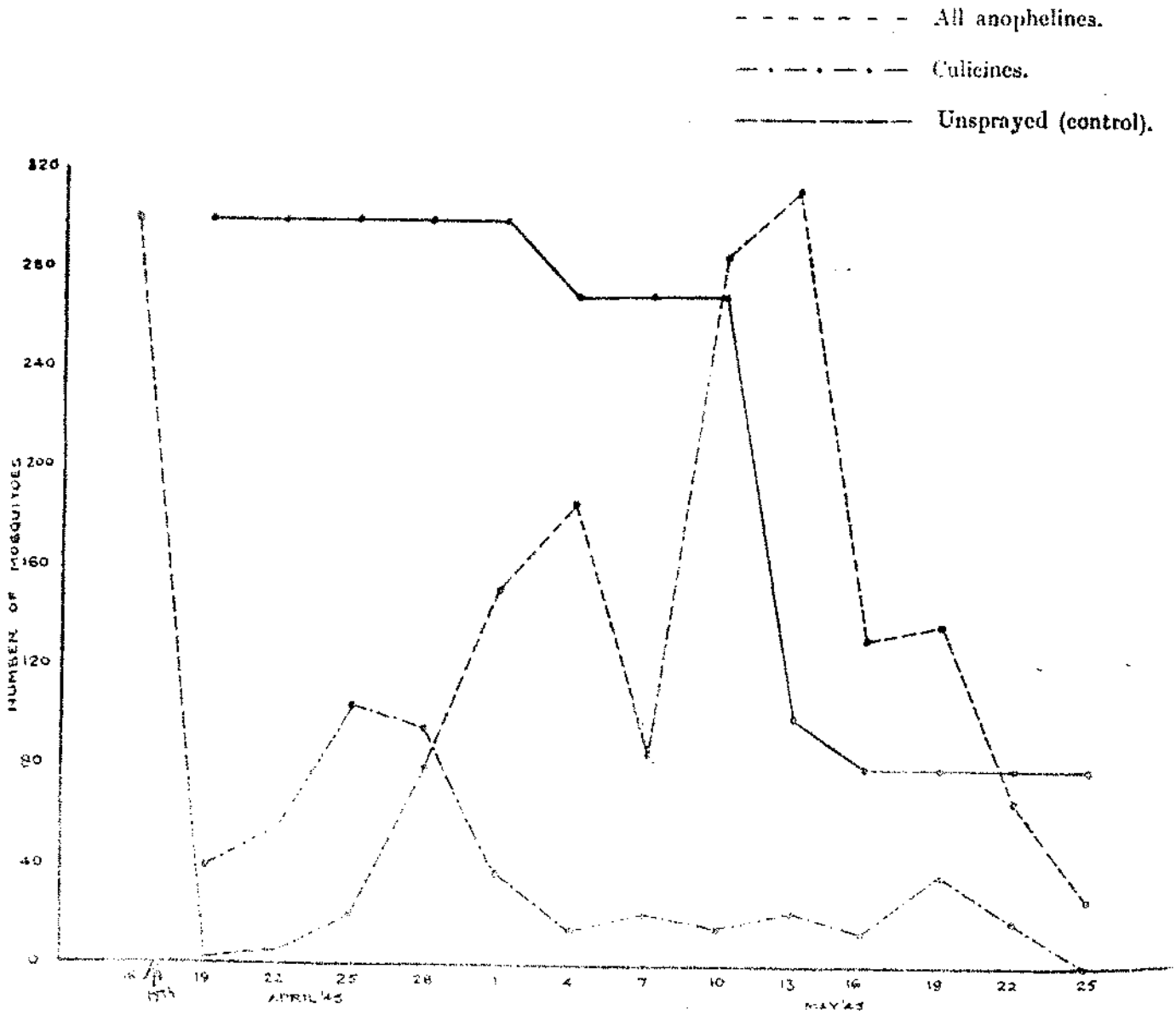
INDOOR SPRAY.

Tarzwell and Stierli (1945) have recorded a high rate of mortality among mosquitoes entering buildings, the walls of which had been sprayed with DDT at the rate of 200 mg. per square foot about five months previously. Gahan and Lindquist (1945) experimenting with *Anopheles quadrimaculatus* found that 5 per cent DDT solution in kerosene when applied as an indoor spray at the rate of 208 mg. per square foot gave a 99 per cent reduction in the number of *A. quadrimaculatus* over a period of 3½ to 4½ months, while 1·25 per cent emulsion similarly sprayed in another area but at the rate of 56 mg. per square foot produced

91 per cent reduction over 3½ to 4½ months. In order to obtain an indication as to the length of residual toxicity of DDT against Indian mosquitoes a number of preliminary experiments were carried out in certain villages near Delhi. DDT was sprayed in the form of 5 per cent DDT-kerosene solution or 2·5 per cent DDT (oil-in-water) emulsion.

Most of the village huts were made of mud bricks and mud plaster excepting a few which were constructed with baked bricks. In each village a number of catching stations were established well in advance of the day on which spraying was done. The density of mosquitoes was recorded by collecting all those in each station by the same person throughout each experiment. In these preliminary experiments the method of obtaining the total catch by spraying a weak solution of pyrethrum was not tried.

Spraying was carried out with stirrup pumps fitted with special nozzles as described above.



Graph ...—Sprayed with 4·5 per cent DDT-turpentine emulsion at 3 c.c. (180 mg. DDT) per square foot.

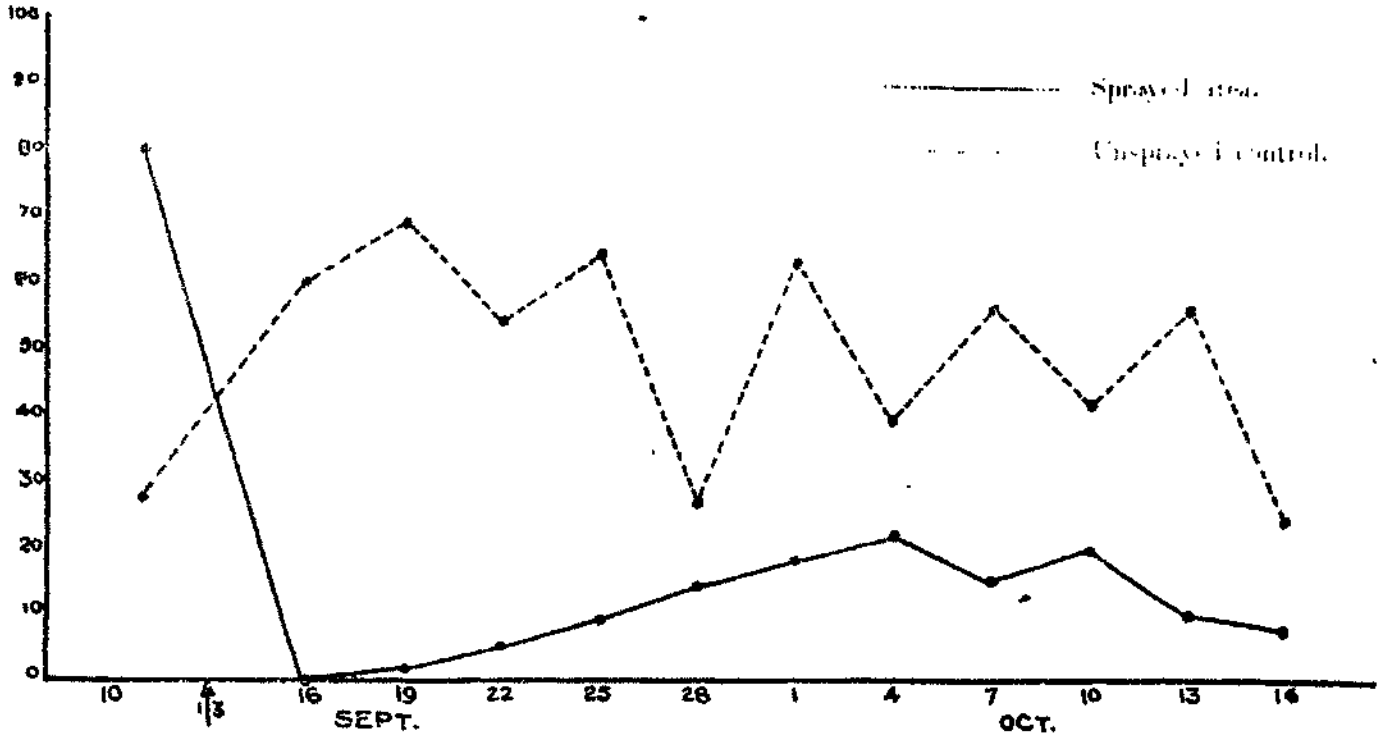
Experiment I.—The whole of Okhla Village (total surface area about 123,800 square feet), about 12 miles from Delhi, was sprayed on April 14 to 16, 1945, with a 4·5 per cent DDT-turpentine emulsion at the rate of 4 c.c. per square foot (180 mg. per square foot). This brought down the number of mosquitoes by 100 per cent during the first 4 days. The number of mosquitoes in the catching station remained appreciably down for about 10 days only after which it progressively increased (Graph 1). The residual effect apparently lasted only for about 10 to 15 days. The study of wing grades and stages in ovarian development, in the mosquitoes collected from various catching stations in the village, also showed that during the first 8 to 10 days the mosquitoes collected were for the most part unfed with their wings in grade 1. Subsequently, however, mosquitoes in later stages of development, both as regards ovaries and wings, were also present. *Culex fatigans* appeared to be very resistant to the effect of DDT. This is in conformity with the results obtained by other workers. Although the toxic effects of DDT practically wore off by the end of the sixth week, observations were continued in this village throughout the dry season to find out whether the rise in humidity with the approach of the rainy season would reactivate the DDT applied on the walls of the huts. Judging from the numbers of living mosquitoes collected from the treated and untreated huts during this period it was apparent that there was no revival in toxicity of the DDT sprayed on the walls.

The whole village was sprayed again on September 13, 1945, as previously, but with a 2·5 per cent DDT-toluene-turpentine emulsion (prepared according to the Antigas Laboratory formula) at the rate of only 2 c.c. per square foot (50 mg. of DDT per square foot). This time the residual effect lasted much longer, and the number of mosquitoes remained appreciably lower for about 34 days (Graph 2) after which this experiment had unfortunately to be discontinued.

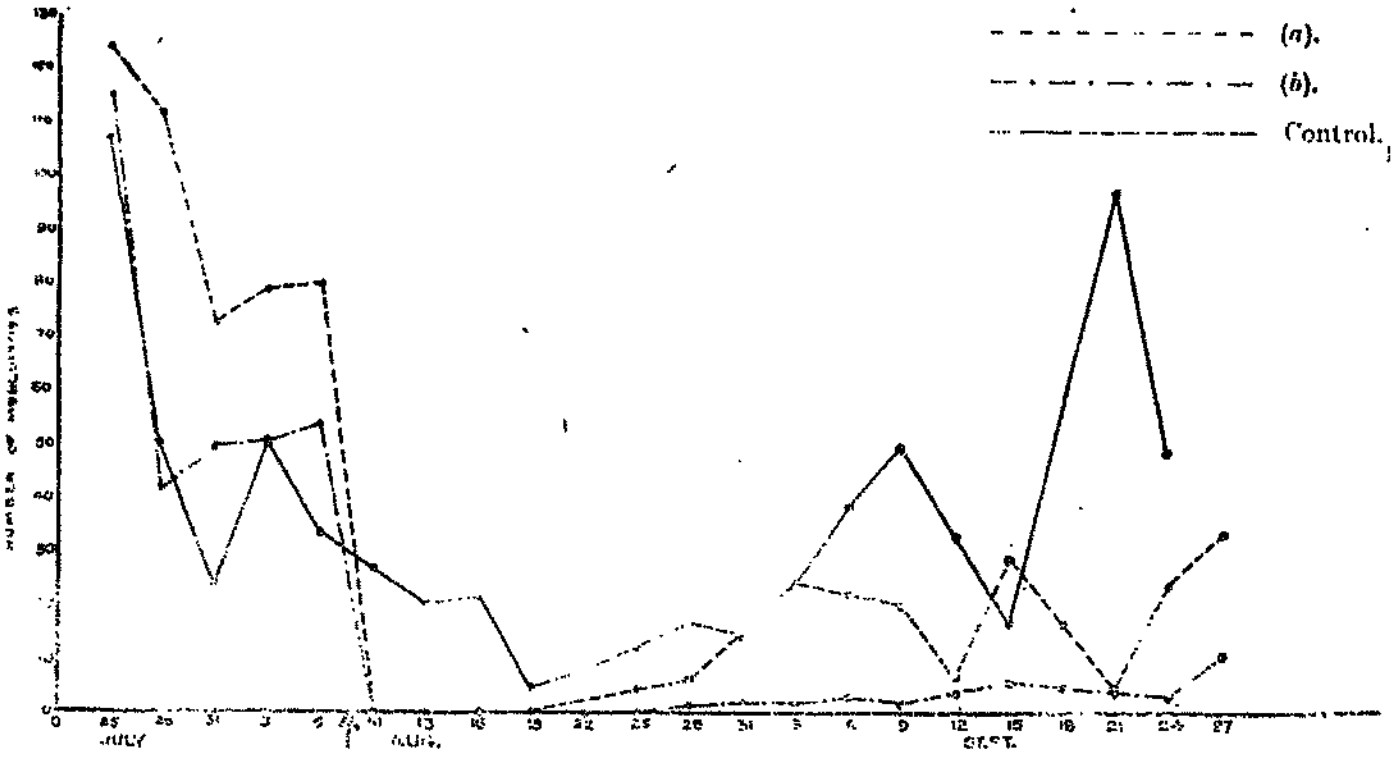
Experiment II.—Two other villages, Timarpur (total wall surface area 50,640 square feet) and Wazirabad (total wall surface area 81,200 square feet), about 3 miles from the Institute, were selected. The former was sprayed with 2·5 per cent DDT-turpentine emulsion on August 8, 1945, at the rate of 6 c.c. per square foot, while the latter with 5 per cent kerosene solution on August 9, 1945, at the rate of 3 c.c. per square foot (150 mg. per square foot in both). In the village sprayed with emulsion there was 100 per cent reduction for about 10 days, after which the effect began to wear off gradually. A comparison with the collections from the control village shows that the effect though not as strong as in the second week after spraying apparently lasts for over one month and a half. In Wazirabad on the other hand, in which DDT-kerosene oil was sprayed, the residual toxicity appeared to last consistently and more effectively throughout the period of observation covering 49 days (Graph 3).

Experiments similar to the above with DDT solutions and emulsions were also carried out (September 1945) in rows of coolie huts (mud bricks and mud plaster) near Sarai Rohilla. The results as to the residual toxicity of solutions and emulsions were very much the same as those described above.

In order to study the repellent action, if any, of the turpentine and kerosene contained in the DDT emulsions and solutions used, eight stables in a row were selected (in Masjid Ghatta) not far from the riverain area. Alternate stables were



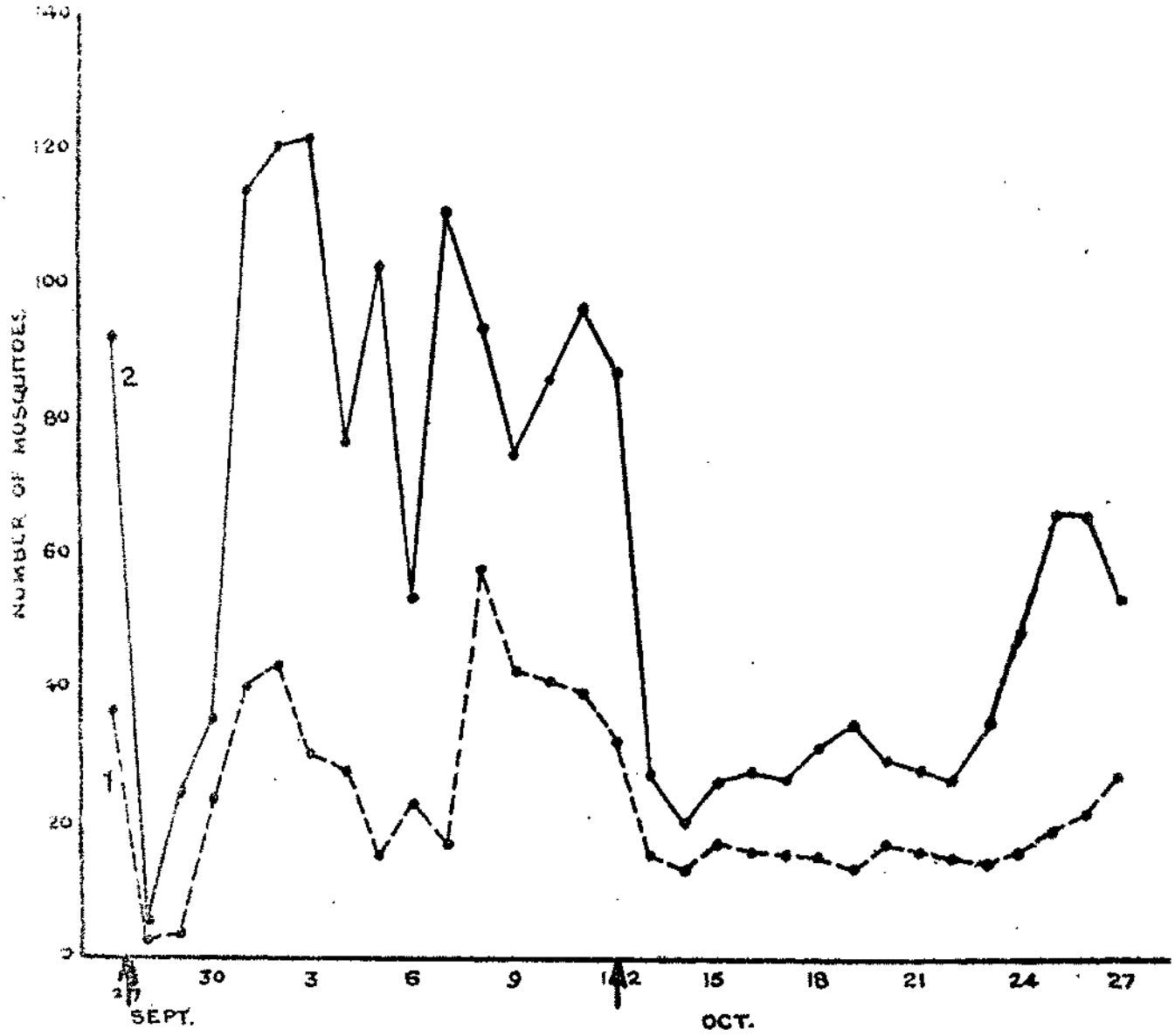
GRAPH 2.—Sprayed with 2·5 per cent DDT-turpentine emulsion at 2 c.c. (50 mg. DDT) per square foot.



GRAPH 3.—(*a*) Sprayed 2·5 per cent DDT-turpentine emulsion at 6 c.c. (150 mg. DDT) per square foot (Timarpur Village).
(*b*) Sprayed 5 per cent DDT-kerosene solution at 3 c.c. (150 mg. DDT) per square foot (Wazirabad Village).

left untreated for comparison while the others were sprayed at the rate of 3 c.c. per square foot of surface area with different preparations as follows :—

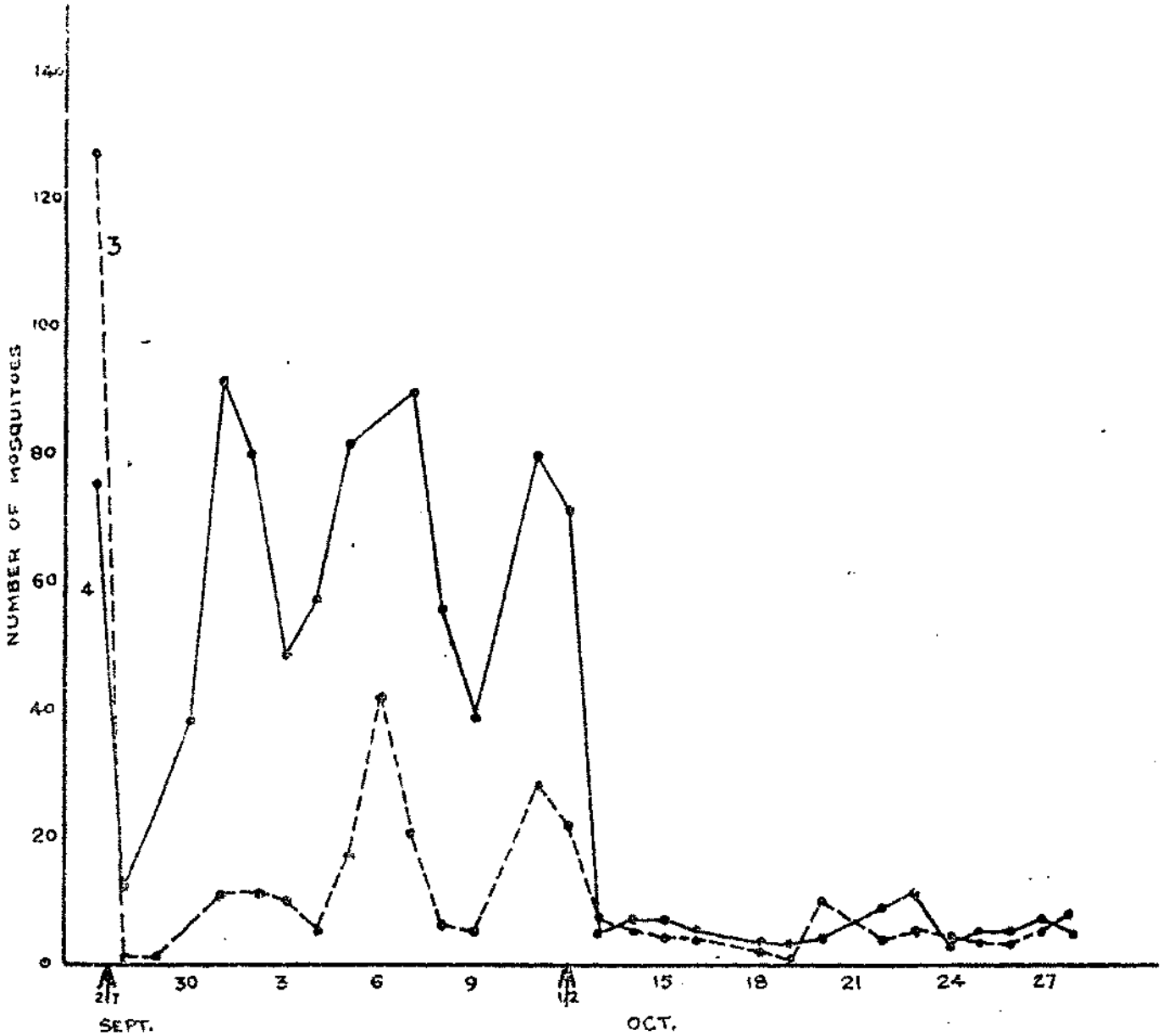
Stable number.	Sprayed on September 29, 1945, with	Resprayed on October 12, 1945, with	Graph number.
1	Kerosene, grade III	Turpentine-soap emulsion	4
2	Control	Control	
3	5 per cent DDT-kerosene solution	5 per cent DDT-turpentine solution	5
4	Control	" "	
5	Turpentine-soap emulsion	Kerosene, grade III	6
6	Control	Control	
7	5 per cent DDT-turpentine emulsion	5 per cent DDT-kerosene solution	7
8	Control	Control	



GRAPH 4. - - - - - - Sprayed 27-9-1945 with kerosene (III grade) without DDT. Resprayed 12-10-1945 with turpentine emulsion without DDT both at 3 c.c. per square foot.

———— (Stable No. 2.) Control.

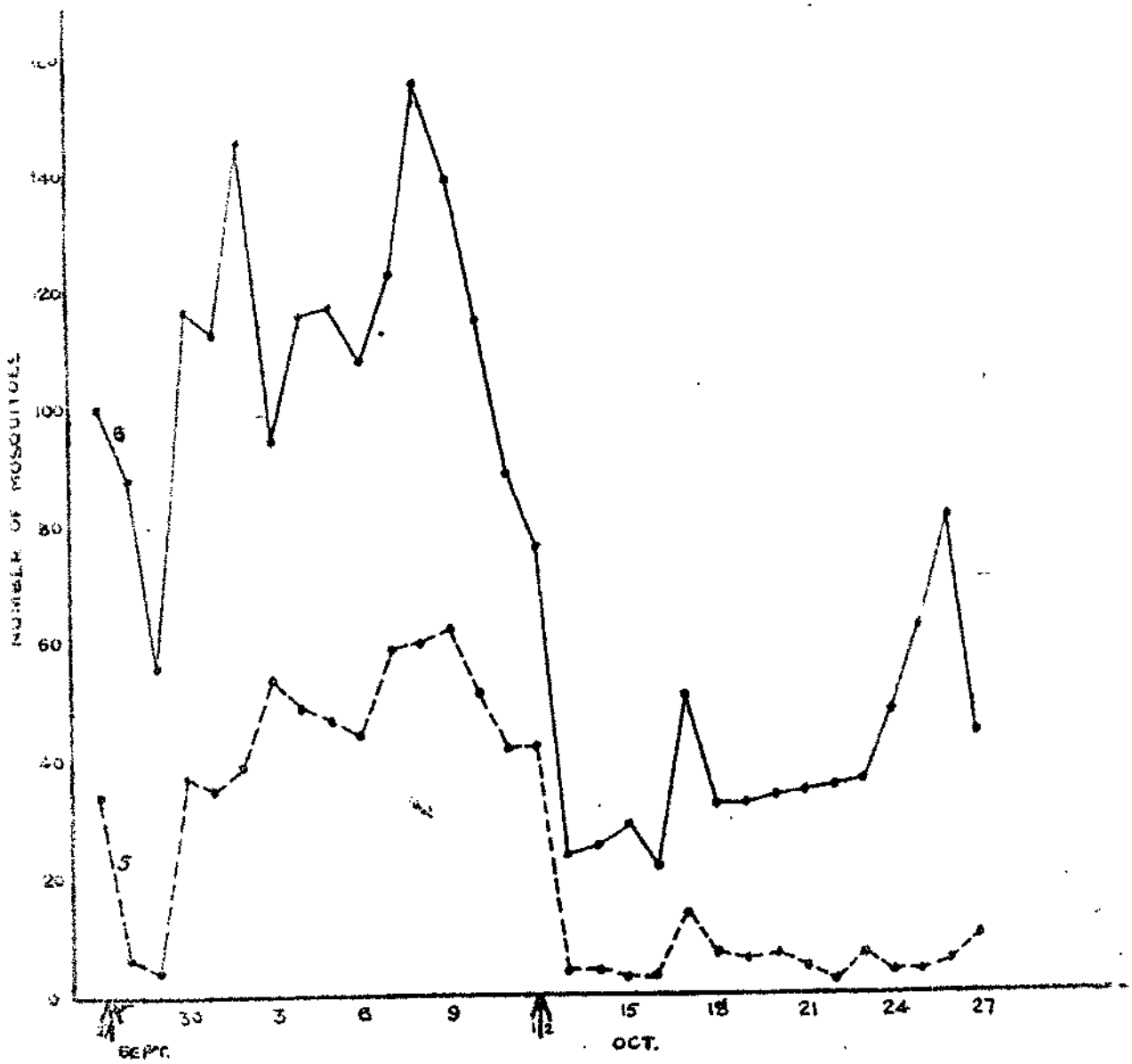
At the time of the second application, the preparations sprayed in different stables were changed so as to eliminate any possible effect due to the location of individual stables in the row. The results of total collections have been shown in Graphs 1 to 7. They indicate that both turpentine emulsion



GRAPH 5. – – – – – – (Stable No. 3.) Sprayed with 5 per cent kerosene-DDT solution at 3 c.c. (150 mg. DDT) per square foot on 27-9-1945.
- - - - - - (Stable No. 4.) Control. Both 3 and 4 resprayed with 5 per cent DDT-turpentine emulsion at 3 c.c. (150 mg. DDT) per square foot.

and kerosene have a definite repellent action which lasts about four days. That the reduction in the number of mosquitoes in the sprayed stables was due to the repellent action of turpentine and kerosene is obvious from the fact that a sudden

fall was observed for a day or so even in the unsprayed stable situated between two sprayed ones. No such fall in the number of mosquitoes was encountered in any of the other catching stations in the villages in this area. They also show



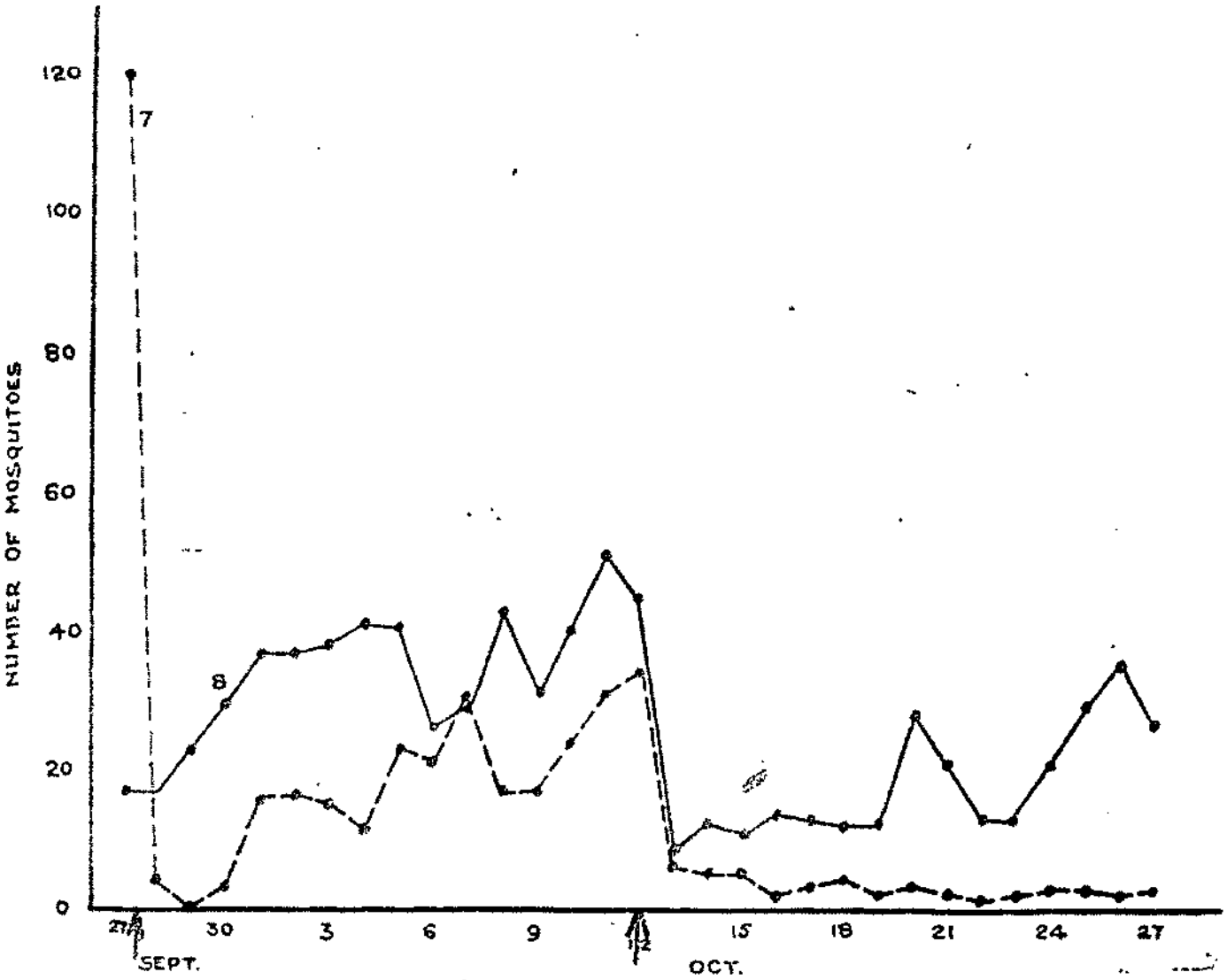
GRAPH 6. - - - - - - (Stable No. 5.) Sprayed turpentine emulsion without DDT at 3 c.c. square foot on 27-9-1945. Resprayed with kerosene oil without DDT at 3 c.c. square foot on 12-10-1945.

——————— (Stable No. 6.) Control.

that towards the end of the mosquito season the residual effect of DDT preparations (oil solutions or turpentine emulsions) as well as the repellent action of turpentine and kerosene apparently last longer than at the beginning.

DDT AS AN OUTDOOR OR BARRIER SPRAY AGAINST ADULT MOSQUITOES.

A number of experiments on outdoor spraying of DDT solutions to control mosquitoes were carried out during the recent war (World War II) by Army and Air Force personnel. In most of these experiments 5 per cent DDT solution in kerosene and fuel oil was sprayed from the air. These experiments were carried



GRAPH 1. – – – – – – (Stable No. 7.) Sprayed with 5 per cent DDT-turpentine emulsion at 3 c.c. (150 mg. DDT) per square foot on 27-9-1945. Resprayed with 5 per cent DDT-kerosene solution at 3 c.c. (150 mg. DDT) per square foot on 12-10-1945.

——— (Stable No. 8.) Control.

out in areas where *A. minimus*, *A. dirus*, *A. philippinensis* and/or *A. jeyporiensis* were the vector species. The results of these experiments have shown that this method of application is effective in bringing down the number of mosquitoes if it is carried out with meticulous attention to detail, otherwise it is far from satisfactory. These experiments showed that when the solution is sprayed at the rate of ½ to 1 gallon per acre it produces a 100 per cent reduction in the

a fair mosquito population and kills most of the larvae in the breeding places. The residual effect by this method of treatment is however, comparatively short and apparently depends upon two factors. The length of time during which the sprayed area will remain free from the prevalence of mosquitoes will vary in inverse proportion to the intensity of mosquito breeding along the periphery of the treated area and directly with the amount sprayed. Spraying ½ to 1 gallon of 5 per cent solution per acre leaves a deposit of only 2·8 to 5·6 mg. DDT per square foot of surface. This quantity is very small and is not enough to have much effect on the insects infiltrating into the treated area.

Barrier spraying was also tried from the ground over the whole area to be protected (ourdoors only) and for a 50 yards belt around it, with DDT-malariol solution at the rate of approximately 5 gallons per acre. Although according to some of the observers this dose produces a complete insect vacuum and maintains the mosquito reduction by 80 per cent for about one month, malariol, like kerosene, is likely to kill all vegetation in the area. Owing to this deleterious effect on vegetation it is not practicable to use such large doses of oil under normal peace conditions.

In order to find out if outdoor spraying has any effect on the mosquito population in the Delhi area, two villages, Jagatpur and Juliana, were selected and their mosquito population recorded as before. The outside walls of all the buildings and the streets and cross roads in the villages together with a 50 yards belt all round them were sprayed with a 5 per cent DDT emulsion in the former village and 5 per cent kerosene solution in the latter, at the rate of 1·5 gallon per acre. The spraying produced little or no effect on the mosquito population resting inside the buildings. It may be mentioned, however, that in the first case, within an hour of spraying the DDT emulsion there was heavy rainfall, which may have washed away some of the emulsion before it had time to dry.

SUMMARY AND CONCLUSIONS.

Various methods of preparing DDT solutions and emulsions have been described. Good emulsions can be prepared by using turpentine or turpentine and toluene combined or medium kerosene extract as solvents. The relative merits of these emulsions have still to be worked out. Of these, emulsion prepared with M. K. E. is the cheapest of the three and that with turpentine alone most costly.

Solutions of DDT in used engine oil and kerosene have been found very effective against mosquito larvae even in small doses (4 to 6 c.c. per 10 square yards). As in this form DDT remains floating on the surface, quantities even greater than the recommended dose are not likely to kill fish or any other fauna present in the water even when the latter is very shallow. Although in our experiments doses below 2 to 4 c.c. of 5 per cent DDT solutions per 10 square yards (100 to 200 mg. per 10 square yards) have not produced a 100 per cent kill of mosquito larvae, it is felt that if suitable spreaders are added to the oil solutions it may be possible to obtain a higher kill even with smaller doses. The spreading power of the oils so far tried by us was only 12 to 18 dynes.

Emulsions of DDT with turpentine as a solvent are more effective than oil solutions as larvicides. When applied at the rate of 100 to 200 mg. of DDT (2 to 4 c.c. of 5 per cent emulsion) per 10 square yards, there is 100 per cent control of anopheline larvæ for 5 to 8 days and a partial control for about 12 days. If the dose is increased to 300 mg. (6 c.c. of 5 per cent emulsion) per 10 square yards, complete control is effected for about 9 days and partial control for over 15 days.

Solutions and emulsions can be applied with the help of ordinary drop bottles. Sawdust soaked in DDT solution appears to be the best method of applying small quantities of DDT on the surface of water as the DDT solution exudes from the sawdust continuously in small quantities and the residual effect persists for a longer period than when the solution is applied in any other way.

When applying small quantities of DDT on the water surface, a better coverage is ensured with emulsions than with oil solutions. With most of the emulsions tried the major part of the DDT sinks down to the bottom of the water instead of floating on the surface and as such is inimical to fish and to other fauna. Consequently emulsions are likely to prove more efficacious against culicine than against anopheline larvæ.

DDT emulsions with turpentine as a solvent have been found more effective than any other preparation of this type, but a part of the DDT in these is probably precipitated to the bottom of the pool.

DDT in solutions or emulsions has no ovicidal properties and does not inhibit oviposition two to three days after application. The aerial spraying of DDT as a larval control measure is wasteful and very erratic. Even doses as large as 20 to 32 c.c. per 10 square yards of DDT-turpentine-toluene solution have not been found to give a 100 per cent kill of anopheline larvæ. This dose, however, killed large numbers of fish when the water was only about 1½ feet deep.

Preliminary experiments with DDT as a residual spray have been described. In villages around Delhi, DDT in kerosene solution or turpentine emulsion sprayed in mud huts at the rate of 150 mg. to 200 mg. per square foot gave a 100 per cent reduction in mosquitoes during the first 4 days, and the partial residual effect persisted for 4 to 5 weeks.

Barrier spraying in a *culicifacies* area does not seem to have any effect on the mosquito population resting inside huts when the DDT-oil solution is sprayed at the rate of 1½ gallons per acre only.

Stirrup pumps fitted with a special nozzle have proved to be the most satisfactory apparatus for applying DDT as an indoor residual spray. A knapsack sprayer was found useful in barrier spraying.

DDT had no toxic effect on any of the workers, although they had been handling it off and on for over one year. No special precautions were taken by and for them. While using oil solutions on a few occasions after about two hours' continuous contact, irritation on the exposed parts of the body was observed, but this was probably due to kerosene and was more acute when working in the sun.

No mask of any type was used over the mouth or the nose when spraying DDT with a stirrup pump. This precaution, however, becomes essential when a petrol driven sprayer is used or when DDT spray is finely atomized as a space spray.

While collecting mosquitoes from sprayed huts, it was observed that most of the specimens were found sitting on new cobwebs and removable clothing. It is obvious that new cobwebs should be removed whenever possible, as they offer an untreated resting place for the mosquitoes and the residual effect of DDT is thus counteracted.

REFERENCES.

BARBER, M. A. (1943) ... Field tests of Gesarol in crankcase oil against anopheline larvae (MS.).

BUTT, N. M. (1938) ... An inexpensive apparatus for mixing larvicides. *J. Mal. Inst. Ind.*, **1**, 2, pp. 147-148.

BUXTON, P. A. (1945*a*) ... The use of the new insecticide DDT in relation to the problem of tropical medicine. *Trans. Roy. Soc. Trop. Med. Hyg.*, **38**, 5, pp. 367–400.

Idem (1945*b*) ... Experiments with DDT in solutions and emulsions against mosquito larvae in West Africa. *Bull. Ent. Res.*, **36**, 2, pp. 165–175.

DEONIER, C. C., BURRELL, R. W., MAPLE, J. D., and COCHRAN, J. H. (1945). DDT as an anopheline larvicide. Preliminary field studies. *J. Econ. Ent.*, **38**, 2, pp. 244–249.

DEONIER, C. C., MAPLE, J. D., JONES, H. A., HISCHEY, E., and EIDE, P. M. (1945). DDT as an anopheline larvicide, laboratory tests. *Ibid.*, **38**, 2, pp. 241–243.

GINSBURG, J. M. (1945) ... Toxicity of DDT to fish. *Ibid.*, **38**, 2, pp. 274–275.

GAHAN, J. B., and LINDQUIST, A. W. (1945). DDT residual sprays applied in buildings to control *Anopheles quadrimaculatus*. *Ibid.*, **38**, 2, pp. 223–230.

GAHAN, J. B., TRAVIS, B. V., and LINDQUIST, A. W. (1945). DDT as a residual type spray to control disease-carrying mosquitoes, laboratory tests. *Ibid.*, **38**, 2, pp. 236–240.

GAHAN, J. B., TRAVIS, B. V., MORTON, F. A., and LINDQUIST, A. W. (1945). DDT as a residual type treatment to control *Anopheles quadrimaculatus*. Practical tests. *Ibid.*, **38**, 2, pp. 231–235.

JONES, H. A., FLUNO, H. T., and HENDRICK, A. B. (1945). DDT insecticidal preparations. *Ibid.*, **38**, 2, pp. 207–210.

LINDQUIST, A. W., MADDEN, A. H., WILSON, A. G., and KNIPLING, E. F. (1945). DDT as a residual type treatment for control of houseflies. *Ibid.*, **38**, 2, pp. 257–261.

RIBBANDS, C. R. (1945) ... The use of DDT as a mosquito larvicide on still waters. *Bull. Ent. Res.*, **36**, 3, pp. 315–330.

SENIOR WHITE, R. (1945) ... House spraying with DDT and with pyrethrum extract compared. First results. *J. Mal. Inst. Ind.*, **6**, 1, pp. 83–87.

TARZWELL, C. M., and STIERLI, M. H. (1945). The evaluation of DDT residual sprays for the control of anopheline mosquitoes in dwellings. *U. S. Pub. Hlth. Repts. Suppl.*, 186, pp. 35–48.

WEST, T. F., and CAMPBELL, G. A. (1946). *DDT the Synthetic Insecticide.* Chapman and Hall, Ltd., London.

TABLE 1.

Solubility of two samples of DDT in 100 c.c. of some common solvents at different temperatures.*

Solvent.	Fine technically pure commercial DDT.			Coarse DDT also supplied as technically pure DDT.		
	35°C.	40°C.	45°C.	35°C.	40°C.	45°C.
Xylol	68·6 gm.	76·4 gm.	85·0 gm.	55·0 gm.	60·2 gm.	65·0 gm.
Kerosene III grade ...	4·5 gm.	5·3 gm.	8·4 gm.	4·3 gm.	5·2 gm.	6·5 gm.
Turpentine oil (vegetable) ...	22·8 gm.	28·0 gm.	37·2 gm.	17·0 gm.	22·7 gm.	32·2 gm.
Medium kerosene extract (Assam Oil Co., Digboi).†	31·0 gm.	35·8 gm.	42·0 gm.	26·2 gm.	32·0 gm.	40·2 gm.

* 10·0 grammes of DDT dissolved in a solvent displaces 6·5 c.c. of fluid at 35°C.

† Medium kerosene extract is light brownish in colour and is a cut of kerosene containing a high percentage of aromatics. The higher solubility of DDT in III grade kerosene as compared with that in II grade (more or less colourless) may be due to the higher aromatic contents of the former. It was however seen that the solubility of DDT in the practically colourless kerosene available in the market in Egypt was comparatively much higher, though the aromatic content judged only by the smell of the sample appeared to be much lower than kerosene oil Grade II available in India.

TABLE II.

Experiment I (24-7-1944).

Rainwater pools treated with very small doses of 5 per cent DDT solution in used engine oil (U.E.O.).

Pond.	Area in square yards.	Treated with 5 per cent DDT-U.E.O. solution.		Average number of larvæ collected.		
		Dose per 10 square yards.	DDT per acre.	Before treatment.	After 6 hours.	After 24 hours.
A	200	0·3 c.c.	0·015 lb.	117·0 A. & C.	148·1	115·2
B	133	0·36 c.c.	0·018 lb.	81·2	87·5	90·0
C	433	0·15 c.c.	0·0075 lb.	80·9	55·7	56·7
D	41	3 c.c. U.E.O. without DDT.		70·7	72·0	61·3

TABLE III.

Experiment II (28-7-1944).

Rainwater pools (A–C) treated with larger doses of 5 per cent DDT solution in used engine oil (U.E.O.).

Pond.	Area in square yards.	Treated with 5 per cent DDT-U.E.O. solution.		Average number of larvæ collected.					
		Dose per 10 square yards.	DDT per acre.	Before treatment.	After 6 hours.	After 1 day.	After 2 days.	After 3 days.	After 4 days.
A	200	6 c.c.	0·3 lb.	118·5	6·5	2·3	7·5	51·8	61·9
B	133	6 c.c.	0·3 lb.	92·0	7·0	0·0	16·5	24·0	51·9
C	433	4 c.c.	0·2 lb.	56·8	0·0	0·0	4·2	3·2	3·1
D	41	44 c.c. U.E.O. without DDT.		54·5	38·5	11·3	27·7	26·5	48·0

TABLE IV.

Experiment II—(*continued*) (1-8-1944).

Rainwater pools (A–C) treated with DDT-used engine oil (U.E.O.).

Pond.	Area in square yards.	Treated with 5 per cent DDT-U.E.O. solution.		Average number of larvæ collected.							
		Dose per 10 square yards.	DDT per acre.	Before treatment.	After 6 hours.	After 1 day.	After 2 days.	After 3 days.	After 4 days.	After 5 days.	After 6 days.
A	200	4 c.c.	0·2 lb.	61·9	9·9	2·7	2·6	2·8	1·1	5·9	4·1
B	133	4 c.c.	0·2 lb.	51·8	0·5	0·5	1·2	0·5	0·5	10·3	10·0
C	433	4 c.c.	0·2 lb.	3·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0
D	41	Untreated	...	48·0	53·6	75·4	105·0	182·5	168·3	111·2	85·7

TABLE V.

Experiment III (11-8-1944).

Rainwater pools treated with small doses of 5 per cent DDT solution in used engine oil (U.E.O.).

Pond.	Area in square yards.	DDT-U.E.O. solution.		Method of application.	Average number of larvæ collected.							
		Dose per 10 square yards.	DDT per acre.		Before treatment.	After 24 hours.	After 2 days.	After 3 days.	After 4 days.	After 5 days.	After 6 days.*R	After 7 days.
E	175·5	2 c.c.	0·1 lb.	By means of a pipette.	11·6	0·0	3·0	6·4	11·1	12·5	18·3	6·0
F	138·2	2 c.c.	0·1 lb.	Soaked saw dust.	18·7	0·1	1·9	4·8	12·7	17·8	21·0	22·5
C	74·6	...	...	...	12·5	17·8	20·8	19·4	18·7	11·6	14·9	14·9

* R = Light shower.

TABLE VI.

Experiment IV (16-8-1944).

Large cement tanks without emergent vegetation treated with 5 per cent DDT-used engine oil (U.E.O.) solution applied by different methods.

Tank.	Area in square yards.	DDT-U.E.O. SOLUTION.		Method of application.	AVERAGE NUMBER OF LARVÆ COLLECTED.										
		Dose per 10 square yards.	DDT per acre.		Before treatment.	After 24 hours.	After 2 days.	After 3 days.	After 4 days.	After 5 days.	After 6 days.	After 7 days.	After 8 days.	After 9 days.	After 10 days.
1	177·7	6 c.c.	0·3 lb.	Sprayed with a hand sprayer.	21·3	0·1	0·0	0·0	0·0	1·1	6·6	9·2	17·5	19·5	39·2
2	177·7	6 c.c.	0·3 lb.	Mixed with Bajri.	5·6	0·0	0·0	0·0	0·0	0·2	0·4	0·4	1·3	3·2	4·1
3	222·2	6 c.c.	0·3 lb.	Mixed with saw dust.	15·9	0·0	0·0	0·0	0·0	0·7	0·4	0·4	0·8	2·1	1·1
4	222·2	6 c.c.	0·3 lb.	Mixed with sand.	3·1	0·0	0·0	0·0	0·0	0·2	0·3	0·6	0·9	1·5	1·3
5	222·2	6 c.c.	0·3 lb.	By means of pipette.	8·9	0·0	0·0	0·0	0·0	0·2	0·1	0·2	0·7	1·8	12·8
6	177·7	6 c.c. U.E.O without DDT.		...	17·7	15·8	6·8	5·7	17·0	13·0	24·0	17·2	20·0	18·2	14·3

Table VII.

Experiment V (14-10-1944).

Cement tanks treated with DDT-turpentine solution.

Pond.	Area in square yards.	2·5 per cent DDT-turpentine.		Method of application.	Average number of larvæ collected.																
		Dose per 10 square yards.	DDT per acre.		Before treatment.	After 4 hours.	After 1 day.	After 2 days.	After 3 days.	After 4 days.	After 5 days.	After 6 days.	After 7 days.	After 8 days.	After 9 days.	After 10 days.	After 11 days.	After 12 days.	After 13 days.	After 14 days.
1	177·7	Control	..	Squirting	20	13·7	18·1	23·4	17·8	16·4	19·1	18·5	19·8	16·3	17·6	12·8	19·6	20·4	2[illegible]·2	3[illegible]
2	177·7	8 c.c.	0·2 lb.	„	25	0	0	0	0	0	1st stage	I	I	I	I	I-II	I-III	[illegible]	15·2	1[illegible]·2
3	222·2	12 c.c.	0·3 lb.	„	20	0	0	0	0	0	0	0	0	0	1st stage	I	I-II	[illegible]	6·2	[illegible]
4	222·2	8 c.c.	0·2 lb.	„	20	0	0	0	0	0	0	0	0	0	„	I-II	I-III	6·2	[illegible]	1[illegible]·2
5	222·2	4 c.c.	0·1 lb.	„	10	0·1	0	0	0	0	0	0	1st stage	1st stage	„	I-II	I-III	9·5	12·[illegible]	1[illegible]
6	177·7	Untreated	..	„	10	7·4	9·8	9·6	9·9	9·6	11·5	9·1	7·3	7·5	7·1	8·5	9·7	21·7	1[illegible]	12·[illegible]

Indian Journal of Malariology, **1**, 1, March 1947.

STUDIES ON SOME INSECTICIDES AGAINST ANOPHELINE ADULTS AND LARVÆ.

Part II.

DDT AS RESIDUAL AND SPACE SPRAY AND AS LARVICIDE.*

BY

I. M. PURI, M.Sc. (Punj.), Ph.D. (Cantab.),

AND

A. K. KRISHNASWAMI, M.B., B.S.

(*Malaria Institute of India, Delhi.*)

VARIOUS methods of preparing and using DDT solutions and emulsions were described by Puri and Rajindar Pal (1947) in Part I of this series. In the present paper are recorded observations relating to a number of experiments carried out partly in the Nilgiris, South India (in 1944) and partly at Marianbari Tea Estate situated in the Bengal Terai (Darjeeling District, North Bengal), where *A. fluviatilis*, and *A. minimus* and *A. philippinensis* are the vector species respectively. In these experiments DDT solutions and emulsions were used both as outdoor and indoor sprays and as larvicides. A few experiments were also carried out with 5 per cent DDT non-wettable dust as a larvicide.

1. DDT AS LARVICIDE.

Suitable breeding places were selected and the density of mosquito larvæ in them recorded by taking the average of three dips, both before and at various intervals after treatment with the larvicide. The breeding places were of three different types: (1) narrow streams with clear slow flowing water and grassy

* Most of the work was financed by the Indian Research Fund Association under the Insecticide and Mosquito Repellent Enquiry.

The authors wish to express their gratitude to the proprietor, manager and staff of the Marianbari Tea Estate, Bengal Terai, for their generous help and co-operation in allowing us to carry out these field experiments in that neighbourhood and in affording accommodation to the staff.

edges, (2) fallow and growing paddy fields, and (3) square pits, 3′ × 3′ and 1′ deep, specially dug in the bed of the river for experimental purposes.

In these experiments DDT was used as a solution: (*a*) in third grade kerosene, (*b*) in used engine oil, or (*c*) in malariol, or (*d*) as a turpentine emulsion. Doses varying from 0·3 c.c. to 10 c.c. (16 mg. to 500 mg.) per 10 square yards were tried. A few experiments using DDT as a 5 per cent dust mixed with an inert diluent were carried out at Mettupalayam, Nilgiris (South India), in December 1944.

Different methods were used for distributing the DDT solutions over the breeding places: (1) direct application by means of a pipette, or (2) mixing them with sand or pebbles and throwing these into the breeding place.

(*i*) *Five per cent DDT dust.*—Five per cent mixture of DDT with collossal kaolin was used in doses of 50 and 100 mg. of DDT per square yard (= ½ lb. to 1 lb. of DDT per acre). The mixture was blown over the breeding place by means of a rubber bulb insufflator. To estimate the density of larvæ in the selected breeding places dips were made at the end of one, two and 24 hours after the application of the DDT dust. The results of these nine experiments are given in tabulated form (Table I).

In the two experiments with 50 mg. DDT per square yard (½ lb. per acre), a 50 per cent reduction in the density of the anophelines was observed at the end of the first and second hours after application and a 100 per cent at the end of 24 hours. With 100 mg. per square yard (= 1 lb. per acre) the reduction at the end of two hours varied from 85 to 100 per cent, while after 24 hours it was 100 per cent. With culicines, however, when the dose was 100 mg. per square yard the effect was practically nil at the end of two hours (experiment 4, Table I), while at the end of 24 hours a 100 per cent mortality was observed. In another experiment (no. 9) there was a reduction of about 90 per cent at the end of one and two hours and 100 per cent at the end of 24 hours. On the day that experiment 4 was carried out there was no strong wind blowing so that the dust remained floating for a long time and the culicines being bottom feeders did not ingest the toxic dose till late. Bishopp (1945) had also observed that DDT applied as a 10 per cent dust at a dosage of 1 to 2 lb. per acre (100 to 200 mg. per square yard approximately) gave a complete kill. According to Deonier, Maple and others (1945) much smaller doses have also produced 100 per cent kill of anopheline larvæ in 24 hours. Such smaller doses, however, were not tried by us.

(*ii*) *Experimental pits.*—Ribbands (1945), studying the effect of 5 per cent DDT solution in experimental pits 3′ × 4′ (depth not given) in which breeding had been allowed to develop, observed that DDT-oil solution applied at the rate of about 0·25 c.c. per 10 square yards (= 4 fluid oz. of solution or 0·0125 lb. of DDT per acre) produced 75 per cent mortality in 24 hours. When the dose was increased to 0·45-0·6 c.c. per 10 square yards (= 0·33 to 0·5 pints of solution or 0·02 to 0·03 lb. DDT per acre) the mortality recorded was 90 per cent, while 1·24 c.c. per 10 square yards (1 pint of solution or 0·062 lb. DDT per acre) produced 100 per cent mortality. Ribbands (*loc. cit.*) recorded that oil alone, even at the rate of 2 gallons per acre (16 c.c. per 10 square yards), did not produce an appreciable reduction in larval density.

Sixteen experimental pits 3′ × 3′ × 1′ deep were dug in the river bed (Mahananda, near Siliguri). They rapidly filled with seepage water. Instead of waiting for natural breeding to commence in these pools, anopheline and culicine larvæ were collected from other breeding places and put into them. Observations were commenced 24 hours later, this time being allowed for any mortality due to natural causes among the larvæ. Different doses of 5 per cent DDT in kerosene and used engine oil were sprinkled over the water surface directly with a pipette and the reduction in the density of larvæ at the end of 24 hours noted (Table II). An analysis of these experiments is tabulated as under :—

Dose per 10 square yards.	Percentage range.	Reduction average, per cent.
0·3 c.c.	73–100	92·5
0·5 c.c.	70–100	94·6
0·6 c.c.	93–100	99·6
0·8 c.c.	93–100	99·0
1·0 c.c. (=24 gm. DDT per acre).	94–100	99·2

Pure kerosene oil and used engine oil (without DDT) were also tested in similar pits side by side to see what effect they produced by themselves. Even doses as high as 10 to 15 c.c. per 10 square yards produced only about 50 to 60 per cent kill among the larvæ.

(*iii*) *Streams and seepages.*—Buxton (1945), carrying out experiments on the control of *A. funestus* larvæ breeding in garden ditches in the Gold Coast, observed that 0·5 c.c. of 5 per cent DDT solution per 10 square yards produced an 80 per cent reduction in larval density. The reduction was a little more than 80 per cent when 1 c.c. per 10 square yards was applied and was 95 to 100 per cent with 2·5 c.c. per 10 square yards. The water in these ditches however was practically stationary.

A number of slow running clear water streams with grassy edges were selected at Marianbari, and after making the preliminary observations, were treated with doses of DDT solution and emulsion at rates varying from 0·5 c.c. to 10 c.c. per 10 square yards. Daily observations were continued till the larval density showed an appreciable increase. In streams a dose of 0·5 c.c. per 10 square yards of 5 per cent emulsion gave a kill of 60 to 76 per cent among the larvæ at the end of 24 hours while the same dose of the oil solutions gave a kill of 67 to 95 per cent. Higher doses did not make any appreciable difference in the kill obtained when either

emulsion or oil solutions were used. Over fifty experiments were carried out and the results obtained have been summarized in Table III. An analysis of the observations is detailed below :—

5 per cent DDT in	Dose per 10 square yards.	Per cent mortality range.
Emulsion ...	1 c.c.	76–100
Kerosene oil ...	1 c.c.	66–100
Emulsion ...	2 c.c.	74
Kerosene oil ...	2 c.c.	86–98
Emulsion ...	3 c.c.	95
Kerosene oil ...	3 c.c.	78–100
Emulsion ...	4 c.c.	100
Kerosene oil ...	4 c.c.	87–100
" " ...	5 c.c.	91–100
Emulsion ...	10 c.c.	86
Kerosene oil ...	10 c.c.	60–100

Residual toxicity was variable (2 to 4 days) in streams even when 5 per cent DDT was applied in large doses, i.e. 10 c.c. per 10 square yards. In all the experiments larvæ apparently carried down by drift were found from the second and third days onwards and fresh breeding commenced within 4 to 5 days.

(*iv*) *Ricefields.*—A number of fallow and growing paddy fields were selected in which movement was extremely slow although water was being let in at one end and out at the other. After making the usual observations, varying doses of 5 per cent DDT oil solutions and emulsions were tried. The results of about 30 experiments show that the dosage of 2 c.c. per 10 square yards produced 56 to 100 per cent (average 92 per cent) reduction in the number of anopheline larvæ; with the dosage of 3 c.c. per 10 square yards the mortality in 24 hours was 80 to 100 per cent (average 97 per cent) and with 5 c.c. per 10 square yards there was a 100 per cent mortality. The residual effect lasted for a period varying from 4 to 8 days (Tables IV and V).

Toxicity to other fauna.—No effect was observed on higher forms of life when 5 per cent DDT was applied in the dosage mentioned above. A dose of 20 c.c. of the 5 per cent emulsion per 10 square yards in the paddy fields with water 3 to 6 inches deep produced 50 per cent kill in 24 hours among small young fish. In the streams, however, no effect was seen on the fish or their young ones, or tadpoles even with a dose of 60 c.c. of 5 per cent DDT per 10 square yards.

2. DDT INDOOR RESIDUAL SPRAY.

A number of huts were selected in different coolie lines on Marianbari Tea Estate. These generally consisted of one or two rooms built of split bamboos, the lower half of which were plastered with mud, and roofed over with galvanized iron sheets. The coolies were not in the habit of applying thinned cowdung on to the walls. This was done on the floor only and that too not daily. In all these experiments total collections were made by the same set of mosquito collectors and observations recorded. Collections were made daily for about a fortnight following the spraying and thereafter every other day till a steady rise in the number of mosquitoes was noticed. Once-a-week collections were made from these houses after spraying 0·5 oz. of very weak pyrethrum solution per 1,000 c.ft. so as to disturb any mosquito that might be in hiding. These were then collected. Spraying was carried out with stirrup pumps fitted with lance and nozzle as described in Part I of this series. The output of the pump was about 20 oz. per minute. It was found necessary to strain the solutions and emulsions through a piece of muslin so as to avoid the nozzle being choked. In actual practice three men per pump were found necessary—one to do the actual spraying, the second to work the pump, the third to keep the bucket filled and also to help in managing to keep the hose from becoming entangled.

In all about 20 experiments were carried out, some (14) with 1 qt. (40 fluid oz.) per 1,000 square feet, others (6) with 2 qts. (80 fluid oz.), giving a residue of 60 and 120 mg. per square foot respectively. The results of these experiments are given in Graphs 1 to 22.

It was found that the residual action was comparatively weaker against culicines, which began to make their appearance early. With both the doses, the duration of residual effect against *A. minimus* was longer than in the case of any of the other species of anophelines. On an average the duration of the residual toxicity lasted for about 66 days with 1 qt. per 1,000 square feet (60 mg. per square foot) and about 75 to 80 days with 2 qts. (120 mg. per square foot). This was estimated from the setting in of a steady increase in the number of mosquitoes to a level approximately equal either to the pre-spraying days' level or to the collections from the unsprayed houses in the same locality. Although with both kerosene oil solutions and emulsions the residual effect lasted for about the same number of days, mosquitoes began to appear much earlier in the DDT-kerosene sprayed houses than in those treated with the emulsion. A summary of the experiments with different doses is given in Table V.

3. DDT AS AN OUTDOOR RESIDUAL SPRAY.

The preliminary reports of experiments on DDT-oil solutions as residual spray by military personnel showed that in eastern India, where *A. minimus* or *A. jeyporiensis* are the malaria vectors, outdoor spraying at the rate of ½ to 1 gallon per acre reduced mosquito prevalence by 100 per cent. This reduction was maintained for a varying number of days. For these experiments fairly extensive areas were sprayed from the air. Spraying from the ground also was tried in some of their experiments, the spray being applied as 5 per cent DDT solution in malariol at the

rate of 5 gallons per acre in the form of a belt all round the area to be protected. This, according to the reports, created a 'barrier' between the mosquitoes and the human population inside. Such large doses of oil however killed most of the vegetation in the sprayed areas.

A number of experiments were carried out at Marianbari Tea Estate to determine the degree and the duration of protection afforded by spraying only the outside of the houses with doses of DDT solutions or emulsions which would not in any way damage the vegetation.

On the tea estate the coolie huts had been built in blocks of about 20 houses each placed more or less in lines.[1] The various groups were quite separate from one another and have been treated as separate entities in these experiments. Total collections of all the mosquitoes were made daily in all the huts including the cattlesheds within the selected coolie line. A belt of 50 yards all round the line was marked out and all the area within it including bushes, fences and lanes, and the outer surfaces of the walls and roofs of huts were sprayed. Any inconveniently large bush was removed so as to facilitate spraying. All the doors and windows of the houses within the area were kept closed while the spraying was being carried out.

Different doses of DDT, both as a 5 per cent solution in kerosene oil and as a 5 per cent turpentine emulsion, were tried in nearly 30 separate experiments. The spraying was done with a stirrup pump fitted with a special nozzle as for indoor residual spray. For spraying tops of houses and of any trees in the area, specially long lances were employed. After spraying daily total collections of mosquitoes were continued as before. Immediately after collection the approximate age of the various mosquitoes collected was recorded from the macroscopic appearance of their abdominal and wing conditions. The number of days elapsed since spraying when the first mosquito appeared was noted and is given in Table VI, separately for: (1) the local vector *A. minimus*, and (2) other species of anophelines, and (3) culicines (Graphs 23 to 26). An analysis of the observations in these experiments is given in Table VII.

The results show that spraying at the rate of 1 and 2 gallons of 5 per cent DDT per acre (about 50 and 100 mg. DDT per square yard) produces an average reduction of 83 to 97 per cent in the anopheline fauna within the sprayed belt. Culicines and some species of anophelines, chiefly *A. vagus*, *A. subpictus*, *A. maculatus*, but not *A. minimus*, made their appearance within 1 to 5 days of the spraying, while *A. minimus* were collected 3 to 5 days after spraying. A steady increase in the total mosquito population within the sprayed area was to be noticed on an average after 6 to 11 days.

In one experiment, 2·5 per cent DDT-turpentine emulsion at the rate of 2 gallons per acre (about 50 mg. DDT per square yard) was sprayed. Ninety-one per cent reduction was observed within 24 hours, culicines and *A. vagus* appearing in large numbers on the third day after spraying.

When sprayed at the rate of 3 gallons per acre either as 5 per cent kerosene or as a 5 per cent DDT-turpentine emulsion (about 150 mg. per square yard) a reduction of 98 to 100 per cent in the total number of mosquitoes was observed. Specimens of *A. minimus* appeared within 2 to 7 days and those of other species within 4 to 6 days. Culicines appeared on the third day. The results of these

later experiments were, however, vitiated by heavy rainfall, which fell almost every day after the spraying operations. In all these outdoor spraying experiments it was observed that the residual effect disappeared if there was a heavy shower of rain following the spraying, and the number of mosquitoes began suddenly to increase, within the sprayed belt, even on the second day. In the absence of rain, or when only light showers fell, the protection lasted comparatively longer. Fay *et al.* (1945), carrying out experiments to determine the effect of different weather conditions on the residual effect of DDT, also found that direct sunlight and the beating action of rain caused accelerated deterioration of DDT residues.

4. DDT FOR SPRAY-KILLING OF MOSQUITOES.

Pyrethrins in sprays have a very quick knock-down effect on mosquitoes. This property is almost completely lacking in DDT. For this reason it is not recommended for space sprays except in combination with some other insecticide having a quick knock-down effect. In order to make a comparative study of the effect of pure DDT and pyrethrum sprays on the sporozoite rate in mosquitoes, four villages were selected in Bengal Terai.

After making the preliminary observations, all the huts in one village: (A) were sprayed twice a week at equal intervals with a 5 per cent solution of DDT in kerosene, in the second (B) with 5 per cent DDT-turpentine emulsion, and in the third (C) with pyrethrum-kerosene spray containing 0·1 per cent pyrethrins. The fourth village was left untreated for comparison. Atomization of the insecticide was done with MISH type hand pressure continuous action sprayer (designed by the senior author).

Collections of *A. minimus* were made regularly from all the villages and the specimens dissected for salivary gland infections.

The dissection of *A. minimus* from these villages was commenced during the first week of July, whilst spraying in the villages A, B and C was commenced on 4th August and continued till the end of October 1945. The average sporozoite rate in all the four villages during July was 0·74 per cent. During the period August 1 to 3 dissections showed an increase in sporozoite rate in three of the villages and it was 3·9 per cent, 0, 2·5 and 2·5 respectively in villages A, B, C and D. For the rest of August the sporozoite rate was 3·4 per cent in the unsprayed village (D), while it was less than 1 per cent in each of the sprayed villages (A, B and C). In September, the rate was 5·7 per cent in village D, while it was about 1 per cent in all the others. In October the rate fell to 0·75 per cent even in the comparison village (D) and was 0 in the sprayed villages (A–C).

The results of dissections in these experiments have been tabulated in Table VIII.

From the results it is obvious that spray-killing of mosquitoes in a village in the Bengal Terai, when carried out twice a week, although it has little appreciable effect on the number of mosquitoes in the houses, has a marked effect in bringing down the sporozoite rate among *A. minimus*. DDT used as a space spray, i.e. as distinct from spraying for residual effect, is apparently as effective for the control of malaria as pyrethrum sprays. From the comparatively greater fall in the number of mosquitoes in villages A and B, it seems probable that when sprayed

regularly with small quantities of DDT, a residual toxicity may gradually be built up in the huts.

SUMMARY AND CONCLUSIONS.

A large series of experiments were carried out in Bengal Terai to study the effect of DDT both as a larvicide and an adult mosquitocide. In these experiments DDT was used in solutions in kerosene, used engine oil or malariol and also as a turpentine emulsion.

As a larvicide its effect was tried in small slow running streams, in seepages, in fallow or growing paddy fields and in experimental pits. In streams, 3 to 4 c.c. per 10 square yards of 5 per cent solution or emulsion gave a 100 per cent kill and 3 c.c. produced the same kill in fallow and growing paddy fields. In experimental pits on the other hand, 0·6 c.c. of 5 per cent solution in kerosene or used engine oil per 10 square yards was found sufficient to produce a 100 per cent kill.

In streams, no residual effect was observed even when DDT was applied in doses 3 to 4 times the minimum larvicidal dose. In fallow and growing paddy fields, the residual effect lasted for 6 to 8 days with doses of 2 to 5 c.c. of 5 per cent solution or emulsion per 10 square yards.

Larvicidal doses of DDT had no apparent ill effect on higher aquatic fauna. No apparent toxic effect on fish was observed in small streams even when a dose of 60 c.c. of 5 per cent solution or emulsion was applied per 10 square yards.

Five per cent DDT solutions and emulsions were used both as residual and space sprays against adult mosquitoes in a large number of experiments.

As an indoor residual spray in mud-plastered bamboo huts a dose of 1 qt. of 5 per cent solution or emulsion per 1,000 square feet of surface (1·2 c.c. or 60 mg. per square foot) reduced the mosquito incidence by nearly 100 per cent for a varying number of days and residual toxicity lasted for nearly two months. The results obtained in the various experiments have been shown in separate graphs.

The duration of the residual effect did not appreciably increase when the dose was doubled.

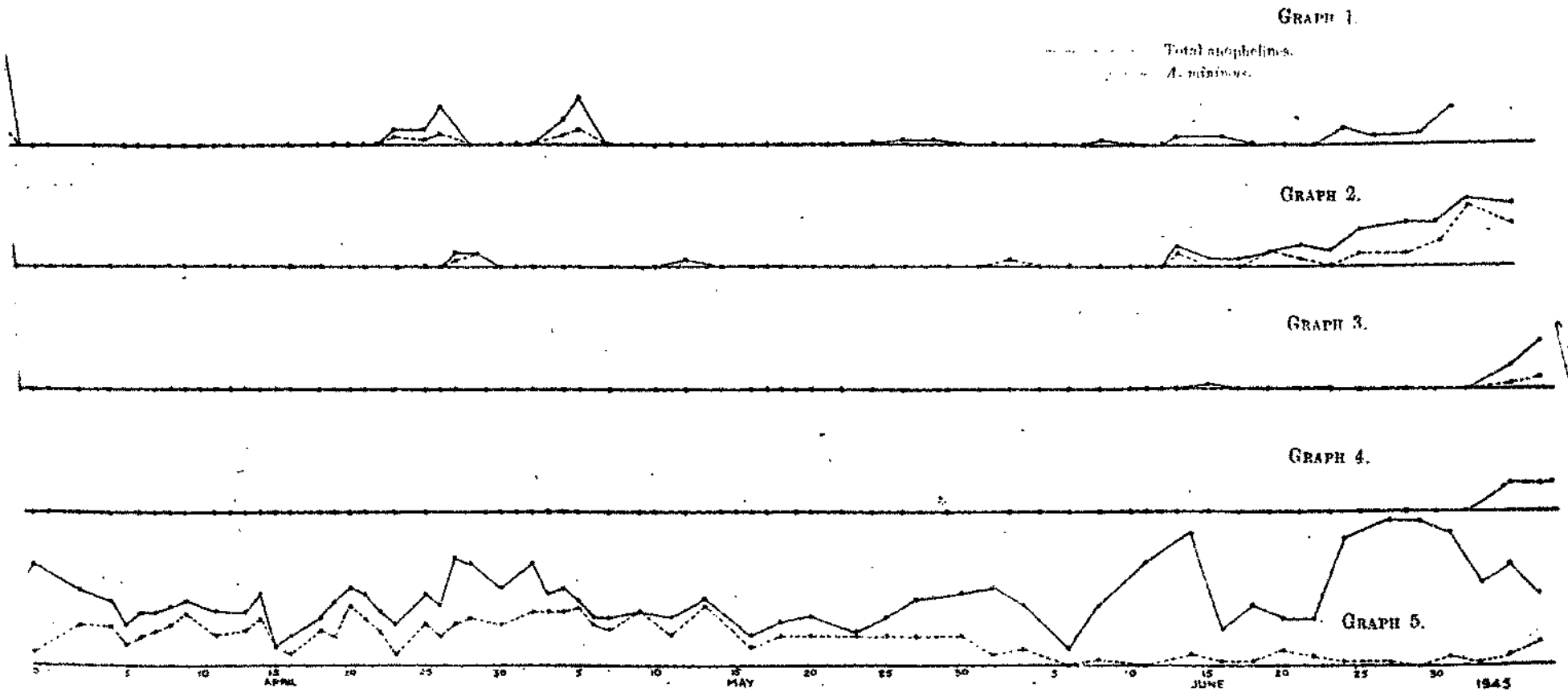
Applied as an emulsion, the effect lasted for a comparatively longer period, though the difference was not very marked.

A. minimus was more sensitive to the DDT residue than the other local anophelines. The effect on culicines was of shorter duration than on any anopheline species.

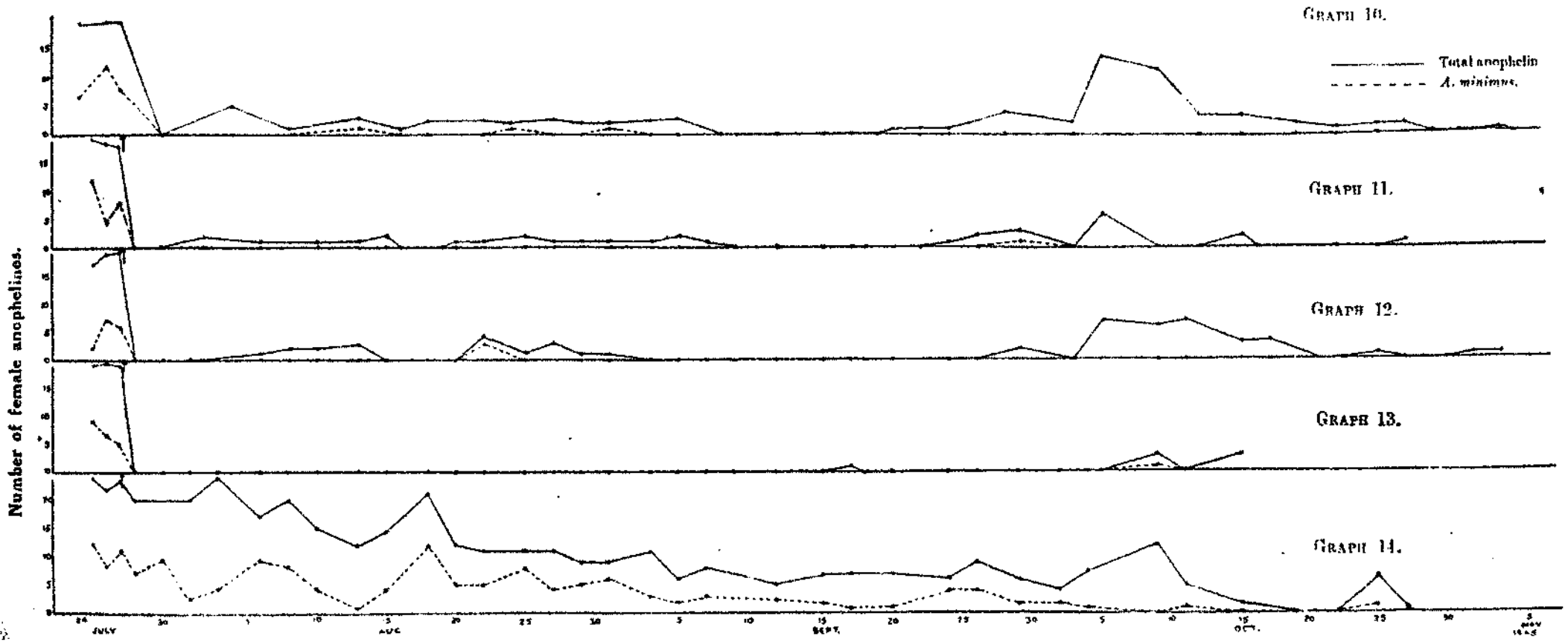
To study the effect of DDT as an outdoor residual spray, a belt 50 yards wide all round a number of groups of human dwellings was sprayed at doses varying from 1 to 3 gallons of 5 per cent solution or emulsion per acre. An appreciable reduction in the number of mosquitoes was observed inside the huts for periods varying from 3 to 13 days. The results of the various experiments are given in the form of graphs.

No difference was observed in either the reduction in mosquito prevalence or in the duration of the residual effect, whether DDT was sprayed in solution or in emulsion form.

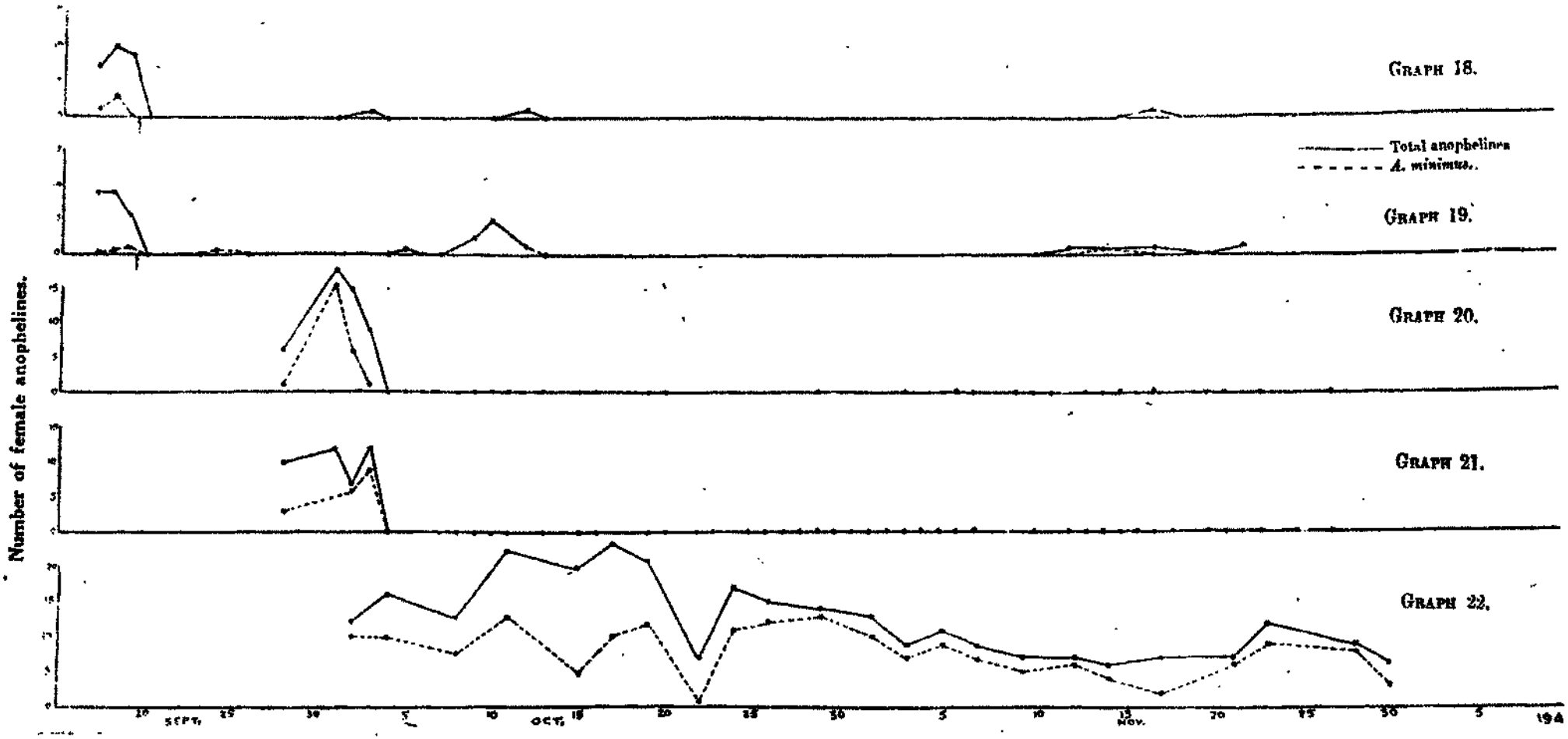
The protection afforded against *A. minimus* was for a longer duration than against either other local anophelines or culicines.



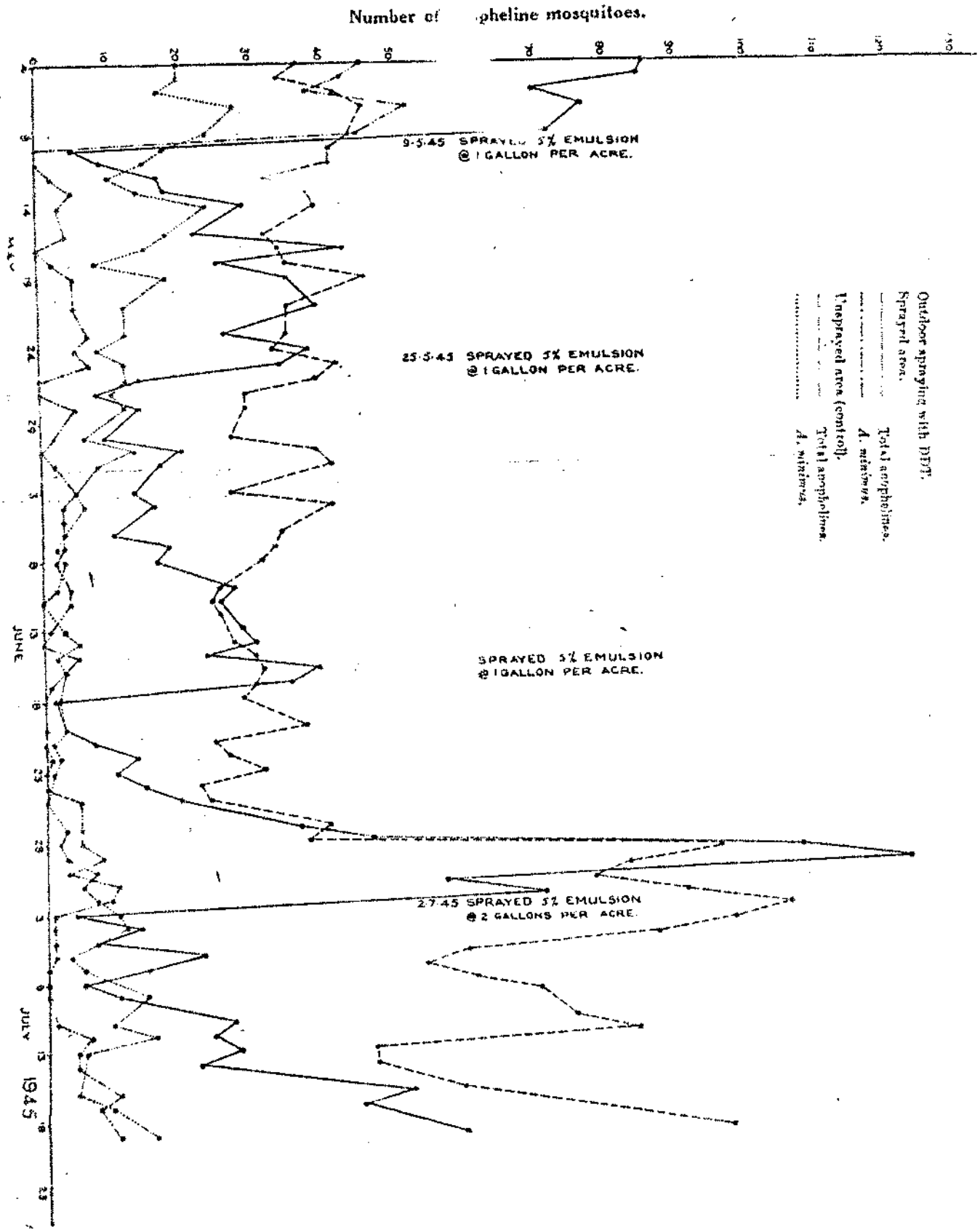
GRAPH 1.—Effect of spraying 5 per cent DDT emulsion at 60 mg. per square foot.
GRAPH 2.—Effect of spraying 5 per cent DDT in kerosene at 60 mg. per square foot.
GRAPH 3.—Effect of spraying 5 per cent DDT in kerosene at 120 mg. per square foot.
GRAPH 4.—Effect of spraying 5 per cent DDT in emulsion at 120 mg. per square foot.
GRAPH 5.—Unsprayed control for experiments 1–4.

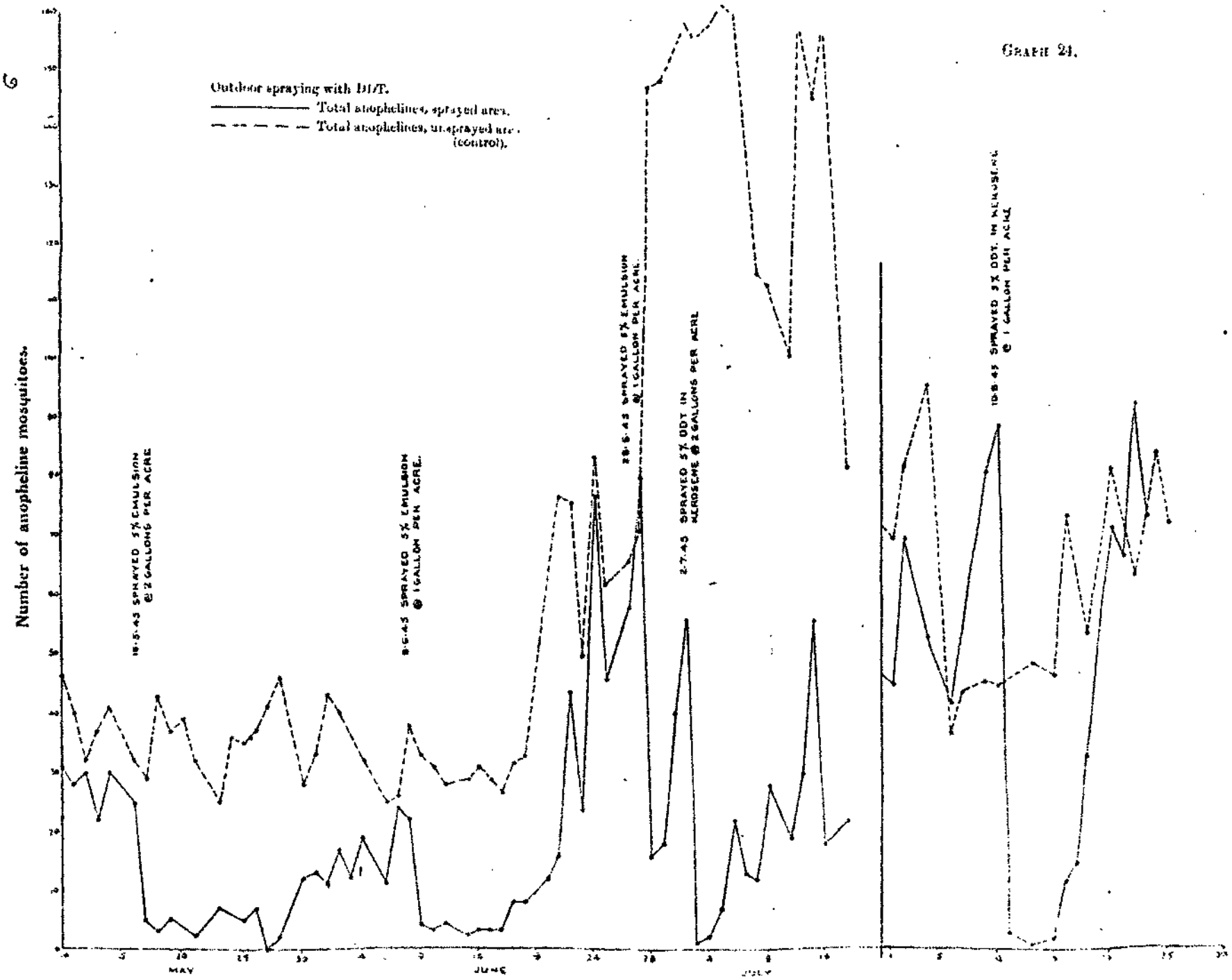


Graph 10.—Effect of spraying 5 per cent DDT in kerosene at 60 mg. per square foot.
Graph 11.—Effect of spraying 5 per cent DDT emulsion at 60 mg. per square foot.
Graph 12.—Effect of spraying 5 per cent DDT in kerosene at 120 mg. per square foot.
Graph 13.—Effect of spraying 5 per cent DDT in emulsion at 120 mg. per square foot.
Graph 14.—Unsprayed control for experiments 10–13.

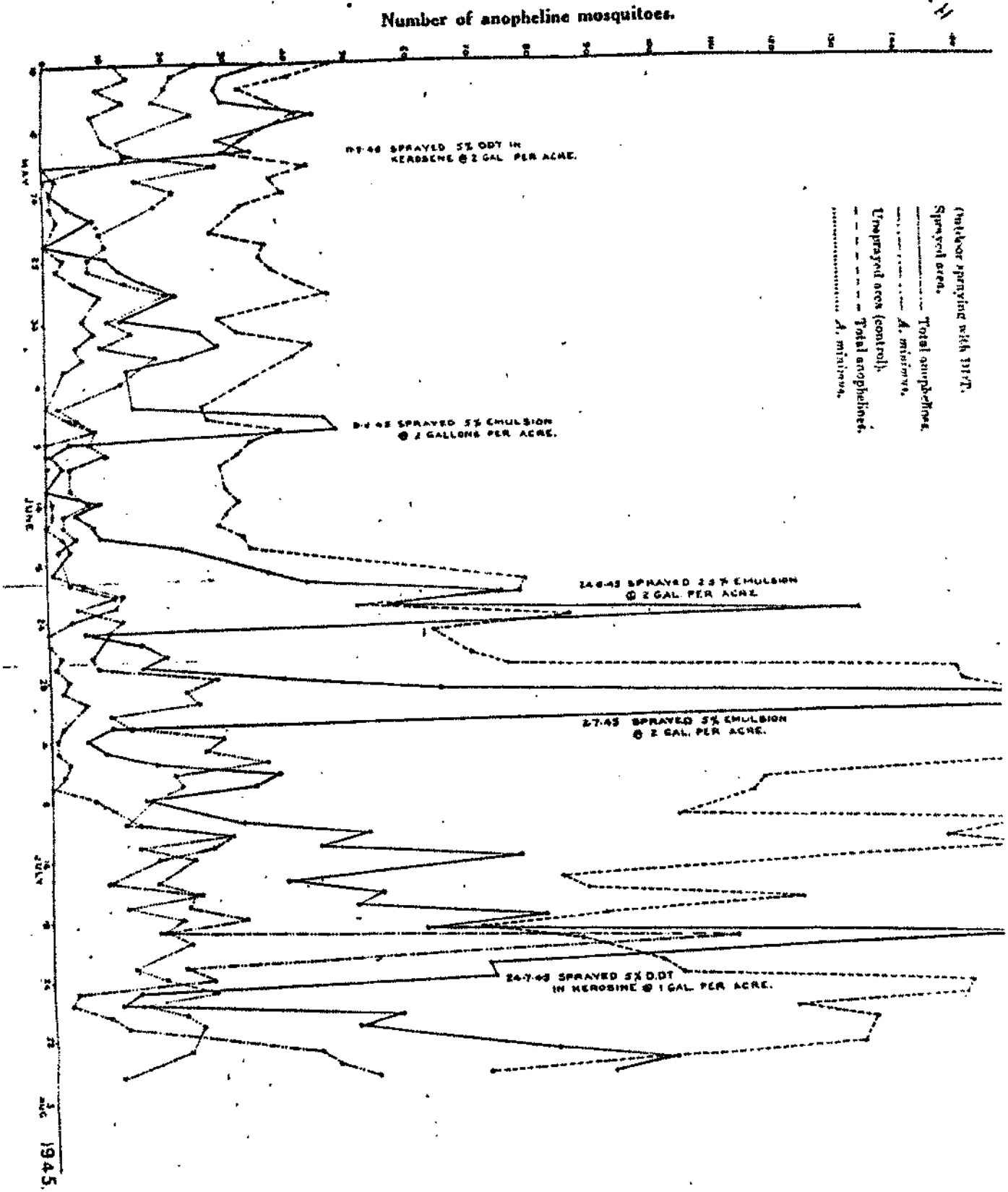


Graph 18.—Effect of spraying 5 per cent DDT emulsion at 120 mg. per square foot.
Graph 19.—Effect of spraying 5 per cent DDT emulsion at 60 mg. per square foot.
Graph 20.—Effect of spraying 5 per cent DDT emulsion at 60 mg. per square foot.
Graph 21.—Effect of spraying 5 per cent DDT in kerosene at 60 mg. per square foot.
Graph 22.—Unsprayed control for experiments 18–21.

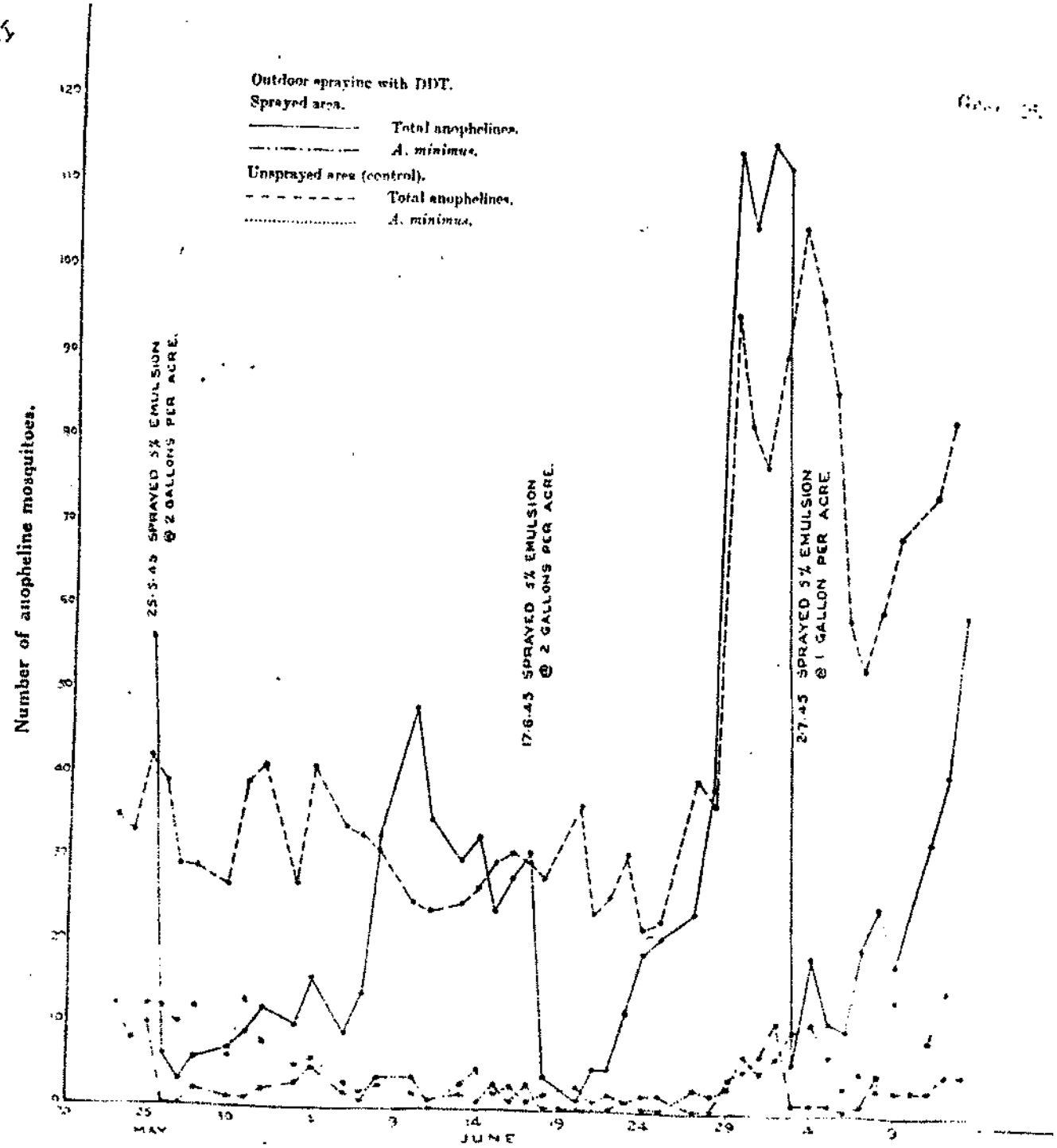

Number of pheline mosquitoes.
Outdoor spraying with DDT.
Sprayed area.
Total anopheline.
A. minimus.
Unsprayed area (control).
Total anopheline.
A. minimus.
9.5.45 SPRAYED 5% EMULSION @ 1 GALLON PER ACRE.
25.5.45 SPRAYED 5% EMULSION @ 1 GALLON PER ACRE.
SPRAYED 5% EMULSION @ 1 GALLON PER ACRE.
27.45 SPRAYED 5% EMULSION @ 2 GALLONS PER ACRE.
MAY
JUNE
JULY
1945


Outdoor spraying with DDT.
Total anophelines, sprayed area.
Total anophelines, unsprayed area (control).
Number of anopheline mosquitoes.
18-5-43 SPRAYED 5% EMULSION @ 2 GALLONS PER ACRE
8-6-43 SPRAYED 5% EMULSION @ 1 GALLON PER ACRE.
28-6-43 SPRAYED 5% EMULSION @ 1 GALLON PER ACRE.
2-7-43 SPRAYED 5% DDT IN KEROSENE @ 2 GALLONS PER ACRE
10-8-43 SPRAYED 5% DDT IN KEROSENE @ 1 GALLON PER ACRE
MAY
JUNE
JULY

GRAPH 21.


Number of anopheline mosquitoes.
Outdoor spraying with DDT.
Sprayed area.
Total anophelines.
A. minimus.
Unsprayed area (control).
Total anophelines.
A. minimus.
SPRAYED 5% ODT IN KEROSENE @ 2 GAL PER ACRE.
SPRAYED 5% EMULSION @ 2 GALLONS PER ACRE.
SPRAYED 5% EMULSION @ 2 GAL. PER ACRE.
SPRAYED 5% EMULSION @ 2 GAL. PER ACRE.
SPRAYED 5% D.DT IN KEROSINE @ 1 GAL. PER ACRE.
MAY
JUNE
JULY
AUG
1945.

156-I


Outdoor spraying with DDT.
Sprayed area.
Total anophelines.
A. minimus.
Unsprayed area (control).
Total anophelines.
A. minimus.
Number of anopheline mosquitoes.
25-5-43 SPRAYED 5% EMULSION @ 2 GALLONS PER ACRE.
17-6-43 SPRAYED 5% EMULSION @ 2 GALLONS PER ACRE.
27-7-43 SPRAYED 5% EMULSION @ 1 GALLON PER ACRE.
MAY
JUNE

The residual effect seemed to diminish rapidly after heavy shower of rain.

In three villages, spray-killing of mosquitoes was carried out twice a week over a period of nearly three months, using 5 per cent DDT-kerosene solution in one, 5 per cent DDT-turpentine emulsion in another, and 0·1 per cent pyrethrum-kerosene spray in the third, a fourth village being untreated for comparison. The results showed a marked reduction in the sporozoite rate among *A. minimus* collected in dwelling houses in the sprayed villages.

DDT used as a space spray (as distinct from spraying for residual effect) seemed to be as effective as pyrethrum sprays for the control of malaria.

REFERENCES.

BISHOPP, FRED C. (1945) ... Medical and public health importance of the insecticide DDT. *Bull. N. Y. Acad. Med.*, **21**, 11, pp. 561–580.

BOXTON, P. A. (1945) ... Experiments with DDT solutions and emulsions against mosquito larvæ in West Africa. *Bull. Ent. Res.*, **36**, 2, pp. 165–175.

DEONIER, C. C., MAPLE, J. D., JONES, H. A., HISCHEY, F., and EIDE, P. M. (1945). DDT as an anopheline larvicide-laboratory test. *J. Econ. Ent.*, **38**, 2, pp. 241–243.

FAY, R. W., SIMMONS, S. W., and CLAPPS, J. M. (1945). Laboratory investigations on the toxicity of DDT residues to the adults of *A. quadrimaculatus*. *U.S. Pub. Hlth. Repts.*, Suppl. 186, pp. 21–34.

PURI, I. M., and RAJINDAR PAL (1947). Studies on some insecticides against anopheline adults and larvæ. Part I. Preliminary experiments at Delhi with DDT. *Ind. J. Mal.*, **1**, 1, pp. 133–158.

RUBANOS, C. R. (1945) ... The use of DDT as a mosquito larvicide in still waters. *Bull. Ent. Res.*, **36**, 3, pp. 315–330.

TABLE I.

Experiments with DDT applied as dust—5 per cent mixture with kaolin.

	Serial number.	Dose DDT per 10 sq. yds. (mg.).	Dose DDT per acre (lb.).	Average number of larvæ per dip. Before treatment. An.	Before treatment. Cul.	1 hour after. An.	1 hour after. Cul.	2 hours after. An.	2 hours after. Cul.	24 hours after. An.	24 hours after. Cul.
5th	1	100	1	35	0	3	0	3	0	0	0
	2	100	1	N	0	4	0	2	0	0	0
	3	100	1	80	0	0	0	0	0	0	0
	4	100	1	N	N	3	N	3	N	0	0
	5	Control	...	24	0	...	...	...	...	33	0
20th	6	50	½	30	0	14	0	16	0	0	0
	7	50	½	18	0	7	0	8	0	0	0
	8	100	1	62	0	9	0	10	0	0	0
	9	100	1	4	38	1	4	0	3	0	0
	10	100	1	14	0	0	0	0	0	0	0
	11	Control	...	60	0	57	0	70	0	59	0

An. = Anopheline larvæ. Cul. = Culicine larvæ. N = Numerous.

TABLE II.

Results of applying DDT solutions as larvicides in experimental pits.

1945.	Serial number.	Larvicide (5 per cent DDT).	Dose. c.c. per 10 sq. yds.	Dose. DDT (mg.) per 10 sq. yds.	Dose. DDT (lb.) per acre.	Average number of larvæ per dip. Before treatment. A	Before treatment. C	24 hours after. A	24 hours after. C	Per cent reduction. A	Per cent reduction. C
October 25.	1	In used engine oil ...	0·3	15	0·015	70	31	9	2	87·0	93·5
	2	In kerosene oil ...	0·3	15	0·015	40	13	2	0	95·0	100·0
	3	In used engine oil ...	0·5	25	0·025	38	7	0	1	100·0	85·7
	4	In kerosene oil ...	0·5	25	0·025	53	24	0	0	100·0	100·0
	5	In used engine oil ...	1·0	50	0·05	47	32	3	0	93·5	100·0
	6	In kerosene oil ...	1·0	50	0·05	60	24	0	0	100·0	100·0
	7	Kerosene oil without DDT	4·0	...	...	38	15	19	6	50·0	60·0
	8	Used engine oil (without DDT).	4·0	...	...	31	20	12	8	61·0	60·0
		Control	(Untreated)		...	43	18	48	15	+11·7	16·6
October 27.	9	In used engine oil ...	0·3	15	0·015	52	5	14	0	—73·0	100·0
	10	In kerosene oil ...	0·3	15	0·015	60	28	0	0	100·0	100·0
	11	In used engine oil ...	0·5	25	0·025	23	12	0	0	100	100·0
	12	In kerosene oil ...	0·5	25	0·025	33	8	0	0	100	100·0
	13	In used engine oil ...	1·0	50	0·05	39	17	0	0	100	100·0

October 27.	14	In kerosene oil ...	1·0	50	0·05	60	9	6	0	100	100·0
	15	Used engine oil (without DDT).	5·0	...	...	56	18	16	12	71·4	33·3
	16	Kerosene oil (without DDT)	5·0	...	...	84	36	23	13	60·8	64·0
		Control	(Untreated)		...	21	21	23	5	9·5	7·0
October 30.	17	In kerosene oil ...	0·3	15	0·015	29	4	1	0	96·5	100·0
	18	In used engine oil ...	0·3	15	0·015	38	3	6	0	84·7	100·0
	19	In kerosene oil ...	0·5	25	0·025	25	7	1	0	96·0	100·0
	20	In used engine oil ...	0·5	25	0·025	14	3	2	0	85·6	100·0
	21	In kerosene oil ...	0·8	40	0·04	31	9	0	0	100	100·0
	22	In used engine oil ...	0·8	40	0·04	37	5	0	0	100	100·0
	23	Kerosene oil (without DDT).	4·0	...	...	71	2	76	45	+5·6	40·6
	24	Used engine oil (without DDT).	4·0	...	...	54	[illegible]	51	10	5·5	71·0
	25	Kerosene oil (without DDT).	8·0	...	...	37	[illegible]	91	52	+146	+100
	26	Used engine oil (without DDT).	8·0	...	...	50	7	45	12	10	74·5
		Control	(Untreated)		...	35	[illegible]	43	0	+23·0	...
November 1 and 2.	27	In kerosene oil ...	0·3	15	0·015	23	[illegible]	0	0	100	100
	28	In used engine oil ...	0·3	15	0·015	54	1	3	0	94·5	100
	29	In kerosene oil ...	0·5	25	0·025	21	1	2	0	91·0	100
	30	In used engine oil ...	0·5	25	0·025	44	1	1	0	97·7	100

A = Anopheles. C = Culicine.

TABLE II—*contd.*

1945.	Serial number.	Larvicide (5 per cent DDT).	Dose.			Average number of larvæ per dip.				Per cent reduction.	
			c.c. per 10 sq. yds.	DDT (mg.) per 10 sq. yds.	DDT (lb.) per acre.	Before treatment.		24 hours after.			
						A	C	A	C	A	C
November 1 and 2.	31	In kerosene oil ...	0·8	40	0·040	5	6	1	0	80·0	100
	32	In used engine oil ...	0·8	40	0·040	38	7	0	0	100	100
	33	Kerosene oil (without DDT).	8·0	...	...	48	31	37	18	23	42
	34	Used engine oil (without DDT).	8·0	...	...	25	26	12	0	52	100
	35	Kerosene oil (without DDT).	15·0	...	...	51	19	32	12	37·0	36·8
	36	Used engine oil (without DDT).	15·0	...	...	46	15	13	0	71·7	100
		Control	(Untreated)		...	44	6	21	5	52·3	16·6
November 3.	37	In used engine oil ...	0·3	15	0·015	53	13	4	1	92·3	92·5
	38	In kerosene oil ...	0·3	15	0·015	31	26	2	2	93·5	91·6
	39	In used engine oil ...	0·5	25	0·025	49	8	2	0	96·0	100
	40	In kerosene oil ...	0·5	25	0·025	56	17	1	0	98·2	100
	41	In used engine oil ...	0·8	40	0·040	65	24	0	0	100	100
	42	In kerosene oil ...	0·8	40	0·040	33	29	0	0	100	100

November 3.	43	Kerosene oil (without DDT).	10·0	..	...	66	18	39	6	41·0	66·6
	44	Used engine oil (without DDT).	10·0	...	...	51	12	20	12	61·6	0
	45	Kerosene oil (without DDT).	15·0	...	...	39	19	22	8	43·6	58·0
	46	Used engine oil (without DDT).	15	...	...	30	14	10	3	66·6	78·6
		Control	(Untreated)		...	38	16	29	14	23·7	12·5
November 6.	47	In used engine oil ...	0·5	25	0·025	43	9	0	0	100	100
	48	In kerosene oil ...	0·5	25	0·025	36	19	0	0	100	100
	49	In used engine oil ...	0·8	40	0·040	25	4	0	0	100	100
	50	In kerosene oil ...	0·8	40	0·040	28	22	0	0	100	100
	51	In used engine oil ...	0·8	40	0·04	31	42	2	1	93·6	95·2
	52	In kerosene oil ...	0·8	40	0·04	44	17	0	0	100	100
	53	Kerosene oil (without DDT).	15·0	...	...	50	31	26	12	48·0	61·3
	54	Used engine oil (without DDT).	15·0	...	...	45	16	13	5	71·0	69·0
		Control	(Untreated)		...	80	22	51	13	36·3	41·0

A = Anopheles. C = Culicine.

TABLE III.

Results of applying different preparations of DDT as larvicide in small streams.

1945.	Serial number.	Larvicide (5 per cent DDT).	Dose. c.c. per 10 sq. yds.	Dose. DDT (mg.) per 10 sq. yds.	Dose. DDT (lb.) per acre.	Average number of anopheline larvæ per dip. Before treatment.	Number of days after treatment. 1	2	3	4	5	6	7	8	9	10
March 26.	1	In kerosene oil ...	0·5	25	0·025	18	2	13	22	9						
	2	In used engine oil	0·5	25	0·025	28	3	12	17 N I	7						
	3	In malariol ...	0·5	25	0·025	17	1	3	14	31	24					
		Control ...	(Untreated)			42	26	24	45	24	18					
March 28.	4	* In malariol ...	0·5	25	0·025	N	3	18	10 I-II	...	19					
	5	* In kerosene oil	0·5	25	0·025	22	1	0	2	...	8					
	6	*In used engine oil	0·5	25	0·025	33	4	3	4	...	9					
		Control ...	(Untreated)			24	45	24	18	...	16					
April 6.	‡7	†In used engine oil	0·5	25	0·025	69	10	21	13	...	13 N I	14 N I	...	22		
	‡8	† In kerosene oil	0·5	25	0·025	47	3	2	2	...	N I	N I	...	9 N I		
	‡9	† In malariol ...	0·5	25	0·025	37	9	5	11	...	22	13	...	21		
	‡10	† In emulsion ...	0·5	25	0·025	40	17	14	17	...	15	25	...	23		
	11	In emulsion ...	0·5	25	0·025	71	14	10	20	...	7	18	...	N I-II		
		Control ...	(Untreated)			57	44	21	50	...	...	51	...	56		

...ences against Anopheline Adults and Larvæ.

April 8.	12	In kerosene oil ...	1·0	50	0·05	39	3	...	0	...	13	...	7 N I	...		18
	13	In used engine oil	1·0	50	0·05	33	13	...	17	...	0	...	5	...	...	22
	14	In malariol ...	1·0	50	0·05	40	0	...	17	...	45	...	3	...	...	N I-II
	15	In emulsion ...	1·0	50	0·05	42	3	...	2	...	11	...	30 N I-II	...	...	27
		Control. ...		(Untreated)		21	19	...	50	...	41	...	56	...	...	38
April 19.	16	In kerosene oil ...	1·0	50	0·05	38	10	11	8	11	R	0				
	17	In emulsion ...	1·0	50	0·05	33	14	19	5	13	R	2				
	18	In malariol ...	1·0	50	0·05	43	15	30	31	44	R	33	...	...	30	N
	19	In used engine oil	1·0	50	0·05	29	11	3	12	7	R	0				
	20	† " "	1·0	50	0·05	28	11	1	6	5	R	0	0	...	22	
	21	† In kerosene oil	1·0	50	0·05	23	0	0	0	...	R	0	13			
	22	* In emulsion ...	1·0	50	0·05	31	0	7	12	3	R	17	0	...	N I	
	23	† " "	1·0	50	0·05	39	3	3	13	2	R	5	0	...	N I-II	
		Control ...		(Untreated)		55	38	56	38	44	R	0				
April 29.	24	* In kerosene oil	1·0	50	0·05	63	6	3	9	...	N I-II					
	25	† " "	1·0	50	0·05	31	3	1	2	...	6					
		Control ...		(Untreated)		26	30	...	26	...	7					

* Applied mixed with sand.
N = Numerous.

† Applied mixed with pebbles.

‡ Average of two experiments.
I, II, III, IV = Stages of larvæ.

TABLE III—*contd.*

1945.	Serial number.	Larvicide (5 per cent DDT).	Dose. c.c. per 10 sq. yds.	Dose. DDT (mg.) per 10 sq. yds.	Dose. DDT (lb.) per acre.	Average number of anopheline larvæ per dip. Before treatment.	Number of days after treatment. 1	2	3	4	5	6	7	8	9	10
July 23.	26	In kerosene oil ...	2·0	100	0·10	23	4	9	8	8	6	...	11			
	27	In used engine oil	2·0	100	0·10	14	5	6	24 I-II	24	18	...	16			
	28	In malariol ...	2·0	100	0·10	50	10	4	17 I-II	19	16	...	7			
	29	In emulsion ...	2·0	100	0·10	30	22	18	8	13 I	15	...	0			
	30	In kerosene oil ...	3·0	150	0·15	34	6	4	7	30 I-IV	28					
		Control ...		(Untreated)		14	18	10	12	16	...	4				
July 23.	31	In used engine oil	3·0	150	0·15	15	4	0	...	11	10	...	2			
	32	In emulsion ...	3·0	150	0·15	40	4	6	...	6	6	...	7			
		Control ...		(Untreated)		50	60	51	...	38	16	...	22			
July 25.	33	In used engine oil	2·0	100	0·1	77	0	0	1	...	2	0	Dry			
	34	In malariol ...	2·0	100	0·1	33	1	3	2	...	3	1	Dry			
		Control ...		(Untreated)		29	32	18	20	...	30	23				

August 20.	‡35	†In emulsion ...	3·0	150	0·15	7	6 I	6 I–IV	10 I–IV	8	5	16	6	8	5	3
	‡36	†In used engine oil	3·0	150	0·15	10	0	3	4 I	3	0	...	6 I	8 I	...	4
	37	†In kerosene oil	3·0	150	0·15	13	0	1 IV	3 I	5 I–IV	5	...	2	Dry		
		Control ...	(Untreated)			12	8	7	10	17	5	...	7	Dry		
August 21.	38	In emulsion ...	3·0	150	0·15	30	1	17 I	25 I-II	20 I-II	...	1	11	...	30	35
	39	In used engine oil	3·0	150	0·15	26	5	6	2	3	...	2	7	...	25 I-II	18
	40	In kerosene oil ...	3·0	150	0·15	17	2	7 I	3 I-II	6	...	2	2	...	Dry	
	41	In malariol ...	3·0	150	0·15	36	7	4 IV	7 I-IV	7	...	12 I-II	15	...	Dry	
	42	In emulsion ...	10·0	500	0·5	33	6	0	6 I-II	30 I-II	...	36 I-IV	39	...	5	26
	43	In used engine oil	10·0	500	0·5	12	4	4	6	0	...	12 I–IV	14 I-II	R	0	0
	44	In kerosene oil ...	10·0	500	0·5	10	4	1	0	0	...	2 IV	0	R	6	0
	45	In malariol ...	10·0	500	0·5	12	0	4	7 I	3	...	0	5 I	R	2	12
		Control ...	(Untreated)			18	31	26	34	19	...	10	27	R	7	11

† Applied mixed with pebbles.
‡ Average of two experiments.

I, II, III, IV = Stages of larvæ.
R = Rain.

TABLE III—*contd.*

1945.	Serial number.	Larvicide (5 per cent DDT).	Dose. c.c. per 10 sq. yds.	Dose. DDT (mg.) per 10 sq. yds.	Dose. DDT (lb.) per acre.	Average number of anopheline larvæ per dip. Before treatment.	Number of days after treatment. 1	2	3	4	5	6	7	8	9	10
August 26.	46	In kerosene oil ...	10·0	500	0·5	22	0	1	...	3	2	0	...	7	9	12
	47	In emulsion ...	10·0	500	0·5	10	0	0	...	7 I–IV	7 I–II	2	...	1	3	3
		Control ...	(Untreated)			27	7	11	...	3	17	Dry				
November 9.	48	In used engine oil	5·0	250	0·25	12	0	...	7 II–IV	...	3	10 I–IV	...	0	...	5
	49	In kerosene oil ...	5·0	250	0·25	14	2	...	0	...	5	5	...	8	...	7
		Control ...	(Untreated)			13	8	...	9	...	5	2	...	10	...	12

I, II, III, IV = Stages of larvæ.

TABLE [illegible].

Results of applying different preparations of DDT as larvicide in fallow and growing paddy fields.

1945.	Serial number.	Larvicide (5 per cent DDT).	Dose. c.c. per 10 sq. yds.	Dose. DDT (mg.) per 10 sq. yds.	Dose. DDT (lb.) per acre.	Average number of anopheline larvæ per dip. Before treatment.	Number of days after treatment. 1	2	3	4	5	6	7	8	9	10
						Fallow fields.										
August 9.	1	In malariol ...	3·0	150	0·15	17	0	0	0	...	0	0	1	12 I	10	13 I-II
	2	In emulsion ...	3·0	150	0·15	48	0	0	0	...	7 I	0	2	17 I-II		
	3	In kerosene oil ...	3·0	150	0·15	50	2	0	0	...	0	7 I-III	14 I-II	0		
	4	In emulsion ...	4·0	200	0·2	12	0	0	0	...	Ploughed up.					
	5	In used engine oil	4·0	200	0·2	14	2	1	...	0	0	,,				
	6	In kerosene oil ...	4·0	200	0·2	12	0	0	...	0	0	,,				
	7	In malariol ...	4·0	200	0·2	12	2	0	...	0	0	,,				
		Control ...	(Untreated)			18	15	17	...	5	...	12	...	14		

I, II, III, IV = Stages of larvæ.

TABLE IV—*contd.*

1945.	Serial number.	Larvicide (5 per cent DDT).	Dose. c.c. per 10 sq. yds.	Dose. DDT (mg.) per 10 sq. yds.	Dose. DDT (lb.) per acre.	Average number of anopheline larvæ per dip. Before treatment.	Number of days after treatment. 1	2	3	4	5	6	7	8	9	10
		Growing paddy fields.														
September 21.	1	In emulsion ...	2·0	100	0·1	10	0	...	0	0	0	N I	N I–II			
	2	In kerosene oil	2·0	100	0·1	12	3	...	0	0	7	3	12	N I		
	3	In used engine oil	2·0	100	0·1	18	0	...	7	0	3	13	8	...	N I–II	
	4	In malariol ...	2·0	100	0·1	16	2	...	0	0	0	...	0	17 I–III	Dry	
		Control ...	(Untreated)			18	14	...	23	...	18	...	31	7	...	12
September 25.	5	In emulsion ...	5·0	250	0·25	8	0	0	0	0	...	Dry				
	6	„ „ ...	10·0	500	0·5	21	0	0	0	0	...	Dry				
	7	In kerosene oil ...	5·0	250	0·25	17	0	0	2	0	...	11 I	Dry			
	8	„ „ ...	10·0	500	0·5	14	0	0	0	3	...	1	24			
	9	In used engine oil	5·0	250	0·25	9	0	0	2	3	...	0	2	10 I–IV	51 I–IV	
	10	„ „ ...	10·0	500	0·5	15	0	0	0	0	...	7 I–II	22 I–II	...	7	

September 25.	11	In malariol ...	10·0	500	0·5	15	0	2	N I	N I	...	Dry		42	26
		Control ...	(Untreated)			9	12	9	14	N I	12	...	...	31	
October 9.	*12	In emulsion ...	2·0	100	0·1	22	3	13	11	18	12 I–IV	12			
	13	In kerosene oil ...	2·0	100	0·1	12	0	0	0	31 I-II	...	12			
	14	In used engine oil	2·0	100	0·1	13	4	0	0	15 I	...	3			
	15	" "	3·0	150	0·15	20	0	4	10 I–IV	3	...	14 I–IV			
	16	In emulsion ...	3·0	150	0·15	26	0	0	0	7	...	13 I			
	17	In kerosene oil ...	3·0	150	0·15	13	0	7 I–IV	0	3	...	12 I–III			
	18	In emulsion ...	10·0	500	0·5	19	0	7	2	0	...	11	...	20 I-II	
	19	In used engine oil	10·0	500	0·5	19	0	0	7	0	...	25 I	...	18	
		Control ...	(Untreated)			22	25	17	33	30	...	41	...	22	
October 18.	20	In emulsion ...	2·0	100	0·1	12	1	4 IV	...	2	12 I	7	16	9	
	21	In used engine oil	2·0	100	0·1	11	0	0	...	2	13 I-II	4 I–IV	17 I-II	12	
	22	In kerosene oil	2·0	100	0·1	23	0	0	...	7 I–IV	9 I–IV	11 I	7	9	
	23	In emulsion ...	3·0	150	0·15	18	1	0	...	4 I	3 I	5 I-II	12 I	15	
	24	In kerosene oil	3·0	150	0·15	14	2	0	...	0	12 I-II	12 I	11 I-II	14	
		Control ...	(Untreated)			14	13	11	...	5	9	7	11	14	

* Average of two experiments. I, II, III, IV = Stages of larvæ. N = Numerous.

TABLE V.

Summary of results of experiments on indoor spraying with DDT for residual effect.

Sprayed 5 per cent DDT in	Dose DDT per sq. ft. (mg.).	Number of experiments.	Average number of days after which mosquitoes first appeared.			Average number of days after which steady increase observed.
			A. minimus.	Other anophelines.	Culicines.	
Emulsion ...	60	8	66 (15–106)	38 (6–98)	10 (1–18)	66
,, ...	120	4	71 (56–96)	67 (3–95)	7 ...	76
Kerosene oil	60	6	33 (6–65)	25 (4–74)	6 (2–9)	68
,, ,,	120	2	25 ...	43 (10–75)	43 ...	81

(Figures within brackets show the minimum and maximum periods after which the first mosquito was collected in the different experiments.)

TABLE VI.

Outdoor spraying with 5 per cent DDT solutions and emulsions.

DDT insecticide.	Dose per acre (gallons).	Number of experiments.	Average maximum per reduction, per cent.	Average number of days after which first mosquito was collected.			Average number of days after which effect disappeared.
				A. minimus.	Other anophelines.	Culicines.	
5 per cent emulsion ...	1	8	88	5	1	2	7
,, ,, ...	2	6	97	3	1	3	11
5 per cent in kerosene oil	1	6	93	4	4	2	7
,, ,, ...	2	4	83	6	12	2	6
,, emulsion ...	3	1	98	6	1	3	6
,, in kerosene oil	3	1	100	7	4	...	7
2·5 per cent emulsion ...	2	1	91	3	1	1	5

TABLE VII.

Analysis of outdoor spraying experiments with DDT solution.

5 per cent DDT in	Dose per acre (gallons).	Number of experiments.	Maximum reduction, per cent.		Duration of residual effect, days.	
			Range.	Average.	Range.	Average.
Emulsion ...	1	8	72–96	88	3–10	7
" ...	2	6	93–100	97	7–13	11
Kerosene oil ...	1	6	77–100	93	3–10	7
" "	2	4	43–100	83	1–9	6

TABLE VIII.

Results of dissections.

1945.	Village A.		Village B.		Village C.		Village D.	
	Number of *A. minimus* dissected.	S.R.	Number of *A. minimus* dissected.	S.R.	Number of *A. minimus* dissected.	S.R.	Number of *A. minimus* dissected.	S.R.
July ...	Total 1,209 specimens of *A. minimus* with S.R. 0·74 per cent.							
August 1–3 ...	77	3·9	31	0	41	2·5	80	2·5
August 4–31	299	1·0	251	0·8	281	0·7	688	3·4
September ...	170	1·2	108	0·9	130	0·8	313	5·7
October ...	103	*Nil*	50	*Nil*	144	*Nil*	305	0·75
November ...	Total number of *A. minimus* dissected 485; S.R. *Nil*.							

Note 1. Village A sprayed with 5 per cent DDT in kerosene oil.
" B " " 5 " " turpentine emulsion.
" C " " 0·1 " pyrethrum spray in kerosene oil.
" D unsprayed for comparison.
" 2. S.R. = Sporozoite rate, per cent.

ndian Journal of Malariology, 1, 1, March 1947.

STUDIES ON SOME INSECTICIDES AGAINST ANOPHELINE ADULTS AND LARVÆ.

Part III.

EXPERIMENT WITH DDT AS A RESIDUAL SPRAY IN SOME VILLAGES IN BALUCHISTAN.*

BY

I. M. PURI, M.Sc. (Punj.), Ph.D. (Cantab.),

AND

M. L. BHATIA, M.Sc. (Punj.), Ph.D. (Cantab.).

(*Malaria Institute of India, Delhi.*)

[December 6, 1946.]

ALTHOUGH the materials and equipment used in experiments with DDT residual sprays carried out at Delhi (Puri and Rajindar Pal, 1947) and in Bengal Terai in 1945 (Puri and Krishnaswami, 1947) (Parts I and II of this series respectively) were practically identical, a certain amount of divergence was noticed in the duration of the residual effect of DDT solutions and emulsions against adult mosquitoes. This variation was apparently due to the difference in the resting and feeding habits of the mosquitoes in the two areas. With the wide publicity given to DDT as a universal mosquitocide and the extravagant claims put forward by various manufacturers as to the duration of the residual toxicity of extremely minute doses, it was felt that the effect of DDT preparations should also be studied in areas in which mosquito anophelines other than *A. culicifacies*, *A. fluviatilis*, *minimus* or *A. jeyporiensis* were the main vector species. Quetta (Baluchistan) its surrounding villages with their short malaria and mosquito season and *A. superpictus* as the chief vector species, offered a very suitable area for making a comparative study of the effect of DDT applied in different forms.

Divergent opinions have been expressed by various workers on the efficacy of emulsions and suspensions of DDT as compared to DDT-kerosene oil solutions as residual sprays. Consequently, it was thought advisable to carry out

* Most of the work was financed by the Indian Research Fund Association under the Insecticide and Mosquito Repellent Enquiry.

comparative field experiments on the duration of the protection afforded by small quantities of DDT applied as solutions, emulsions and suspensions.

Methods of preparing DDT solutions and emulsions and the apparatus required for their application were described in Part 1 of this series. A suspension of DDT was prepared by wet-grinding coarse DDT crystals (technically pure commercial DDT) with gum acacia and water by means of a stone pestle and mortar. One pound of powdered gum acacia was dissolved in 7 lb. of water and mixed with 2 lb. of DDT. This mixture was ground together into a fine paste. The resultant suspension concentrate contained 20 per cent DDT. This was diluted to the required strength at the time of spraying. The spraying was carried out with stirrup pumps fitted with fine nozzles, the average discharge rate from which was 22 oz. per minute. Two such stirrup pumps were worked by six men in two parties of three men each.

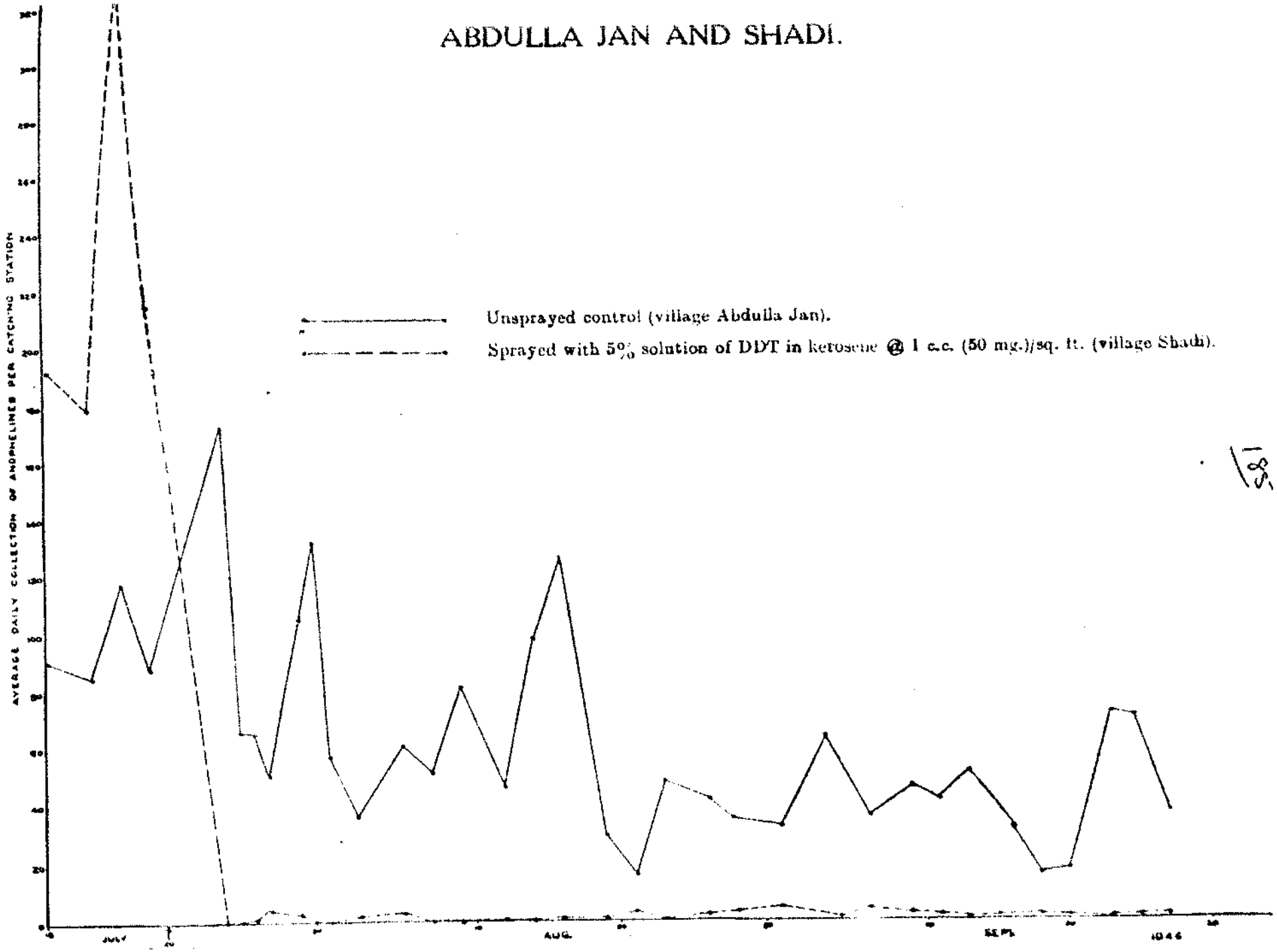
Four villages, two of them large enough to be divided into two separate parts for differential treatment, were selected for comparative field experiments. These villages were situated along the Samungli Road about 3½ miles due west of Quetta. They were located within a radius of half a mile from the Lora Nalah, which was the main source of mosquito breeding and the distance between the individual villages was not more than half a mile. They consisted of mud-walled houses, each with a small enclosed courtyard.

Catching stations of different types, some dwelling houses and some cattle-sheds, were selected, at least two in each section of the village under different treatments. Mosquitoes were collected from these catching stations on alternate days in the morning from 8 a.m. to 10 a.m. Each village and section of village was allotted to specified mosquito collectors, who worked in the same village throughout the experiment though, as will be seen, this was not absolutely necessary. An attempt was made to collect the total mosquito population from each of the catching stations. This was done by closing all openings into the room and covering the door with a black cloth curtain having in the centre a sleeve-like trap made of white mosquito netting. A weak solution of pyrethrins, 0·02 per cent in kerosene, was then sprayed in the room and the mosquitoes knocked down were collected from the floor which was covered with white sheets. The majority however flew into the mosquito net sleeve, from which they were collected and transferred to test tubes. The species of mosquitoes encountered were *A. superpictus*, *A. stephensi*, *A. culicifacies*, *A. dthali*, *A. fluviatilis*, *A. turkhudi* and *A. pulcherrimus*. Of these, *superpictus* constituted the major part of the collection, the last three species being caught only occasionally. It was observed that all the species reacted alike to spraying with pyrethrum solutions, in that they all flew away from it into the mosquito net sleeve.

The following experiments were carried out to evaluate the effect of DDT sprays on adult mosquitoes when applied as an indoor and outdoor residual spray :—

Experiment I.—All the houses in Shadi Khan village (total surface area 22,799 square feet) were sprayed with a 5 per cent DDT solution in kerosene at the rate of 1 c.c. per square foot (50 mg. per square foot or 1 litre per 1,000 square feet). This brought the number of mosquitoes down to insignificant numbers for the whole period of observation, i.e. nearly 10 weeks after treatment (Graph 1).

ABDULLA JAN AND SHADI.



185

Experiments II and III.—Village Razab Khan was divided into two parts. Part A (total surface area about 23,500 square feet) was sprayed with 1·25 per cent DDT-turpentine-toluene emulsion (Antigas Laboratories) at the rate of 2 c.c. per square foot (25 mg. of DDT per square foot) and Part B (total surface area 15,700 square feet) was treated with 1·25 per cent DDT-turpentine emulsion at the same rate as in Part A. In the part of the village (A) treated with turpentine-toluene emulsion the number of mosquitoes resting in the houses remained continuously low, but in the portion treated with turpentine emulsion, the catches were not markedly reduced after the treatment.

Four weeks after the first treatment, all the houses in both portions were re-sprayed as previously, and at the same dosage. The second treatment brought the catches down to insignificant numbers in both the parts. The number of mosquitoes collected fell precipitously after the second treatment, even in the portion treated with turpentine emulsion. From the results of the experiments it was obvious that the Antigas emulsion acted much better than the turpentine emulsion. When the results obtained with DDT-turpentine emulsion are compared with those of similar experiments carried out at Delhi during the previous year (Puri and Rajindar Pal, *loc. cit.*), one is struck by the failure of the turpentine emulsion at Quetta. The only possible explanation to account for this failure is that presumably the quality of the turpentine used at Quetta was very poor. Possibly it contained a higher percentage of rosins, which formed an impermeable coating on the DDT crystals, thus making them ineffective to the mosquitoes. This experiment also shows that the dosage of 25 mg. of DDT per square foot is not enough to produce a 100 per cent reduction in the density of mosquito prevalence in this area (Graphs 2 and 3).

Experiments IV and V.—Sabzal Khan village was also divided into two parts. Part A (total surface area 24,800 square feet) was sprayed indoors with 1·25 per cent DDT suspension in water at the rate of 2 c.c. per square foot (25 mg. per square foot). In the second part (B) outdoor spraying only was done. The external surfaces of the walls and the courtyards (area 12,400 square feet) were sprayed with 1·25 per cent DDT suspension in water at the rate of 4 c.c. per square foot (50 mg. DDT per square foot). The results show that, whereas in the part in which indoor spraying was done the number of mosquitoes found in houses was extremely low, there was no apparent reduction in the portion treated outdoors only. A second treatment with the same strength of DDT suspension and at the same rate was carried out 4 weeks later. This, however, did reduce the number of mosquitoes to some extent, even in the portion treated outdoors.

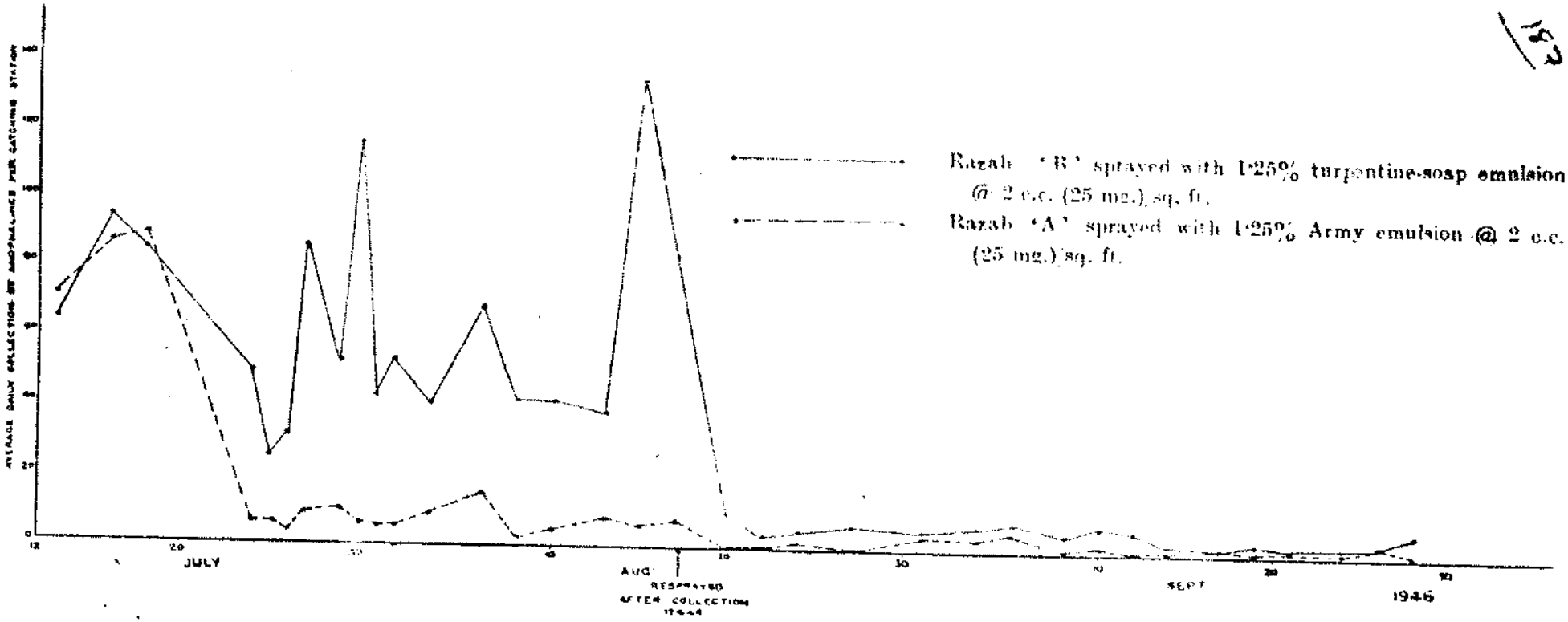
Abdulla Jan village was left untreated for comparison. The average number of mosquitoes collected from different catching stations in the various experiments have been shown in separate graphs for different experiments (Graphs 1 to 3).

EFFECT OF DDT RESIDUAL SPRAY ON INFECTION RATES OF MOSQUITOES.

Specimens of *A. superpictus*, the principal vector species in Quetta, collected from the various villages were dissected for their gland infection and the infection rates recorded separately for each village. The result of dissections during each

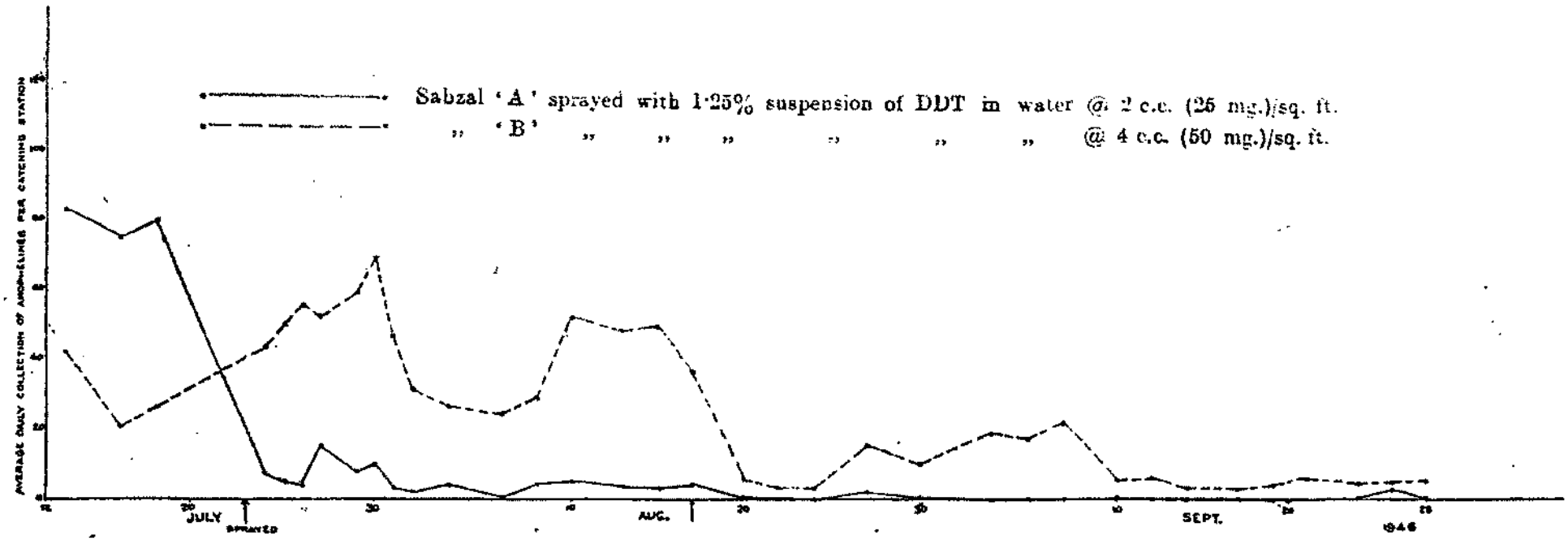
GRAPH 2.

RAZAB.



GRAPH 3.

SABZAL.



Page - 187

week from these villages are recorded in Table I. An analysis of this table shows that in the untreated village infected specimens prevailed from the week ending August 3 to that ending August 31, 1946. In the village treated with kerosene solutions no infected specimens were found but the number collected and available for dissections was rather small.

Despite the large number of mosquitoes dissected from the village treated with emulsions in very small dosage of DDT per square foot (25 mg. DDT per square foot), only one infected mosquito was encountered in the week ending August 17, 1946. This showed that small dosage, though not enough to give a 100 per cent reduction in mosquito prevalence, is sufficient to produce appreciable reduction in infection rate among the mosquitoes present.

In the part of the village treated outdoors only with DDT suspension, the rates of infection prevailing were rather high, in fact, even higher than in the untreated village, but in the portion treated indoors no infected mosquito was found. At first sight, it seemed very strange that the village treated with DDT, even though it was done only outdoors, showed a higher infection rate among the mosquitoes than that found in the untreated village (Abdulla Jan). Looking for an explanation, it seems possible that another untreated village which was only about two furlongs from village Sabzal Khan was probably the main source of infected mosquitoes. This untreated village was over half a mile distant from the untreated village which was being used for comparison.

SUMMARY AND CONCLUSIONS.

The method of preparing a 20 per cent DDT suspension is described.

Experiments with indoor spraying of DDT-kerosene solution, DDT-toluene-turpentine emulsion, DDT-turpentine emulsion and DDT suspension as an indoor spray are described. Against the species of Anopheles prevailing in Baluchistan kerosene solution sprayed at the rate of 50 mg. per square foot proved effective as an indoor spray for nearly 10 weeks (the duration of the experiment), although 1 c.c. spray over one square foot of surface could not have given good uniform coverage.

Emulsions and suspensions sprayed at the rate of 25 mg. per square foot brought the mosquitoes down to very small numbers, but in order to get a more effective control a dosage of 50 mg. would be preferable.

Outdoor spraying of DDT at the rate of 50 mg. per square foot did not appear to have any effect on the mosquitoes. A second application, however, did help to bring the number of mosquitoes down, but it is not possible to say whether or not this was due to the cumulative effect of DDT.

An analysis of the infection rate among mosquitoes collected from various villages treated with DDT emulsions and suspensions at the rate of only 25 mg. of DDT per square foot shows that although such a small dosage is not enough to produce a 100 per cent reduction in the number of mosquitoes prevalent in houses, yet it does appreciably bring down the infection rate among the mosquitoes present.

REFERENCES.

PURI, I. M., and KRISHNASWAMI, A. K. (1947). Studies on some insecticides against anopheline adults and larvæ. Part II. DDT as residual and space spray. *Ind. J. Mal.*, **1**, 1, pp. 159–181.

PURI, I. M., and RAJINDAR PAL (1947). Studies on some insecticides against anopheline adults and larvæ. Part I. Preliminary experiments at Delhi with DDT. *Ibid.*, **1**, 1, pp. 133–158.

TABLE I.

Results of dissections of anopheline mosquitoes collected from various villages.

	ABDULLA JAN.			VILLAGE SHADI KHAN.			VILLAGE RAZAB KHAN.			VILLAGE SABZAL.		
	UNTREATED VILLAGE.			TREATED WITH 5 PER CENT DDT IN KEROSENE OIL.			TREATED WITH ARMY AND TURPENTINE EMULSIONS.			TREATED WITH SUSPENSION.		
	Number dissected.	Number with gland infection.	Per cent.	Number dissected.	Number with gland infection.	Per cent.	Number dissected.	Number with gland infection.	Per cent.	Number dissected.	Number with gland infection.	Per cent.
July 10 to 19 ...	33	0	0	52	0	0	41	0	0	72	0	0
Week ending :—				→			→			→		
July 27 ...	7	0	0	11	0	0	0	0	0	35	0	0
Aug. 3 ...	177	2	1·1	4	0	0	125	0	0	109	0	0
„ 10 ...	204	1	0·5	0	0	0	143	0	0	79	1	1·3
„ 17 ...	168	1	0·6	0	0	0	219	1	0·5	177	3	1·7
							→			→		
„ 24 ...	97	1	1·0	6	0	0	23	0	0	21	1	4·8
„ 31 ...	124	2	1·6	6	0	0	14	0	0	34	0	0
Sept. 7 ...	93	0	0	3	0	0	30	0	0	50	1	2·0
„ 14 ...	195	0	0	6	0	0	13	0	0	24	0	0
„ 21 ...	138	0	0	2	0	0	5	0	0	18	0	0
„ 28 ...	109	0	0	...	...	...	13	0	0	15	0	8

→ indicates treatment with DDT.

All the infected mosquitoes in Sabzal village were found in the part of village treated outdoor.

Indian Journal of Malariology, 1, 1, March 1947.

STUDIES ON SOME INSECTICIDES AGAINST ANOPHELINE ADULTS AND LARVÆ.

Part IV.

EXPERIMENTS WITH DDT AND 666 AS RESIDUAL SPRAY IN SOME VILLAGES AROUND DELHI IN 1946.*

BY

I. M. PURI, M.Sc. (Punj.), Ph.D. (Cantab.),

AND

A. K. KRISHNASWAMI, M.B., B.S.

(*Malaria Institute of India, Delhi.*)

[January 16, 1947.]

A NUMBER of experiments on the residual toxicity of DDT solutions and emulsions were carried out during the mosquito season in 1945 in the villages around Delhi and in the Himalayan foothills of Bengal. These have been described in Parts I and II of this series. In most of the experiments with indoor residual sprays, a fairly large dosage of DDT (200 mg. per sq. ft.) was used. In most experiments with such large doses the number of mosquitoes remained appreciably low for long periods, but the cost involved was fairly high. In order to cut down the cost and also to ascertain the minimum dosage of DDT required to produce the optimum residual effect, field experiments were organized simultaneously in the villages around Delhi and Quetta (Baluchistan) during 1946.

* Most of the work was financed by the Indian Research Fund Association under the Insecticide and Mosquito Repellent Enquiry.

The Quetta experiments have already been described in Part III of this series, while those conducted at Delhi form the subject of this paper.

As a result of the intensive search for synthetic insecticides by various manufacturers another powerful insecticide, called gammexane (benzene hexachloride or 666), has been placed on the market. Opinions expressed as to its toxicity to insects, particularly mosquitoes, have been very diverse. With a view to ascertain its efficacy against mosquitoes as compared with DDT, a number of comparative field experiments were carried out with various preparations of this insecticide.

DDT.

Methods of preparing solutions and some emulsions were described in Part I (Puri and Rajindar Pal, 1947). Since emulsions prepared with turpentine as a solvent are very expensive, others were prepared with MKE (medium kerosene extract). A formula for the preparation of a stable emulsion concentrate, using MKE as a solvent for DDT, was suggested by the Assam Oil Co., Digboi, Assam, with phenol and potassium hydroxide as the emulsifiers. A very stable emulsion concentrate containing 28 per cent DDT can be prepared with this formula, but as phenol was in short supply it was not used in the experiments here described.

A miscible solution of DDT in MKE was prepared by using oleo-rosin liquid soap* as the emulsifier. This solution contains 33 per cent DDT and can be diluted with water without vigorous shaking, giving a very stable emulsion. The miscible solution can be prepared as follows :—

Thirty parts by weight of DDT is dissolved in 50 parts by volume of hot MKE, and 10 parts (by weight) of oleo-rosin emulsifier added to the solution. The concentrate thus prepared is turbid and clears on the addition of 5 parts by volume of turpentine which brings the final concentration of DDT to 33 per cent. If there is any moisture in the ingredients clarification may not be complete and the concentrate is then liable to break up into two layers. This is not however a particular disadvantage as the concentrate mixes again on shaking and emulsifies with water without much difficulty.

Various suspensions of DDT in water were tried. Except for a commercial wettable powder containing 50 per cent DDT, the others were prepared in the laboratory by wet grinding of DDT by means of a stone pestle and mortar. The details of the method of preparation have already been described by Puri (1947). In the experiments carried out in September 1946, a 20 per cent DDT concentrated suspension was used. This contained as much as 10 per cent gum acacia, and was the suspension tried at Quetta (Puri and Bhatia, 1947). In

---

* The formula for the preparation of a 33 per cent DDT miscible solution and for the oleo-rosin emulsifier was developed by Dr. S. Siddiqi, Assistant Director, Industrial and Scientific Research Laboratories, Delhi. The unstinted help given by him and his staff, particularly Dr. K. Chakrawarti, is gratefully acknowledged.

later experiments, the quantity of gum acacia was much reduced and concentrated suspensions were prepared according to the following formulæ* :—

(1)	DDT	605	parts.
	Gum acacia	25	,,
	Water	470	,,
(2)	DDT	605	parts.
	Gelatine	5	,,
	Gum acacia	10	,,
	Water	480	,,

The concentrated suspension can be very easily diluted to any required strength at the time of spraying. While being sprayed the suspension should be kept constantly agitated, so as to prevent the DDT particles from settling down to the bottom.

GAMMEXANE (benzene hexachloride or 666).

This insecticide is supplied by the manufacturers in various forms, differing mainly in the percentage of the gamma isomer (the main active principle of 666) contained in them. Only two preparations of gammexane were available for these experiments, gammexane D939 and gammexane LG140. The former is in the form of a so-called deodorized powder, containing 13 per cent of gamma isomer, while the latter is a solution containing 10 per cent of the active principle. Gammexane D939 has very low solubility in kerosene, 3·8 gm. being soluble in 100 c.c. of 3rd grade kerosene at 35°C. and 4·8 gm. at 45°C. As preliminary experiments with 3 to 4 per cent solution of this powder in kerosene gave very poor reduction in mosquito prevalence and no residual effect, no field experiments were conducted with solutions containing such a low percentage of gamma isomer. Field experiments were therefore carried out with stronger solutions, containing 0·5 per cent and 1 per cent gamma isomer, prepared by diluting the 10 per cent concentrated solution, gammexane LG140, with kerosene.

Suspensions of gammexane D939 in water were also tried, prepared by the same method as employed for the preparation of suspensions of DDT powder. As gammexane is a much finer powder than the commercial DDT, it was comparatively easier to prepare suspensions of the former.

TECHNIQUE OF EXPERIMENTS.

The mode of application of DDT and gammexane solutions, emulsions and suspensions was the same as described already in Parts I to III of this series. In

---

* Besides the above two formulæ, the following formula has also been utilized for making concentrated DDT suspension :—

DDT	605	parts.
Gelatine	10	,,
Water	485	,,

all the experiments, DDT preparations were applied on the whole of the walls and ceilings of the rooms and sheds. The discharge rate of the various nozzles fitted to the stirrup pumps was about 16 oz. per minute.

Seven villages around Delhi were selected and each divided into 3 to 4 convenient parts for differential treatment with the various preparations of the two insecticides. In most cases one part in each village was left untreated for comparison. Catching stations of different types, some cattlesheds and some dwelling houses were selected, at least two in each section of the village under different treatments. Mosquitoes were collected from the catching stations twice a week, between 8 a.m. and 11 a.m. by the same insect collector. The routine followed was to make hand collections for half an hour after which the catching station was closed and sprayed with 0·02 per cent pyrethrins in kerosene. Mosquitoes knocked-down by the spray were collected from the floor previously covered with a white sheet in an attempt to determine the total mosquito population of each catching station.

The following experiments were carried out in the different villages with the various preparations :—

Experiment I.

Okhla Village.—In this village two groups (A and B) of four houses each were selected. Three houses in group A (1,814 sq. ft.) were sprayed on August 20, 1946, with 1·25 per cent DDT-turpentine emulsion at the rate of 2 c.c. (25 mg. DDT) per sq. ft., while in group B (2,240 sq. ft.) three houses were sprayed with 1·25 per cent DDT-turpentine-toluene emulsion at the same rate. The fourth house in each group was left untreated for comparison. The results of observations on the prevalence of mosquitoes in the treated and untreated houses have been shown in Graph 1, while the collection of mosquitoes—*culicifacies* and all anophelines separately—are given in Table I. In the group of houses treated with DDT-turpentine emulsion, the prevalence of mosquitoes was reduced on the second day to about 7 per cent of the original number (from 122 to 16·6 per man-hour catch). This number rose to about 25 per cent on the 12th (32·3 per man-hour catch) and 55 per cent (68 per man-hour catch) on the 19th day of spraying. In B group treated with DDT-turpentine-toluene emulsion, there was nearly a 100 per cent reduction (from 108·6 to 2 per man-hour catch) on the second day, the number of mosquitoes rising to 20 per cent of the original number (6·6 per man-hour catch) on the 12th day, to 23 per cent (14·6 per man-hour catch) on the 15th day and to 30 per cent (17·3 per man-hour catch) on the 19th day. Thirty days after the first treatment the houses in both the groups were re-sprayed as before. In the group treated with DDT-turpentine emulsion, the prevalence of mosquitoes remained between 6 and 22 per cent (56 to 32 per man-hour catch) for about 38 days, except on the 35th day after treatment when the number went up to 42 per cent of the original number (39·3 per man-hour). In the other group, the number ranged between zero and 37 per cent (2·32 per man-hour), till the end of the experiment (38 days).

Experiment II.

Jogibai Village, containing about 50 houses, was divided into three parts. All the houses in one part (5,156 sq. ft.) were sprayed with 2·5 per cent DDT suspension (prepared with 10 per cent gum acacia) at the rate of 2 c.c. (50 mg. DDT) per sq. ft. The houses in the second part were sprayed with 2·5 per cent DDT-turpentine-toluene emulsion at the same rate and the third part was left untreated for comparison. Mosquitoes were collected twice a week from two selected catching stations in each of the sections of the village. The results of these collections are shown in Graph 2, while the catch per man-hour for all anophelines and for *culicifacies* separately are shown in Table II. In both the treated sections of the village the number of mosquitoes in the houses remained very low practically throughout the period of observation, lasting for about 80 days, the number in the houses sprayed with suspension being generally lower than in those sprayed with emulsion.

Experiment III.

Juliana Village, containing about 150 houses, was divided into three parts. Two of these (21,370 and 16,290 sq. ft. respectively) were sprayed exactly as in experiment II, but at the rate of only 25 mg. DDT per sq. ft. applying 2 c.c. of 1·25 per cent spray. The third portion of the village was left untreated for comparison. Up to about 30 days after spraying, the number of mosquitoes remained low (about 10 per man-hour) in the sections treated, after which the figure began to rise gradually. The residual effect appeared to go off more quickly in the case of those treated with suspension than those with emulsion. Fifty days after the first treatment, the two sections were re-sprayed. As, however, the mosquito season was coming to an end (October 30, 1916) the dose was halved to 12·5 mg. DDT per sq. ft. At the same time the section treated with suspension was further divided into two parts, one being treated with DDT-gum acacia suspension and the other with DDT-gelatine suspension. The number of mosquitoes in all the treated areas continued to remain below 12 per cent of the original number (8 to 9 per man-hour) for about 4 weeks after treatment, when the experiment was discontinued due to the low prevalence of mosquitoes, even in the comparison catching stations. Observations on the number of mosquitoes present in treated and untreated catching stations are recorded in Graph 3 and Table III.

Experiment IV.

Silampur Village.—In this village, containing about 200 houses, the comparative residual effect of three different types of DDT miscible solutions, turpentine-toluene-dry soap, turpentine-oleo-rosin soap and medium kerosene extract-oleo-rosin soap, was studied. The village was divided into four separate sections. Three of these were treated with the three emulsions (45,877 sq. ft. with turpentine-toluene emulsion, 21,836 sq. ft. with turpentine-oleo-rosin soap emulsion and 41,418 sq. ft. with MKE-oleo-rosin soap emulsion), the fourth section being left untreated for comparison. All the emulsions were diluted to contain 1·25 per

cent DDT and were sprayed at the rate of 2 c.c. (25 mg. DDT) per sq. ft. The average total collections of mosquitoes, made twice a week from two selected catching stations in each of these four sections of the village, are shown in Graph 4 and the catch per man-hour in Table IV. The reduction (95–100 per cent) in the number of mosquitoes was appreciable in all the treated sections (0–4 per man-hour), but the maximum reduction was with turpentine-toluene emulsion and the minimum with turpentine-rosin soap emulsion. In the houses treated with the latter emulsion, the number of mosquitoes began to increase gradually one week after spraying from 13·5 per cent of the original level on the 8th day to 76·5 per cent on the 23rd (from 10 per man-hour to 60). This area was therefore re-sprayed with the same emulsion and at the same rate at the end of this period. The prevalence of mosquitoes came down to almost nil on the day following the second treatment, and remained between 2 and 45 per cent of the original number (1 to 10 per man-hour, except on one day when it was 30) till the end of the experiment (about 4 weeks after re-spraying). In the other two treated areas, however, the average daily collection ranged between 0 and 42 per cent of the initial number, that in the area treated with MKE-rosin soap emulsion being a little higher than in that treated with turpentine-toluene emulsion.

Experiment V.

Joorbag Village.—This small village, containing about 80 houses, was divided into three parts. All the houses in them were sprayed with the same three types of emulsion as used in experiment IV, except that they contained 2·5 per cent DDT (instead of 1·25 per cent) and DDT was applied at the rate of 50 mg. per sq. ft. of wall surface. A neighbouring village, Rampur, was left untreated for comparison. The average collections of mosquitoes from selected catching stations in these two villages have been shown in Graph 5 and the catch per man-hour in Table V. In all the three treated portions of the village (Joorbag) the prevalence of mosquitoes went down by 99·5 to 100 per cent on the day following the spraying and ranged between 0 and 12·5 per cent of the original number in all three for nearly 8 weeks, after which the experiment was discontinued. The collections from the untreated village remained more or less constant.

Experiment VI.

Wazirabad Village.—This village was divided into three separate parts; the houses in one part (26,864 sq. ft.) were sprayed with 2·5 per cent DDT-water suspension* (prepared with gum acacia) at the rate of 2 c.c. (50 mg. DDT) per

---

* The concentrated DDT suspension containing about 20 per cent DDT was prepared according to the following formula :—

DDT	...	...	...	2 lb.
Gum acacia	...	...	...	1 „
Water	...	...	...	8 „

sq. ft. The houses in the second part (41,120 sq. ft.) were sprayed at the same rate with DDT-water suspension prepared from a commercial wettable powder containing 50 per cent chalk and probably some casein soap, while the third portion of the village was left untreated for comparison. The observations on the average prevalence of mosquitoes collected from selected catching stations have been shown in Graph 6 and the catch per man-hour in Table VI. In the areas treated, the prevalence of mosquitoes went down appreciably 24 hours after treatment, and remained between 1·5 and 25 per cent of the original number throughout a period of about 60 days, after which owing to the approach of the cold weather the experiment was discontinued.

EXPERIMENT VII.

Massigarh Village.—This village was divided into two parts; the houses in one part (15,055 sq. ft.) were sprayed with a 2·5 per cent solution of DDT in III grade kerosene at the rate of 2 c.c. (50 mg. DDT) per sq. ft. Houses in the other part with a wall surface of 9,635 sq. ft. were treated at the same rate but with gammexane LG140 diluted with kerosene (1 in 20) to contain 0·5 per cent gamma isomer. In both the areas a 100 per cent reduction in the prevalence of mosquitoes was observed 24 hours after spraying. In the part treated with gammexane, mosquitoes appeared on the 4th day and their number steadily increased, reaching far above the original number on the 10th day. Twenty-two days after the first treatment, this area was re-sprayed, this time using a 1 in 10 dilution of gammexane LG140, the final spray containing 1·0 per cent gamma isomer. The day following the second treatment, the number of mosquitoes went down by practically 100 per cent and remained so for nearly 10 days, after which, however, the number began to increase steadily. Twenty days after the second treatment, when the number of mosquitoes in the houses had gone up beyond 50 per cent of the original number, this part of the village was further subdivided into two. In one of these subdivisions a 1 per cent suspension of gammexane D939 was sprayed at the rate of 2 c.c. per sq. ft. while the other was similarly treated, but using a 2 per cent suspension of the same powder. These two suspensions contained 0·13 and 0·26 per cent gamma isomer respectively. No mosquitoes were found in the houses by the end of 24 to 48 hours. The number of mosquitoes remained below 15 per cent of the original density for over three weeks, after which, owing to the approach of the cold weather, the experiment was discontinued. Whether this reduction in the number of mosquitoes was due to the application of gammexane in suspension form, to any cumulative effect of the repeated applications of gammexane or to the probable increased susceptibility of mosquitoes to insecticides at the approach of the cold weather, has yet to be determined.

In the area sprayed with DDT-kerosene solution, a complete absence of mosquitoes was observed for about 10 days, after which their number began to increase gradually, becoming fairly high on the 28th day after spraying. This area was re-sprayed as before with DDT, 32 days after the first treatment. Since then the number of mosquitoes remained at a low figure till

the end of the experiment, about 35 days after the second treatment with DDT solution.

SUMMARY AND CONCLUSIONS.

Methods of preparing 30 per cent DDT emulsion using MKE as solvent and the preparation of a 50 per cent DDT suspension concentrate in water have been described.

The comparative residual toxic effect of DDT and gammexane applied in the form of solutions, various types of emulsions and suspensions has been studied in different villages around Delhi. Various preparations were applied at the rate of 25 and 50 mg. DDT per sq. ft. The effect produced on the prevalence of mosquitoes in the specially selected catching stations has been studied both for all anophelines and for *A. culicifacies* separately. The results of total collections of mosquitoes from catching stations are recorded in the form of graphs, while the mosquito catches per man-hour in the various experiments have been separately tabulated.

The experiments show that the turpentine emulsions prepared with dry soap or with oleo-rosin soap are not so effective as those prepared with MKE or toluene-turpentine combined as solvents for DDT. The turpentine emulsions applied at the rate of 25 mg. DDT per sq. ft. are effective only for about 2 weeks, but when re-sprayed at the same dosage give a better protection than after the first treatment. This may be due to the cumulative effect of the two applications of DDT. The other emulsions (MKE-oleo-rosin soap or turpentine-toluene emulsions), as well as the suspensions, however, when applied at the above rate have a much longer toxic effect extending from about 45 to 60 days.

All emulsions when sprayed at the rate of 50 mg. per sq. ft. have a strong toxic effect against anophelines in the Delhi area for a period up to about 8 weeks (*see* experiments in Joorbag and Jogabai).

Under the conditions prevailing in Delhi rural area, the residual toxic effect of DDT when applied in the form of suspensions appeared to be better than when applied in any other form, whether in solution or emulsion. DDT suspensions in water prepared by gum acacia or gelatine and gum acacia when applied at the rate of 25 mg. DDT per sq. ft. have an appreciable residual effect for about 6 weeks, and for eleven weeks when applied at the rate of 50 mg. per sq. ft. (Jogabai).

Solutions of gammexane containing 0·5 per cent and 1 per cent gamma isomer had very little residual effect against mosquitoes. Whatever effect there was lasted for not more than a week to ten days. The duration of the residual effect of gammexane D939 applied in the form of a water suspension containing 0·13 and 0·26 per cent gamma isomer was, however, quite pronounced over a prolonged period, but the experimental conditions under which this test was carried out do not permit a conclusive opinion till further investigations.

REFERENCES.

PURI, I. M. (1947) ...	The practical application of DDT for malaria control in rural and urban areas in India. *Ind. J. Mal.*, **1**, 1, pp. 211–220.
PURI, I. M., and BHATIA, M. L. (1947).	Studies on some insecticides against anopheline adults and larvæ. Part III. *Ibid.*, pp. 183–191.
PURI, I. M., and RAMNDAR PAL (1947).	Studies on some insecticides against anopheline adults and larvæ. Part I. *Ibid.*, pp. 133–155.

TABLE

OKH

Insecticide sprayed.	Concentration of DDT in spray per cent.	Dose. c.c. per sq. ft.	Dose. mg. DDT per sq. ft.	Species mosquito.	Man-hour. Before spraying.	Number of days 1	4	8	11	14	18	21	26	29	30
[illegible]-flux suspension.	1·25	2	25	An.	122·7	16·7	32	14	32·7	36	68	19·3	23·3	*	5·3
				A.c.	17·3	0·7	1·3	2	3·3	6	6·7	2·7	3·3	..	0·7
[illegible]-toluene emulsion.	1·25	2	25	An.	108·7	2·0	8·7	3·3	3·3	14·7	17·3	6·0	16·0	*	0
				A.c.	4·0	0	0	0	0·7	0·7	2·0	0·7	4·0	..	0
Control (untreated).	..	..	..	An.	172	134	122	92	70	72	78	61	42	..	64
				A.c.	19	10	17	33	28	38	13	27	7	..	8

An. = Total
A.c. = A.
* Re-sprayed

TABLE

JOGA

Insecticide sprayed.	Concentration of DDT in spray per cent.	Dose. c.c. per sq. ft.	Dose. mg. DDT per sq. ft.	Species mosquito.	Man-hour. Before spraying.	Number of days 1	6	8	10	17	21	26	34
DDT-gum acacia suspension.	2·5	2	50	An.	172	0	7	6	2	[illegible]	7	[illegible]	1
				A.c.	48	0	1	0	0	0	2	0	1
Turpentine-toluene emulsion.	2·5	2	50	An.	147	1	11	7	6	1	3	4	4
				A.c.	28	0	1	2	0	0	1	0	0
Control (untreated).	..	..	..	An.	172	175	90	69	90	..	19	29	43
				A.c.	60	66	31	12	23	..	15	11	6

An. = Total
A.c. = A.

I.

I.A.

COLLECTION.

after treatment.

36	40	48	50	53	57	60	64	67	70	74	77	81	84	88	91	95
18	26	10·7	23·3	28	18	18·7	36	32	21·3	26·7	12·7	29·3	12	6	6	2·7
7·3	4·7	2	0·3	5·3	3·3	2·7	9·3	5·3	7·3	4·7	8·7	1·3	2·7	2·0	0	0
4	4	1·3	5·3	9·3	16·7	12·7	16·7	32	27·3	6·7	8·7	6	6	4·7	1·7	5·3
0	2	0	0·7	1·3	2	0	1·3	3·3	3·3	1·3	0	0·7	1·3	0	0	0
58	53	84	60	45	60	76	70	70	60	46	31	41	70	40	66	64
25	25	41	10	6	12	26	21	16	7	5	15	12	8	7	16	6

anophelines.
culicifacies.
as before.

II.

BAI.

COLLECTION.

after treatment.

36	40	44	47	51	54	57	61	64	68	71	75	78	82	85	89
10	5	16	15	23	16	10	10	11	9	3	2	4	5	3	3
0	0	0	0	2	5	0	2	1	0	0	0	0	0	0	0
7	9	7	4	24	31	26	11	17	16	21	4	6	8	11	11
1	3	2	0	3	6	9	1	3	1	6	0	0	0	0	0
67	53	56	112	96	100	91	84	84	92	64	62	76	91	54	85
22	34	14	80	36	27	28	31	30	34	24	20	10	12	8	7

anophelines.
culicifacies.

TABLE

JULI

Insecticide sprayed.	Concentration of DDT in spray per cent.	Dose. c.c. per sq. ft.	Dose. mg. DDT per sq. ft.	Species mosquito.	Before spraying.	Man-hour Number of days 1	3	7	11	16	23	30	35
Turpentine-toluene emulsion.	1·25	2	25	An.	38	6	10	5	3	8	5	11	12
				A.c.	1	0	2	2	0	1	0	0	0
DDT-gum acacia suspension.	1·25	2	25	An.	61	0	1	3	3	11	3	6	11
				A.c.	9	0	1	0	0	0	0	0	3
Control (untreated).	..	..	..	An.	107	21	41	36	8	44	17	40	55
				A.c.	5	1	3	1	0	0	2	3	7

An. = Total
A.c. = A.
* Area re-sprayed with 1·25 per cent
* Area subdivided into two parts A
Part A sprayed with DDT-
Part B sprayed with DDT-gum

TABLE

SILAM

Insecticide sprayed.	Concentration of DDT in spray per cent.	Dose. c.c. per sq. ft.	Dose. mg. DDT per sq. ft.	Species mosquito.	Before spraying.	Man-hour Number of days 1	2	5	9	14	17	22	24
Turpentine-rosin soap emulsion.	1·25	2	25	An.	71	4	4	10	11	30	33	43	60*
				A.c.	3	2	0	1	1	0	2	0	1
Turpentine-toluene emulsion.	1·25	2	25	An.	59	0	0	0	0	6	3	9	5
				A.c.	9	0	0	0	0	1	0	0	0
MKE-rosin soap emulsion.	1·25	2	25	An.	74	2	5	10	10	15	14	17	25
				A.c.	16	0	0	0	0	1	0	0	0
Control (untreated).	..	..	..	An.	68	18	32	48	55	37	49	38	33
				A.c.	9·3	7	16	5	8	3	8	4	4

An. = Total
A.c. = A.
* Re-sprayed

III.

ANA.

COLLECTION.

after spraying.

38	42	45	49	51	53	56	60	64	67	71	74	81	84
15	6	17	8	*	8	7	2	2	3	2	3	1	1
0	3	1	0	..	0	0	0	0	0	0	0	0	0
8	9	19	15	A† An.	16	2	6	2	6	2	4	0	4
				A.c.	0	0	0	0	0	0	0	0	0
0	1	1	3	B An.	18	4	8	14	6	0	6	0	0
				A.c.	0	0	0	0	0	0	0	0	0
27	49	81	35	..	56	20	30	34	42	28	20	41	24
4	8	2	2	..	7	3	1	3	5	1	4	6	7

anophelines.
culicifacies.
turpentine-toluene emulsion at 1 c.c. (12·5 mg. DDT) per sq. ft.
and B.
gelatine suspension (1·25 per cent) at 1 c.c. (12·5 mg.)/sq. ft.
acacia suspension (1·25 per cent) at 1 c.c. (12·5 mg.)/sq. ft.

IV.

PUR.

COLLECTION.

after treatment.

26	29	33	36	38	40	43	45	47	49	51	56	58	63	65
4	10	17	30	20	10	5	27	10	6	4	4	8	4	6
0	0	0	0	0	1	0	2	0	0	0	0	0	0	0
8	10	11	8	11	4	4	20	9	3	0	8	7	5	3
0	1	0	1	1	0	0	0	0	0	0	1	0	0	0
24	26	40	21	19	20	13	16	18	5	0	5	12	14	5
0	3	0	0	0	0	0	0	0	1	0	0	0	1	1
53	63	58	47	33	30	22	74	54	34	50	23	56	41	62
2	6	8	2	2	1	1	6	2	4	1	2	4	4	0

anophelines.
culicifacies.
as before.

TABLE

JOOR

Insecticide sprayed.	Concentration of DDT in spray per cent.	Dose. c.c. per sq. ft.	Dose. mg. DDT per sq. ft.	Species mosquito.	Man-hour. Before spraying.	Number of days 1	2	8	11	13	15	18
Turpentine-[illegible] emulsion.	2·5	2	50	An.	98	1	1	0	0	0	0	1
				A.c.	16	0	0	0	0	0	0	0
Turpentine-[illegible] emulsion.	2·5	2	50	An.	114	0	0	0	0	0	1	1
				A.c.	15	0	0	0	0	0	0	0
MKE-[illegible] suspension.	2·5	2	50	An.	190	0	1	1	3	1	0	6
				A.c.	20	0	1	0	1	0	0	0
Control (untreated).	..	..	..	An.	120	47	82	27	40	76	58	85
				A.c.	4	2	14	1	1	5	4	2

An. = Total
A.c. = *A.*

TABLE

WAZIRA

Insecticide sprayed.	Concentration of DDT in spray per cent.	Dose. c.c. per sq. ft.	Dose. mg. DDT per sq. ft.	Species mosquito.	Man-hour. Before spraying.	Number of days 1	5	12	15	18	21	23
DDT-gum acacia suspension.	2·5	2	50	An.	91	2	5	0	4	2	3	3
				Ac.	33	0	2	0	4	0	0	0
DDT-commercial suspension.	2·5	2	50	An.	150	2	7	1	6	3	3	5
				Ac.	14	0	0	0	2	1	1	0
Control (untreated).	..	..	..	An.	179	80	40	36	70	28	45	60
				Ac.	17	7	18	18	34	8	11	16

An. = Total
A.c. = *A.*

V.

BAG.

COLLECTION.

after treatment.

20	24	27	29	32	34	36	38	41	43	48	50	53	55	57	60
2	1	3	1	1	1	1	7	0	2	4	1	0	3	0	0
1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
0	2	0	3	2	1	1	2	5	3	2	0	4	1	0	1
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4	6	1	7	7	5	5	7	10	12	2	4	1	1	1	1
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
98	110	77	80	43	24	21	24	33	55	38	26	35	22	28	22
7	4	1	0	5	0	0	1	3	4	2	0	4	1	1	0

anophelines.
culicifacies.

VI.

BAD.

COLLECTION.

after treatment.

25	30	32	35	37	40	42	44	46	49	53	56	58	60	63	65
3	9	6	16	9	3	0	4	3	4	2	2	1	2	0	1
0	1	3	2	5	0	0	1	0	1	0	0	1	1	0	0
5	7	3	11	8	2	6	2	5	5	1	0	1	1	2	1
0	0	0	2	1	0	0	1	0	1	0	0	0	1	1	0
70	103	95	83	47	56	70	49	33	36	16	52	15	4	12	11
18	18	13	8	15	10	0	8	5	3	1	16	0	1	2	2

anophelines.
culicifacies.

TABLE

MASSI

Insecticide sprayed.	Concentration of DDT in spray per cent.	Dose.		Species mosquito.	Before spraying.	Man-hour							
		c.c. per sq. ft.	mg. DDT per sq. ft.			Number of days							
						1	4	10	13	17	29	22	25
DDT in kerosene	2·5	2	50	An.	43	0	0	0	14	1	5	..	10
				A.c.	11	0	0	0	3	0	2	..	5
666 in kerosene	†	2	..	An.	25	0	1	8	6	5	37	‡	0
				Ac.	8	0	0	1	1	1	15	..	0
Control (untreated).	..	..	..	An.	36	8	44	17	40	55	27	..	49
				Ac.	1	0	6	2	3	7	4	..	8

An. = Total
A.c. = A.
* Re-sprayed as
† 0·5 per cent
‡ Re-sprayed 1·0
§ Area subdivided
Part A sprayed
Part B sprayed

VII.

GARH.

COLLECTION.

after spraying.

28	32	35	39	42	43		45	49	53	66	60	63	67	70	73
16	15*	3	5	10	..		0	2	7	2	0	1	5	0	4
3	0	0	0	4	..		0	0	1	1	0	0	1	0	1
0	1	8	11	21	A	An.	0	4	6	6	4	0	12	0	4
						Ac.	0	0	0	2	0	0	0	0	2
9	0	1	3	2	§ B	An.	0	8	12	6	10	16	8	4	6
						Ac.	0	6	0	2	4	2	6	0	0
81	35	56	20	30	..		34	42	28	20	14	41	24	34	23
2	2	7	3	1	..		3	5	1	4	0	6	7	3	1

anophelines.
culicifacies.
before.
solution of 666 (LG140) in kerosene.
per cent of 666 (LG140) in kerosene at 2 c.c. per sq. ft.
into two parts A and B.
with 1 per cent 666-gelatine-gum acacia suspension at 2 c.c./sq. ft.
with 2 per cent 666-gelatine-gum acacia suspension at 2 c.c./sq. ft.

Indian Journal of Malariology, 1, 1, March 1947.

THE PRACTICAL APPLICATION OF DDT FOR MALARIA CONTROL IN RURAL AND URBAN AREAS IN INDIA.

BY

I. M. PURI, M.Sc. (Punj.), Ph.D. (Cantab.).
(*Assistant Director, Malaria Institute of India.*)

[December 24, 1946.]

DDT (dichlor-diphenyl-trichloroethane) is an exceedingly powerful contact insecticide, comparing very favourably with pyrethrum sprays. Although, when used for spray-killing of mosquitoes it has no knock-down effect, yet it has been observed that if regularly used its action helps to bring down appreciably the infection rate among the mosquitoes in the same way as sprays containing pyrethrum extracts. The property of DDT which has proved most important in the control of mosquitoes and other noxious insects, is its residual toxicity to those which come to rest on surfaces on which it has been applied. It is a slow-acting insecticide and has no apparent immediate action on the mosquito coming into contact with it. If, however, the insect has been exposed to the minimum lethal dose, it will die in four to six hours. The mosquito can acquire this minimum lethal dose merely by resting for a sufficiently long period on a surface on which DDT has been sprayed. The length of contact necessary to produce the lethal effect varies directly with the period which has elapsed since the time of application, and up to a certain limit inversely with the amount of DDT deposited on the surface. The results of experiments carried out in different parts of India and in other countries show that the duration of the residual toxicity of DDT sprayed on a given surface varies in different localities, the effective periods recorded varying from eight to ten weeks up to four or five months, or even longer. There is evidence that DDT deposits lose their toxicity rapidly when subjected to continuous high temperature,* but experiments at Delhi have shown that the high temperature and the extreme variations in it and in atmospheric humidity met with during April and May and again from August to October, have no appreciable effect on the duration of the residual toxicity. As the acquisition of the lethal dose of the insecticide depends on the length of contact, the effectiveness of

* It has been observed that DDT applied to the metal surface of an aircraft loses nearly 50 per cent toxicity if the machine is left in the tropical sun even for two or three days.

the residual toxicity in any area is naturally influenced by the resting habits of the mosquito.

A dosage of DDT varying between 25 and 200 mg. per square foot has been recommended by different workers. There is no doubt that the quantity sprayed tends to influence the length of the residual effect, but the latter is not prolonged proportionately. Experiments have shown (Puri and Krishnaswami, 1947) that for indoor spraying a dosage of 50 mg. of DDT per square foot will keep down the number of mosquitoes appreciably for over eight weeks, and if properly sprayed on the walls, one, or possibly two, applications at this dosage are enough for a short malaria season of three to four months. In some localities, a dosage of only 25 mg. per square foot has sufficed to produce a residual toxic effect for over six weeks. It may be mentioned that if only the walls and ceilings of occupied houses are treated, a number of safe resting places are provided for the mosquitoes by clothing, saddlery, untreated furniture, freshly spun cobwebs, etc., in the rooms. This will naturally tend to counteract the residual effect of the DDT deposits in the houses. When applying DDT, all possible surfaces should be thoroughly and carefully sprayed, even though such treatment considerably prolongs the actual spraying time.

COMPOSITION OF DDT SPRAYS.

DDT may be applied in the form of a solution, emulsion or suspension. Although DDT-kerosene oil solution has proved satisfactory, the pronounced smell which lingers for two or more days after treatment and the temporary hazard of fire, especially in bamboo and thatched huts in rural areas, are both serious disadvantages. For these and other reasons, the superiority of emulsions and suspensions over solutions is now widely recognized, and has already been admitted by many workers. By some (Gahan *et al.*, 1945), the first two are considered even more efficacious than the last.

In order to produce a deposit not exceeding 50 mg. of DDT per square foot on a wall surface, the quantity of a 5 per cent solution, emulsion or suspension must be limited to 1 c.c. With the apparatus at our disposal (stirrup pumps), even when the output from the nozzle is reduced to 450 c.c. per minute, it is not possible to spray 1 c.c. of the fluid over one square foot and cover the whole of the area uniformly. If this is attempted, the distribution is very patchy, and although it may give some degree of malaria control, this may be comparatively very poor. A good uniform coverage is obtainable by applying at the rate of at least 2 c.c. per square foot when the output from the nozzle is about 450 c.c. per minute (the stirrup pump working at 30 to 60 lbs. air pressure per square inch). Unpainted wood, mud-plaster or ordinary plastered walls and most other wall surfaces usually found in rural areas in India are able to retain 4 c.c. of spray per square foot, without any appreciable run-off, while glossy painted surfaces and impervious wall surfaces will take on only about 2 c.c. per square foot. In order to apply these quantities satisfactorily and at the rate of only 50 mg. of DDT per square foot, the spray has to be diluted to 1·25 per cent or 2·5 per cent respectively. This dilution of the emulsion or suspension is very simple, as one has only to add an additional quantity of water, but with oil solutions any further dilution will increase the cost of the spray and the hazard of fire as well. Moreover, when oil solutions are

applied to an absorbent surface, part of the solution is bound to penetrate into the substratum, carrying with it the portion of DDT contained in it. This fraction will be completely innocuous so far as the mosquitoes are concerned. In order to deposit 50 mg. of DDT on the surface, it will be necessary to spray more than 1 c.c. of a 5 per cent solution per square foot. On the other hand, when suspensions and emulsions are used, only the vehicle is absorbed, while practically the whole of the DDT remains on the surface, more so in the case of suspensions than that of emulsions. Absorption of DDT solution by the porous substratum can, however, be obviated to some extent by spraying plain water on the wall before an oil solution is applied.

The main objection against the use of emulsions and suspensions is that they leave whitish marks on the surface sprayed. This disadvantage, however, is not a serious drawback when using them in rural areas in India. In urban areas where people are more fastidious, it is suggested that the polished front surface of the furniture should be wiped soon after spraying. This will be found easier in the case of suspensions than when emulsions are used.

PREPARATION OF SPRAYS.

Various methods for the preparation of emulsions have already been described (Puri and Rajindar Pal, 1947). A number of dusts suitable for making suspensions, presumably prepared with purified micronized DDT and some wetting agent, are now available in the market. One of these containing 50 per cent DDT and 50 per cent chalk or other inert powder has been subjected to a number of tests at the Malaria Institute of India.* Although it makes very good suspension in water, the white marking on furniture and dark surfaces after spraying is very pronounced.

A number of methods for the preparation of suspensions have been tried at the Malaria Institute of India, with a view to eliminate the chalk or any other white diluent in the wettable DDT concentrate. If micronized pure DDT were available, the preparation of suspensions would be very easy, as the DDT powder has then only to be treated so as to render it wettable. Micronized DDT, however, is not available in this country, and even if it were, it would be very expensive. The commercial DDT obtainable in India at the present time is extremely coarse, and has to be thoroughly ground to render the particles small enough to disperse uniformly in water. The difficulty of dry grinding of DDT has been generally recognized. Consequently, wet grinding of the coarse DDT available was tried in the presence of a wetting agent which would also facilitate grinding. Among the various adjuvants used were gum acacia, mucilage of vegetable origin, glue, gelatine (of animal origin), sodium silicate, soap powder, rosin soap and sulphonated castor oil (Turkey red oil). Of these, gum acacia and gelatine were found to be the most effective, and with their help a paste containing 55 to 60 per cent DDT can be easily prepared. For the preparation of this concentrate, no elaborate apparatus is necessary and ½ lb. of DDT may be ground into a thin paste in half an

* On a small scale, a wettable powder containing about 95 per cent DDT is also being manufactured in America, but its probable cost per pound is not yet known, nor whether it can be made available in large enough quantities.

hour in an ordinary stone mortar (diameter 10 inches × depth 5 inches) with a stone pestle. On a large scale the paste may be prepared in a steel ball mill or a heavy edge runner. The ingredients necessary for the preparation of these suspensions are readily available in any bazaar in India. The quantities needed are comparatively small, and their cost as compared to that of materials for the application of DDT in other ways almost negligible. The three alternative formulæ which were found to yield the best results are given as follows, in order of merit :—

(1) DDT 605 gm., gelatine 10 gm., water 485 c.c.
(2) DDT 605 gm., gelatine 5 gm., gum acacia 10 gm., water 480 c.c.
(3) DDT 605 gm., gum acacia 25 gm., water 470 c.c.

Dissolve the gelatine and/or powdered gum acacia in hot water. Allow the solution to cool. Pour it into the stone mortar or steel ball mill and add to it DDT powder. Grind the whole into a fine homogeneous paste. In a mortar 10 × 5 inches it takes about half an hour to grind half a pound of DDT. With a steel ball mill, electrically driven, very much larger quantities may be ground in a short time. This paste, if there has not been much evaporation during the grinding process, will contain 55 per cent DDT. It can easily be diluted with water before use. To obtain a 2·5 per cent spray, one part is diluted to 22, while to make a weaker suspension the amount of water should be proportionately increased. At the time of spraying, the suspension should be stirred occasionally with a stick to prevent the particles from settling.

EQUIPMENT FOR APPLICATION.

Field experiments in both rural and urban areas have conclusively shown that a stirrup pump is the most satisfactory and economical apparatus for applying DDT as an indoor residual spray under Indian conditions. Although it is a two-man unit, it is very mobile and less fatiguing to use than knapsack sprayers. The stirrup pump should be fitted with a light lance about 4 feet long having a cut-off valve at one end and a single or double fine whirl-type spraying nozzle at the other. The nozzles should have an orifice of 1/24 to 1/48 inch, giving an output of about 20 oz. per minute per nozzle when working at a pressure of 40 to 50 lbs. per square inch. When kept 18 to 24 inches from the wall the spray swath is about 4 feet wide with a single nozzle and about 7 when double nozzle* is being used. It is advisable to pass the spray through muslin, so as to remove any extraneous matter which would otherwise block the nozzle. In addition, a strainer should be fitted at the lower end of the lance.

Stirrup pumps made with such a nozzle can develop a pressure of about 75 to 80 lbs. In order to avoid any hose bursts due to such high pressure, a relief valve should be fitted to the pump, so that the rubber hose is not under any circumstances subjected to any pressure higher than about 55 lbs. per square inch. A stirrup pump with a pressure relief valve incorporated in it has been so designed that while it is being operated the suspension is kept constantly agitated. Such a pump has been found very satisfactory. For large scale operations such a pump

* When a double nozzle is being used, the two nozzles should be so adjusted that the inner edges of the spray swathes of the two nozzles just meet about 24 inches from the nozzles.

fitted to a large container (30 gallons) and whole assembly mounted on a trolley will be very useful and will save a great deal of time and labour.

COST OF MATERIAL.

The comparative cost of various types of formulations for preparing one ton of DDT ready for use by different methods has been given in the Table. As the aim is to apply 25 to 50 mg. of DDT per one square foot, it is necessary to prepare a 1·25 or 2·5 per cent spray. Consequently, the quantity of kerosene has been calculated for a 2·5 per cent solution. The price of DDT has been calculated at Rs. 37/8/- per 10 lbs. of technically pure commercial DDT.

TABLE.

Showing comparative cost of different formulations.

	Ingredients.	Quantity.	Cost of ingredients.	Total cost.
			Rs. As. P.	Rs. As. P.
		Solutions		
1. Kerosene-DDT.	DDT ...	One ton (2,240 lbs.)	8,400 0 0	
	Kerosene ...	8,960 gals.	9,520 0 0	17,920 0 0
		Emulsions		
2. Turpentine-toluene emulsion.	DDT ...	2,240 lbs.	8,400 0 0	
	Toluene ...	3,497 „	1,049 2 0	
	Turpentine ...	3,406·6 „	980 0 0	
	Alcohol ...	484 „	60 8 0	
	Dry soap ...	250·9 „	225 13 0	10,715 7 0
3. Turpentine-dry soap (20% emulsion).	DDT ...	2,240 lbs.	8,400 0 0	
	Turpentine ...	9,732 „	2,798 0 0	
	Dry soap ...	247·3 „	222 8 0	11,420 8 0
4. M.K.E.-dry soap	DDT ...	2,240 lbs.	8,400 0 0	
	M.K.E.* ...	9,367 „	1,170 14 0	
	Soap ...	326 „	293 8 0	9,864 6 0

* M.K.E. = Medium kerosene extract.

TABLE—*concld.*

	Ingredients.		Quantity.	Cost of ingredients.	Total cost.
				Rs. A. P.	Rs. A. P.
5. Turpentine-rosin soap (20 per cent concentrated).	DDT	...	2,240 lbs.	8,400 0 0	
	Turpentine	...	8,736 „	2,512 10 0	
	Rosin soap	...	1,120 „	1,120 0 0	12,032 10 0
6. M.K.E.-rosin soap (33 per cent concentrated).	DDT	...	2,240 lbs.	8,400 0 0	
	M.K.E.	...	3,733 „	466 10 0	
	Rosin soap	...	746·7 „	746 12 0	
	Turpentine	...	373·4 „	107 8 0	9,720 14 0
			Suspensions		
1. Acacia-DDT ...	DDT	...	2,240 lbs.	8,400 0 0	
	Gum acacia	...	75 „	56 4 0	8,456 4 0
2. Gelatine-DDT ...	DDT	...	2,240 lbs.	8,400 0 0	
	Gelatine	...	37·5 „	150 0 0	8,550 0 0
3. Gelatine-acacia-DDT	DDT	...	2,240 lbs.	8,400 0 0	
	Gum acacia	...	37·5 „	28 2 0	
	Gelatine	...	18·8 „	75 4 0	8,503 6 0
4. Commercial DDT (50 per cent) wettable powder at about 3/12/- per lb. (bulk supply).	DDT and inert diluents.		4,480 lbs.	17,920 0 0	17,920 0 0

M.K.E. = Medium kerosene extract.

An analysis of this Table shows that the suspensions made with gum acacia and gelatine are the cheapest of all the other preparations. The costs given, however, do not include fabrication charges. The suspensions can be very easily prepared with an ordinary pestle and mortar or a steel ball mill and the charges are not very heavy. As these suspensions can be diluted to contain any required percentage of DDT, they are so far the most satisfactory and economical commercial preparations available.

COST OF TREATMENT.

An analysis of the various experiments carried out at Delhi and Quetta has shown that a dosage of 50 mg. of DDT per square foot, if sprayed in the form of a suspension, keeps down the density of mosquitoes very considerably for ten weeks or more. According to the very encouraging results obtained by Afridi and Bhatia (personal communication) in the control of malaria in Baluchistan, even smaller dosage of about 35 mg. of DDT per square foot or 1 c.c. of 2·5 per cent DDT spray per square foot applied twice in three months is probably sufficient to bring about a marked fall in the incidence of malaria.

Practical experience in the field and laboratory has shown that—

(1) With stirrup pumps even when fitted with a nozzle having a discharge rate of only 16 oz. per minute, it is not possible to cover one square foot of wall surface uniformly with 1 c.c. of spray fluid. When this small quantity is sprayed, practically half the surface is left untreated.*

(2) Two c.c. of 2·5 per cent DDT suspension, equivalent to 50 mg. of DDT per square foot, should give protection from malaria for about ten to twelve weeks.

(3) Nearly 10 per cent of the total amount of spray used should be considered as wasted.

If the discharge rate of a stirrup pump (a three-man unit) is 20 to 40 oz. per minute, it should take only about 4 minutes to spray 1,000 square feet of wall surface at the rate of 2 c.c. per square foot, if a single nozzle is used, or only 2 minutes if a double nozzle is fitted to the stirrup pump. In actual practice, however, a great deal of time is wasted in moving from one house to another and in shifting the bucket from place to place. This time ordinarily amounts to nearly 50 per cent of that spent in actual spraying operations, but may be much longer if the villages are scattered about.

Calculating on the above basis the following is an analysis of the expenses for indoor residual spray of 1,000 huts each of 1,000 c. ft. capacity (10 × 10 × 10 feet) or 500 square feet wall and ceiling surface, at the rate of 50 mg. per square foot, which should give protection from malaria for about ten to twelve weeks.

Cost of material.—

Total surface area to be sprayed in 1,000 huts ...	500,000 sq. ft.
DDT suspension 2·5 per cent at the rate of 2 c.c. per square foot = 1,000,000 c.c. (approx.)	219 gals.
Total quantity of this suspension after allowing 10 per cent as wastage (approx.)	240 gals.

* However, as far as malaria control is concerned it appears that even this type of application (half the wall surface left untreated) may give fairly good results.

Cost of 240 gals. of 2·5 per cent DDT suspension :—

	Rs.	AS.	P.	Rs.	AS.	P.	Rs.	AS.	P.
DDT 60 lbs. at Rs. 37/8 per 10 lbs.	225	0	0						
Gelatine 8 oz. at Rs. 4/- per lb. ...	2	0	0						
Gum arabic 16 oz. at As. -/8/- per lb.	0	8	0						
Labour (1 coolie at Re. 1/- per day) for fabrication (5 hours a day for 10 days)	10	0	0						
Total cost of material				237	8	0			

(ii) labour, transport and expert supervision.—

Six spraying units of 3 men each will take 0·77 day (of six hours) to spray 1,000 huts. Allowing for time spent in moving from room to room and from village to village, it will probably take four times the actual spraying time — or 0·77×4=3 days. One supervisor will be necessary to control labour.

Six spraying units comprising in all :

	Rs.	AS.	P.	Rs.	AS.	P.	Rs.	AS.	P.
1 supervisor at Rs. 120/- per mensem for 3 days	12	0	0						
6 superior field workers at Rs. 60/- each per mensem for 3 days ...	36	0	0						
12 field workers at Rs. 30/- per mensem for 3 days ...	36	0	0						
Total cost of labour ...				84	0	0			
Cost of transport for 3 days at Rs. 18/- per day				54	0	0			
Overhead expenses, charge on equipment* and expert supervision for 3 days at Rs. 40/- per day ...				120	0	0			
Total cost of labour, etc. ...							258	0	0
Total expenditure for one treatment of 1,000 huts of 1,000 c.ft. area ...				.....					495 8 0
Cost per hut per treatment				.....			.....		Annas 7·9

* *Equipment required*—

6 stirrup pumps fitted with fine nozzle		Rs. 318/- each.
Bucket, etc.	... ...	„ 47/-
Pestle and mortar	... ...	„ 10/-
TOTAL	...	Rs. 375/-

In a rural area with a short malaria season necessitating only a single application of DDT, the expense of malaria control with DDT residual spray works out at 7·9 annas per hut and the expenditure per capita will be about 2·0 annas calculating at the rate of 4 persons per hut. With a somewhat longer season (about 20 weeks) the second application need be of only half the dosage (25 mg.) of DDT per square foot, and the total cost for two applications under such circumstances works out at 496 + 376 = 872 = 13·95 annas per hut, the expense per capita being 3·49 annas.

Although ordinarily in urban areas 5 persons are estimated as occupying 1,000 c.ft. of ubilt up space, for purposes of DDT residual treatment calculations may be made at the same rate as in rural areas.

The lowest figure calculated by Russell, Knipe and Sitapathy (1943) for malaria control in a South Indian village by spray-killing of mosquitoes over a period of 22 weeks was annas 3 per capita. In their calculations, however, the rates charged for labour and supervision (Rs. 12/- and Rs. 25/- respectively) were less than half those charged for in calculations above. They have not included any fabrication charges for emulsion concentrates. Moreover, the figure, 3·49 annas per capita in the case of DDT residual spray suspensions, is for a more or less complete mosquito control. Expense for malaria control only (reduced infectivity rate among the mosquito population) by DDT residual spray will be much less than that for complete mosquito control as the dosage of DDT can then be greatly reduced.

SUMMARY.

1. As an indoor spray, 50 mg. of DDT per square foot is sufficient to keep the number of mosquitoes appreciably down for 10 to 12 weeks, if sprayed in the form of a suspension.

2. A 1·25 to 2·5 per cent suspension of DDT should be used at the rate of 4 to 2 c.c. respectively.

3. Three persons can spray 1,000 huts in ten days with the help of a stirrup pump fitted with a single or double nozzle, the output of which is 20 oz. or 40 oz. per minute respectively.

4. The cost of application is about 2·0 annas per capita (including cost of labour, material and expert supervision) for each round of spraying in both rural and urban areas.

5. The second application need not be made at full strength and 25 mg. of DDT per square foot will probably be found sufficient. The cost per capita for two applications under such circumstances works out to 3·49 annas per capita.

REFERENCES.

GAHAN, J. B., TRAVIS, B. V., and LINDQUIST, A. W. (1945). DDT as a residual-type spray to control disease-carrying mosquitoes: Laboratory tests. *Jl. Econ. Ent.*, **38**, 2, pp. 236–240.

GAHAN, J. B., TRAVIS, B. V., MORTAN, F. A., and LINDQUIST, A. W. (1945). DDT as a residual type treatment to control *Anopheles quadrimaculatus*. Practical tests. *Ibid.*, **38**, 2, pp. 231–235.

PURI, I. M., and KRISHNASWAMI, A. K. (1947). Studies on some insecticides against anopheline adults and larvæ. Part II. DDT as residual and space spray and as larvicide. *Ind. J. Mal.*, **1**, 1, pp. 159–181.

PURI, I. M., and RAJINDAR PAL (1947). Studies on some insecticides against anopheline adults and larvæ. Part I. Preliminary experiments at Delhi with DDT. *Ibid.*, **1**, 1, pp. 133–158.

[illegible], P. [illegible], and SHAPVEEV, N. R. (1943). Malaria control by spray-killing of adult mosquitoes. Fourth season's result. *J. Mal. Inst. Ind.*, **5**, 1, pp. 59–76.

Indian Journal of Malariology, 1, 1, March 1947.

AN ENQUIRY ON CERTAIN ASPECTS OF PALUDRINE.

BY

LIEUT.-COLONEL M. K. AFRIDI, M.C., D.T.M. & H., I.M.S.,

S. P. RAMAKRISHNAN, M.B., B.S., D.P.H.,

A. GOSWAMI, M.B., D.T.M.,

AND

M. K. MENON, M.B., B.S.

(*Malaria Institute of India, Delhi.*)

[December 28, 1946]

INTRODUCTION.

PALUDRINE, since its discovery in 1945, has been subjected to a number of tests on avian and human malaria. Recent work (Fairley, 1946; Maegraith *et al.*, 1946) has shown that it is superior in certain respects to mepacrine in the therapeutics of malaria. Apart from its low toxicity, the drug was shown to have the advantage of producing a clinical cure by a single dose therapy in a limited number of cases. It was with a view to test this possibility that this enquiry was planned, the object being to determine the optimum single dose of the drug which would effectively control the clinical symptoms of malaria.

Certain villages around Quetta, Baluchistan, were chosen due to their high endemicity and to the fact that the transmission season in this region lasts only about 12 weeks. It was expected therefore that a sufficient number of cases would become available in a short period of time. It was preferred to test the drug on cases in a village to trials in a hospital because in the former the population being a fixed one the follow up is easier than of patients attending a hospital. The first village selected for the enquiry was Kechi Beg situated 6 miles to the south of Quetta. It has a population of approximately 2,000 inhabitants, most of whom belong to the indigenous Brauhi Tribe of Baluchistan. The spleen and parasite rates determined in the first week of June 1946 were 23·6 and 1·97 per cent respectively, based on an examination of 152 children between 2 and 10 years.

TECHNIQUE.

The enquiry commenced on July 6, 1946, and continued until October 2, 1946. A one-room village hut situated centrally near the village bazaar was used as the dispensary. This was visited daily in the morning and evening for an average total period of 5 hours. Towards the end of July, however, visits on Sundays were discontinued. All patients were first examined by a medical officer of the enquiry who, after prescribing treatment for the general cases, referred cases complaining of fever to a second medical officer. The latter, after recording the temperature, prepared thick and thin blood smears from each case and stained them by the rapid staining method of Jaswant Singh and Bhattacharji (1944). The slides were examined on the spot while the patients waited and thick smears were searched for at least five minutes, before they were declared negative.

Cases with parasites in their blood were placed on one of the trial regimes, while those with no detectable parasites were given a placebo sodium salicylate mixture* and advised to attend again.

Dosage regimes.—Out of a wide range of dosage regimes for paludrine drawn up by the Medical Research Council, three were selected, whilst a fourth one used was mepacrine, for purposes of comparison. Thus the four regimes were :—

Regime A.—A single dose of one tablet of paludrine (100 mg.).

Regime B.—A single dose of three tablets of paludrine (300 mg.).

Regime C.—Two tablets of paludrine twice a day for as long as the patient attended up to a maximum of 3 days.

Regime D.—Three tablets of mepacrine daily in two doses for as long as the patient attended, up to a maximum of 3 days.

The doses mentioned above were for adults and were halved for children between 6 and 12 years of age. To those under 6 years of age, one-third of the adult dose was administered.

All malaria cases were placed on the four regimes in rotation till the last week of July. After that new patients visiting on Fridays and Saturdays were placed on regimes A and B alternately, in order to eliminate the need for supervising the dose on Sundays. This was the only way in which the staff could have a much-needed day off during the week. Patients placed on regimes C and D who missed a visit were given a double dose at the next. Every dose was administered personally by a medical officer.

On September 3, a review of the cases treated revealed that unless the procedure so far followed was modified, the data secured at the end of the

---

* Mixture sodium salicylate—

Soda bi-carb	Grains	20
Soda salicylas	,,	10
Spt. ammonium aromaticus	Minims	10
Aqua chloroform	Half ounce.	

enquiry would be insufficient for analysis. Action was accordingly taken in two directions :—

(*a*) A second treatment centre was opened in a neighbouring village called Ahmad Kanzai on September 3, 1946. The procedure for treatment and recording of cases adopted in this village was exactly the same as that followed in the original centre at Kechi Beg. The spleen and parasite rates in this village were 69·6 per cent and 4·3 per cent respectively as determined on September 12, 1946, based on the examination of 23 children between 2 and 10 years of age.

(*b*) Mepacrine treatment regime D was discontinued after September 12, 1946.

CLASSIFICATION OF CASES.

Originally, it was intended that the analysis of case sheets should be confined to those patients who paid at least 3 visits. On a closer study of the case sheets, however, it became clear that this restriction would entail the loss of much valuable information, particularly as some of the cases with incomplete records had a definite bearing on the effectiveness or otherwise of the various regimes. The incomplete case sheets could be classified as under :—

(*a*) Patients who attended only for one day. The later history of many of these cases was obtained either by visiting their homes or when they attended the dispensary for a recurrence of the malarial attack. Although all of them asserted that they were cured of the original attack such testimony was deemed insufficient to classify them as cures. They have, therefore, been omitted from all tables except Table VI.

(*b*) Patients who attended for a minimum of two days in whom—

(*i*) Fever persisted on the last day of attendance. From the clinical point of view such patients were classed as uncured, irrespective of the results of their blood examination, provided there was no other apparent cause for the fever.

(*ii*) Temperature reached normal on the last day of attendance. These represent clinical cures and have been included in Table III, but excluded from Table I, as the day on which parasites disappeared from their blood was not determined.

ANALYSIS OF CASES.

Out of a total of 563 cases placed on trial regimes, complete records regarding the day of the disappearance of fever and parasites are available in respect of 241 cases and are analysed in Table I.

Of the remainder, 224 cases attended only for one day, their distribution in the various regimes being 66 in regime A, 69 in regime B, 53 in regime C and 36 in regime D. The remaining 98 cases attended for a minimum of two days and data regarding the persistence or otherwise of pyrexia on the last day of attendance is shown in Table II.

TABLE I.

Regime.	Total cases.			First attack. Day on which temperature reached normal. 0	1	2	3	4	5	6	7	Day on which asexual parasites were not found. 0	1	2	3	4	5	6	7
A	67	M.T.	51	14	2	16	10	6	3	0	0	8	2	11	16	6	4	2	2
		B.T.	15	6	0	4	1	3	0	1	0	0	1	[illegible]	1	3	1	1	0
		Mixed	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
B	74	M.T.	51	18	1	9	11	10	0	2	0	3	1	7	25	6	3	2	1
		B.T.	19	5	0	4	6	2	2	0	0	0	0	8	8	1	1	0	0
		Q	2	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0
		Mixed	2	1	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0
C	66	M.T.	47	[illegible]	1	19	8	2	1	2	0	4	3	19	15	3	1	2	0
		B.T.	16	[illegible]	0	5	4	1	2	1	0	0	1	3	6	2	0	3	1
		Q	1	[illegible]	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
		Mixed	2	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0
D	34	M.T.	29	[illegible]	0	8	3	3	2	2	1	3	0	12	7	3	2	2	0
		B.T.	4	[illegible]	0	3	0	0	1	0	0	1	0	2	0	0	1	0	0
		Mixed	1		0	1	0	0	0	0	0	0	0	1	0	0	0	0	0

M.T. = malignant tertian. B.T. = benign tertian.

TABLE II.

Regime.	Total number of cases treated.	Number of cases in which fever persisted.	fever disappeared.
A	28	21	7
B	18	11	7
C	31	19	12
D	21	14	7

THE EFFECT OF VARIOUS REGIMES ON THE TREATMENT OF THE FIRST ATTACK.

The clinical cure of a first attack of malaria by various regimes has been calculated by adding the figures for cures within 3 days in Table I and those in whom fever disappeared on the last day of attendance in Table II. This is set out in Table III.

TABLE III.

Regime.	Number of cases treated.	Number of clinical cures of first attack.	Percentage.
A	95	74	78
B	92	81	88
C	97	78	84
D	55	41	75

The effect on asexual parasites is brought out in Table IV, which shows the percentages of cases within different regimes in whom parasites disappeared in 3 days.

TABLE IV.

Regime.	Total cases.	Number of cases in whom asexual parasites disappeared in 3 days.	Percentage.
A	67	47	70
B	74	58	79
C	66	53	80
D	34	26	76

OCCURRENCE OF SUBSEQUENT ATTACKS.

A frequency table of subsequent attacks of malaria amongst patients placed on trial treatment is set forth in Table V. The figures do not include recurrences

TABLE V.

| Regime. | Homologous infections. | | |

amongst cases on regimes C and D who at the time of the original attack attended the dispensary for less than 48 hours. In Table VI given below, the recurrences of malaria with homologous infections have been worked out on the total cases under trial.

TABLE VI.

Regime.	Total cases.	Number of cases with 2nd and 3rd attacks.	Per cent.
A	163	22	11
B	161	10	6
C	150	7	5
D	91	2	2

COMPARATIVE EFFECTS OF VARIOUS REGIMES.

Table VII summarizes the effects of various regimes on malaria cases under trial :—

TABLE VII.

Regime.	Percentage of cases in whom		
	fever disappeared in 3 days.	parasites disappeared in 3 days.	recurrences occurred.
A	63	72	14
B	71	80	6
C	71	80	5
D	58	76	2

DISCUSSION.

Bearing in mind the limitations imposed by the conditions under which this enquiry was organized it is possible to make a definite claim in two respects only :—

(*a*) That all patients placed on trial treatments were diagnosed microscopically by competent observers.

(*b*) That the drugs were actually swallowed by the patients in the dosages prescribed.

The value of our data in other respects was largely influenced by the circumstance whether or not the patients attended the dispensary regularly. For instance, the fact that fever or parasites were recorded to have disappeared after more than 3 days, does not necessarily indicate a defective or delayed response to therapy, as frequently such patients had not attended the dispensary during the interval. On the other hand, many cases are recorded as incomplete, because fever persisted on the last day of attendance. Since all of these cases attended for at least 48 hours and many of them regularly for 5 or 6 days, it is reasonable to classify such cases as indicating unfavourable response (Table II).

On the whole, the various tables presented show that from the point of view of controlling fever in three days all the paludrine regimes proved as effective as mepacrine. Nor was mepacrine in the dosages under trial more effective than paludrine in clearing the parasites from the peripheral blood. As regards recurrences, mepacrine appeared to be somewhat superior, in that a lesser percentage of patients under mepacrine reported sick with a second attack of malaria than those on paludrine. Even in this respect paludrine regimes B and C yielded results which compare well with mepacrine.

It should, however, be pointed out that malaria in Baluchistan happened to be moderate in intensity in the year of this enquiry and it is possible that the dosages utilized above might not prove effective in the treatment of severe attacks after repeated infections in epidemic years. While our data is insufficient to counter this contention, it was observed that cases responded to paludrine therapy equally rapidly in September when transmission was at its height, as in the low transmission months of July and August and that in a small number of cases with heavy infection, fever and parasites disappeared soon after the patients were placed on paludrine. The only exceptional case was that of a child aged 4 on regime C (50 mg. of paludrine twice a day for 3 days) who came in with nearly 75 per cent of the red cells parasitized with *P. falciparum* infection. In this case, the asexual parasites disappeared on the second day, but a low form of fever persisted for 12 days of observation for which there was no other obvious cause.

As regards *P. malariæ* infections, the number of cases under trial was too low to permit a proper appraisal of the effect of paludrine. Of four such cases, one under regime C showed no response up to 7 days of observation, but in the remaining three (one under regime C and two under regime B) the fever and parasites disappeared in 3 days, and the patients did not report again within the 25 days during which the dispensa[illegible]

CONCLUSIONS.

Comparison of the different paludrine regimes in the present enquiry leads us to the following conclusions :—

(*a*) The single dose treatments with 100 mg. and 300 mg. of paludrine both produce a clinical cure in a high proportion of cases, a clinical cure being defined as abatement of fever and disappearance of parasites from the peripheral blood within 3 days of the attack.

(*b*) The curative effects of the multiple dosage therapy with paludrine in regime C were not significantly superior to those observed in the single dose therapy of 300 mg. (regime B).

(*c*) Mepacrine in the dosages under trial proved in no way superior to paludrine, although in recurrences the former appeared to be somewhat superior, in that a lesser percentage of patients under this drug reported sick with a second attack of malaria than among those on paludrine. Even in this respect paludrine regimes B and C yielded results which compare well with mepacrine.

Taking into consideration the above conclusions and the great convenience of a single dose therapy, it is clear that regime B (*i.e.*, 300 mg. given as a single dose) would be the method of choice in the treatment of malarial attack under rural dispensary conditions in India where it is difficult, if not impossible, to ensure the repeated attendance of the patients. This regime is to be preferred to 100 mg. single dose therapy as it is comparatively more rapid in its curative effect and gives a greater latitude in safeguarding patients from developing pernicious symptoms particularly as in rural practice there are no facilities for assessing the severity of infections in patients attending the dispensaries. A small proportion of the cases may prove refractory, as actually happened in the trial, but such exceptions are not peculiar to paludrine therapy, as in two cases under mepacrine in the present series, fever persisted for 6 and 7 days of continuous observation respectively.

SUMMARY.

With a view to determine the optimum single dose of paludrine for the clinical cure of a malarial attack, an enquiry was undertaken in two villages, Kechi Beg and Ahmad Kanzai, four and six miles south of Quetta, Baluchistan. The enquiry began on July 6, 1946, and lasted up to October 2, 1946.

Out of a total of 563 cases placed on trial regimes of paludrine and mepacrine, complete records regarding fever and parasites are available in respect of 241 cases. Analysis of these cases and others with incomplete records show that the optimum single dose of paludrine to obtain a clinical cure of a malarial attack was 300 mg.

REFERENCES.

FAIRLEY, N. H. (1946) ... Research on paludrine (M 4888) in malaria. *Trans. Roy. Soc. Trop. Med. Hyg.*, **40**, 2, pp. 105–151.

JASWANT SINGH, and BHATTACHARJI, L. M. (1944). Rapid staining of malarial parasites by a water soluble stain. *Ind. Med. Gaz.*, **79**, 3, pp. 102–104.

MACGRAITH, B. G., *et al.* (1946) ... Paludrine in the treatment of malaria. *Brit. Med. J.*, **1**, p. 903.

Indian Journal of Malariology, 1, 2, June 1947.

A BRIEF REVIEW OF THE HISTORY AND DEVELOPMENT OF THE MORE IMPORTANT ANTIMALARIAL DRUGS*.

BY

MAJOR-GENERAL SIR GORDON COVELL, M.D., D.P.H., I.M.S.
(*Director, Malaria Institute of India.*)

[January 7, 1947.]

CINCHONA ALKALOIDS.

UNTIL a few years ago a discussion dealing with antimalarial drugs seldom took place without a reference to the story of the Countess of Chinchon, wife of a Viceroy of Peru, who was said to have been cured of a severe attack of malaria by a decoction of the bark of the cinchona tree after all other remedies had failed and to have subsequently introduced it into Europe about the year 1640.

Unfortunately for the romanticists, an intensive study of the recently discovered official diary of the Count of Chinchon has proved that the Countess enjoyed remarkably good health in Peru. There is no evidence that she ever suffered from malaria, and she certainly did not take the bark back to Europe, for she died in Columbia on her way home, probably from yellow fever.

The true story of the introduction of cinchona bark into Europe, though less romantic, is in some respects even more interesting. In the latter part of the sixteenth and throughout the seventeenth century there was a brisk trade in medicinal barks from South America to Spain and Italy. One of these, known in Peru as *quinua-quinua*, was derived from the tree *Myroxylon peruiferum*, from the bark of which was extracted a non-specific febrifuge, marketed in Europe under the name of Peruvian balsam. At times the demand for this bark exceeded the supply, and the exporters thereupon began to substitute another of similar appearance which was taken from the *quina-quina*† trees of Peru, and finally the adulterant supplanted the original bark (Haggis, 1941). It seems therefore that

* Read before a meeting of the All-India Pharmaceutical Conference, Indian Science Congress, held in Delhi, January 7, 1947.

† This was the name applied to the cinchona tree by European merchants at that period. Its original native name is not known.

we owe the discovery of one of the most important drugs in the history of therapeutics to the machinations of dishonest traders. The famous Swedish botanist, Linnaeus, however, who had no reason to doubt the veracity of the original story, gave the name *cinchona* to the *quina-quina* tree in honour of the Countess of Chinchon.

Powdered cinchona bark was sent from Spain and Italy to England about the year 1655, and it was used there against 'intermittent fevers' for the next two centuries (Russell *et al.*, 1946). Cinchona cultivation was commenced in Java in 1854 by the Dutch with seedlings brought by Hasskarl from Bolivia and Peru. In 1860, the British geographer, Clements Markham, made an expedition to South America, as the result of which a cinchona plantation was started near Ootacamund, Madras Presidency, where over 2½ million trees were established by the year 1872.

Throughout the latter half of the eighteenth century, cinchona bark was extensively used in India, where it was popularized by the surgeons of the numerous ships trading with that country. During the first half of the nineteenth century, the bark passed through a phase of unpopularity which was very largely due to the malign influence of a certain Dr. Johnson, a naval surgeon, who visited Calcutta in 1804. He treated his first case with cinchona and failed to effect a cure. He bled his second case, who recovered, and thenceforth adopted a line of treatment consisting of mercury in large doses, purging and venesection. On his return to London, he wrote a book on tropical diseases, in which the administration of cinchona bark as a remedy for malaria was vehemently condemned (Johnson, 1813). As a result the use of the bark was practically abandoned in India, and even when re-introduced, it was for many years used only as a tonic after the subsidence of the fever. An example of the type of treatment which was prescribed during this period is as follows (Field, 1939) :—

1st day	...	bled 35 oz., 20 leeches.
2nd ,,	...	,, 20 oz., 20 ,,
3rd ,,	...	,, 24 oz., 12 ,,
4th ,,	...	,, 24 oz., 8 ,,
5th ,,	...	½ gr. quinine repeated after one hour.

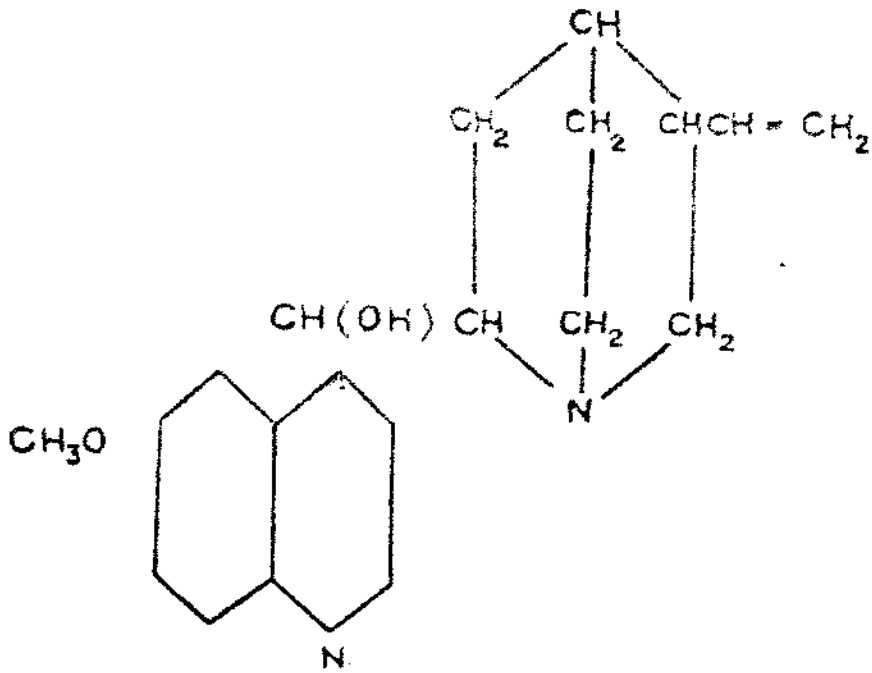
During this period the patient received 55 grains calomel, 46 grains blue pill and daily purges of colocynth, hyoscyamus, jalap, camboge, senna and salts.

From about the middle of the nineteenth century onwards the popularity of the cinchona alkaloids was re-established, largely through the influence of Edward Hare, who came to India in 1839. In the course of 9 years while in medical charge of European regiments in the Burmese war and throughout the siege of Delhi in the Indian Mutiny, Hare treated nearly 7,000 cases of fever, with a mortality of less than one-half per cent (Covell, 1943).

Two French pharmacists, Pelletier and Caventou, isolated the alkaloids quinine and cinchonine from cinchona bark in 1820. The bark contains at least 20 alkaloids, but only four occur in any considerable quantities, namely, quinine, quinidine, cinchonine and cinchonidine. Each of these is effective in the treatment of malaria, but quinine has been the one most generally used, partly by chance and partly for commercial reasons. Actually, cinchonine is slightly more effective than

quinine, while quinidine and cinchonidine are slightly less so. Quinidine has a depressant effect on the heart, while cinchonine is apt to produce gastro-intestinal irritation and other unpleasant effects. The least toxic of the four is cinchonidine.

The toxic manifestations of quinine (cinchonism) may include tinnitus, deafness, amblyopia, photophobia, diplopia, headache, gastro-intestinal disturbances and urticaria. Usually such symptoms are mild and transient, but gross overdosage may result in permanent injury to the retinal and auditory ganglion cells or to the optic nerve.



QUININE

Chemically quinine is a quinoline compound of complex molecular structure, first synthesized by Woodward and Doering in 1944 (Russell *et al.*, 1946). The formula consists of three parts: the quinoline component (6-methoxy-quinoline). the quinucleidine part (a complex ring with a vinyl group) and the connecting [illegible] a hydroxy group (HCOH). Quinidine is an optical isomer of quinine; cinchonine and cinchonidine are optical isomers lacking the methoxy group.

The antipyretic effect of quinine is due to central action on the temperature regulating mechanism, resulting in peripheral vaso-dilatation. There are a number of theories as to how it destroys the plasmodia of malaria, but its exact manner of action has yet to be proved. It has no demonstrable action on the sporozoites of malaria, but it has a potent effect in interrupting the schizogonic cycle of all the human malaria parasites. It has little or no action on the gametocytes of malignant tertian malaria, but exerts a limited effect on those produced in benign tertian and quartan infections.

During the war of 1914–18 the armies engaged on certain fronts, more especially in Macedonia and East Africa, suffered very severely from malaria. Quinine was then the only effective antimalarial drug known, and in an attempt to prevent relapses, the dosage was pushed to extreme limits. For instance in Macedonia, in exceptional cases as much as 100 to 120 grains daily were administered by combined intravenous and intramuscular methods. It is astonishing to read that serious consequences from such heroic doses were comparatively uncommon. Quinine amblyopia was observed in a few cases only and with rare exceptions the loss of vision was transient (Phear, 1920).

It was the shortage of quinine in Germany during this period which first directed attention to the need for synthetic antimalarials, and which provided the stimulus for the brilliant series of investigations culminating in the production of pamaquin, and subsequently of mepacrine, by the German chemists.

PAMAQUIN (PLASMOQUINE : PLASMOCHIN).

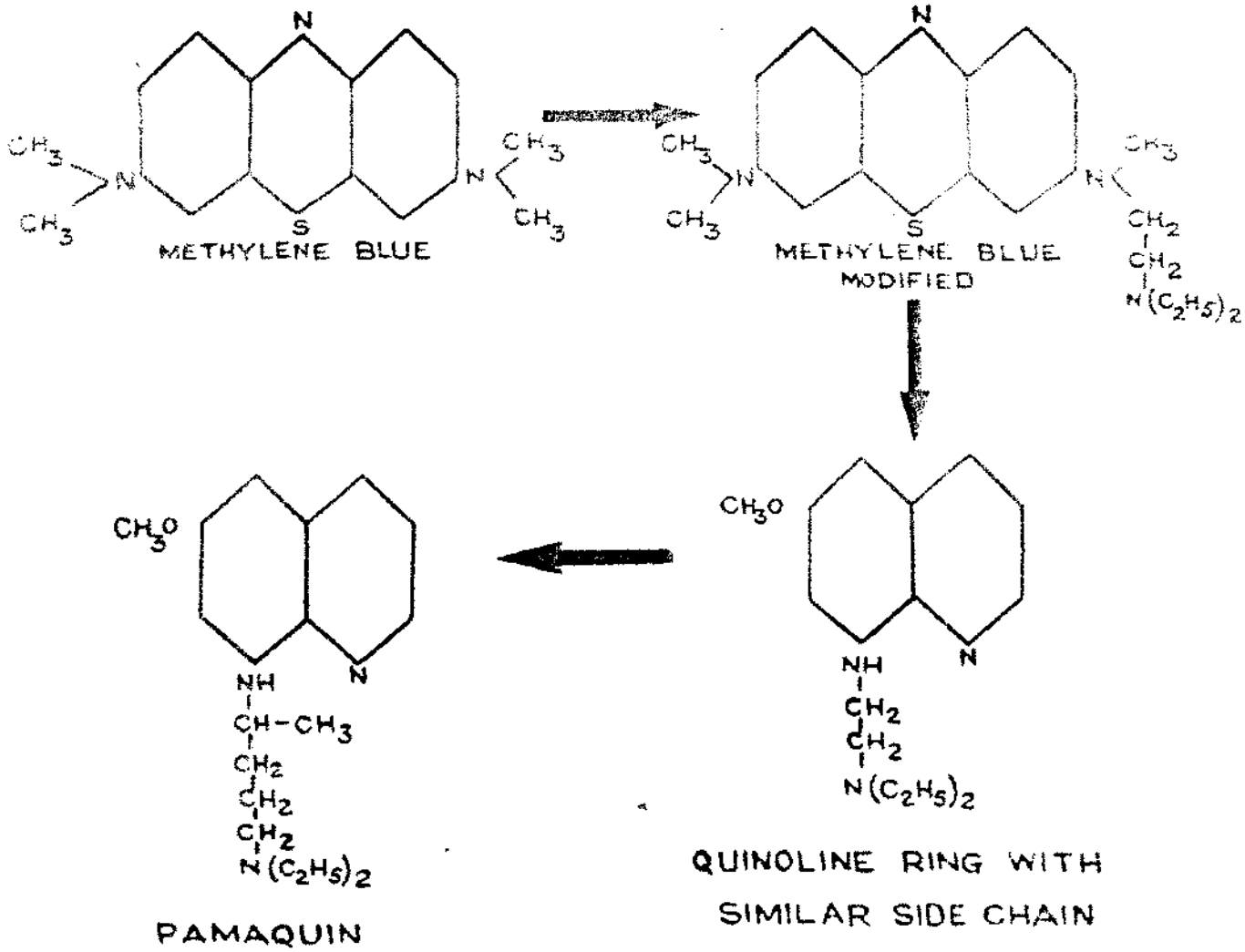
This was the first of the synthetic antimalarials, and was selected in 1925 by Schulemann and his co-workers in Germany as the most effective of a number of drugs synthesized by them, following the observation of Ehrlich that methylene blue has some inhibitory effect on plasmodia. An amino compound of methylene blue gave the first promising results. This led to the synthesis of quinoline compounds containing nitrogen in an aliphatic side-chain and finally, in 1924, to pamaquin, which is an 8 (4-diethylamino-1-methyl-butylamino)-6-methoxy quinoline (Schulemann *et al.*, 1932). It has no action on sporozoites, except possibly to some extent in a dosage dangerously high for general use. It has some inhibitory effect on the exo-erythrocytic forms of avian malaria. Unlike quinine and mepacrine, it has a marked destructive action on the gametocytes of malignant tertian malaria, as well as on those of benign tertian and quartan. It has practically no effect on the schizonts of malignant tertian malaria, though it exerts considerable schizonticidal action in benign tertian and quartan infections. With certain strains of benign tertian and quartan malaria, pamaquin has a remarkable effect in reducing the relapse rate, particularly when given in combination with quinine or mepacrine.

When pamaquin was first introduced, high hopes were entertained that its gametocidal properties, particularly in malignant tertian infections, would prove a potent factor in reducing the incidence of malaria by rendering the population non-infective to mosquitoes. The results of attempts to attain this object have, for a variety of reasons, proved generally disappointing, and the chief function of pamaquin in the treatment of malaria is not the destruction of gametocytes, nor the suppression of the clinical attack, but the reduction of the relapse rate; its greatest value being in benign tertian and quartan infections, which are the most prone to relapse.

Pamaquin is readily absorbed, slowly excreted and may exhibit cumulative toxicity of a most serious and even fatal nature. Only a small margin of safety exists between the therapeutic and toxic doses. For this reason it should never be administered except under strict medical supervision.

Recent research in the U. S. A. has been directed to the development of a drug of the pamaquin series which will lower the relapse rate in benign tertian malaria

without the disadvantages of pamaquin. The most promising of these up to date is SN 13276, but it remains to be seen whether this drug can be given with safety in dosage sufficient to procure the desired result. It has been said to have a destructive effect on the red blood corpuscles in coloured races, and should this report prove to be well founded, it is unlikely to be used to any extent in this country.



MEPACRINE (ATABRIN: ATABRINE, QUINACRINE HYDROCHLORIDE).

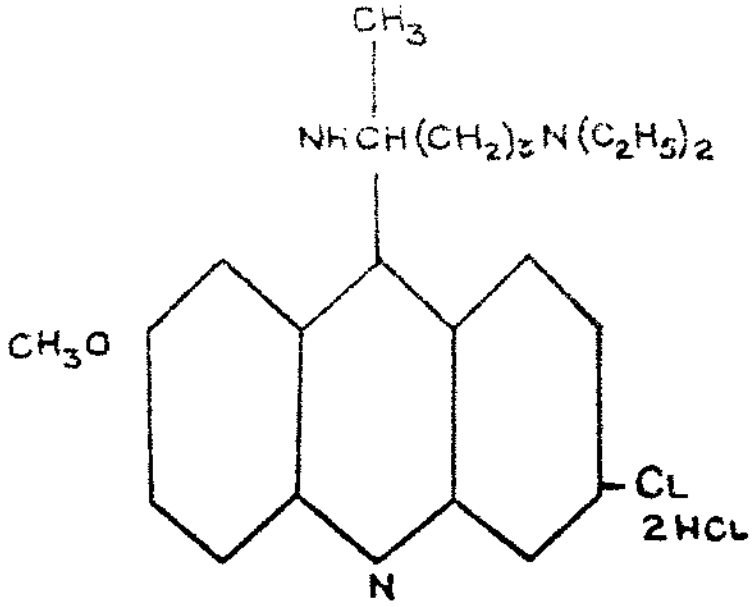
Mepacrine is an acridine dye, in which the quinoline ring is broadened to the acridine ring. It was originally developed in Germany in 1930 by Mietzsch, Mauss, Kikuth and their colleagues.

As the result of their experiments with pamaquin, they accepted the principle of introducing a basic radical by means of an aromatic amino group. In the hope of decreasing toxicity, they replaced the pamaquin ring by the acridine, which is relatively closely related to quinoline. By introducing the chlorine atom and a

methoxyl group into the acridine ring they obtained a dihydrochloride of 2-chloro-5-(ω-diethylamino-α-methyl butylamino)-7-methoxyacridine, which finally received the name of mepacrine (Mauss and Mietzsch, 1933).

It is essentially a schizonticide, with a marked action against the asexual forms of all species of human malaria. Like quinine, it acts as a gametocide in benign tertian and quartan, but not in malignant tertian infections. Its mode of action is not precisely known, but there is evidence that it exerts a direct action on the parasites in the blood.

It does not destroy the gametocytes of malignant tertian malaria, but causes a slightly more rapid disappearance of the sexual forms in benign tertian and quartan infections than does quinine. It has little if any greater effect on the



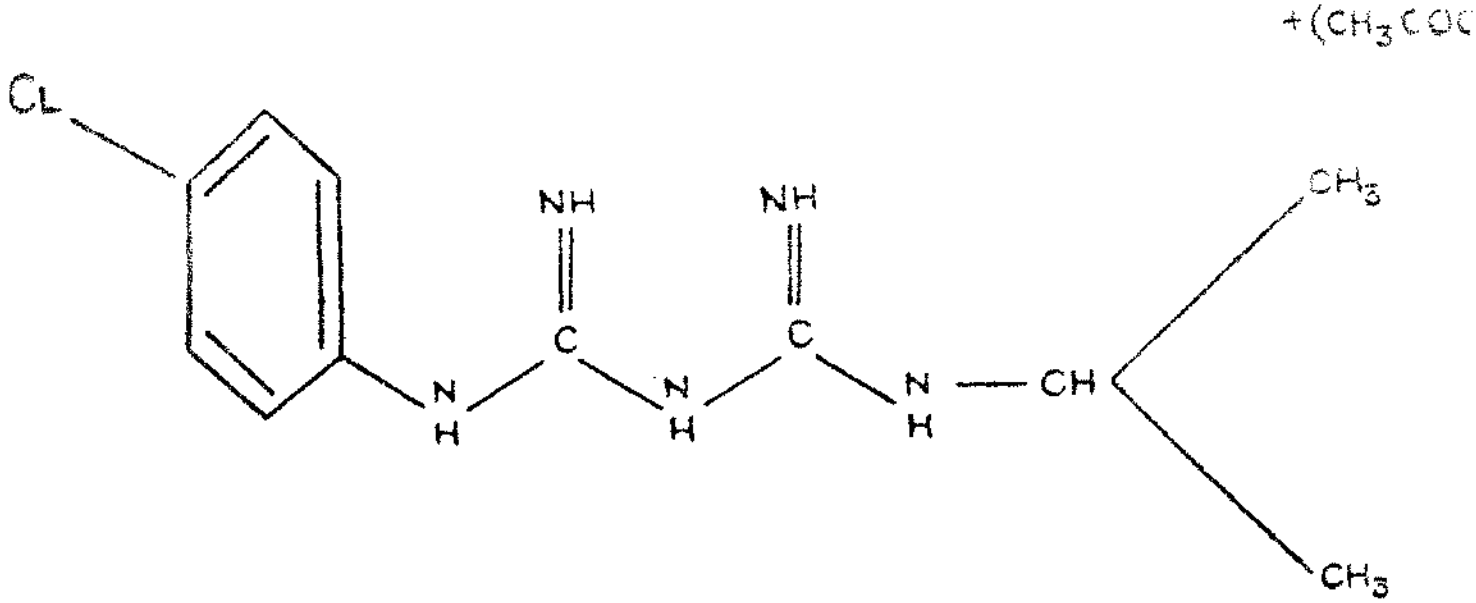
MEPACRINE

relapse rate in benign tertian infections than has quinine, though with mepacrine there is said to be a longer interval between the termination of treatment and relapse.

Mepacrine is rapidly absorbed and slowly excreted. [illegible] regards toxicity, experience accumulated during the recent war indicated that it is a relatively non-toxic drug, and a daily dose of 0·1 gm. was taken by large numbers of individuals over periods of two years or longer with no evidence of toxicity. Such symptoms as occur are usually of a gastro-intestinal nature, but there is some evidence that the drug is a cortical stimulant, and occasionally mental symptoms have been reported which, though transient, are likely to cause considerable alarm to the friends and relatives of the patients. This hazard, together with the yellow coloration of the skin which is a comparatively common feature, constitutes a definite drawback to the use of mepacrine, particularly under civilian conditions.

PALUDRINE (M. 4888).

This drug was synthesized during the recent war by Rose and Curd at the Imperial Chemical Industries Laboratories in England, the biological side of the investigation being carried out by Davey (Curd, Davey and Rose, 1945). These workers selected pyrimidine as the starting point of their researches, instead of quinoline or acridine, the basic structures of pamaquin and mepacrine respectively. Pyrimidine was chosen because of the presence of this ring in nucleoproteins and in certain sulpha drugs, notably sulphadiazine, which were known to possess anti-malarial activity. Later, it was discovered that this property could be greatly enhanced by the inclusion of the guanidine group. This led to the synthesis of certain derivatives of biguanide, of which paludrine has proved the most effective in the treatment of malaria. Its chemical name is N_1-*p*-chlorophenyl-N_5-isopropylbiguanide acetate. It has been subjected to clinical trials at the Liverpool



PALUDRINE

School of Tropical Medicine (Maegraith *et al.*, 1946) and more extensively in Australia (Fairley, 1946). A series of field trials in various parts of this country under the direction of the Malaria Institute of India is now in progress, and has already yielded promising results. It is the only drug that can be used with confidence to ensure complete causal prophylaxis against malignant tertian malaria, having a definite lethal action on the pre-erythrocytic forms. In benign tertian infections it acts as a partial causal prophylactic only. It will however effectively suppress all forms of malaria when given as a single dose once, or at most twice, weekly. It is a powerful schizonticide in benign and malignant tertian malaria, producing its effects on the early schizont and preventing chromatin division and the formation of merozoites. A single dose of the drug will control the clinical attack in both these infections, though there is as yet some doubt as to its efficacy in quartan malaria.

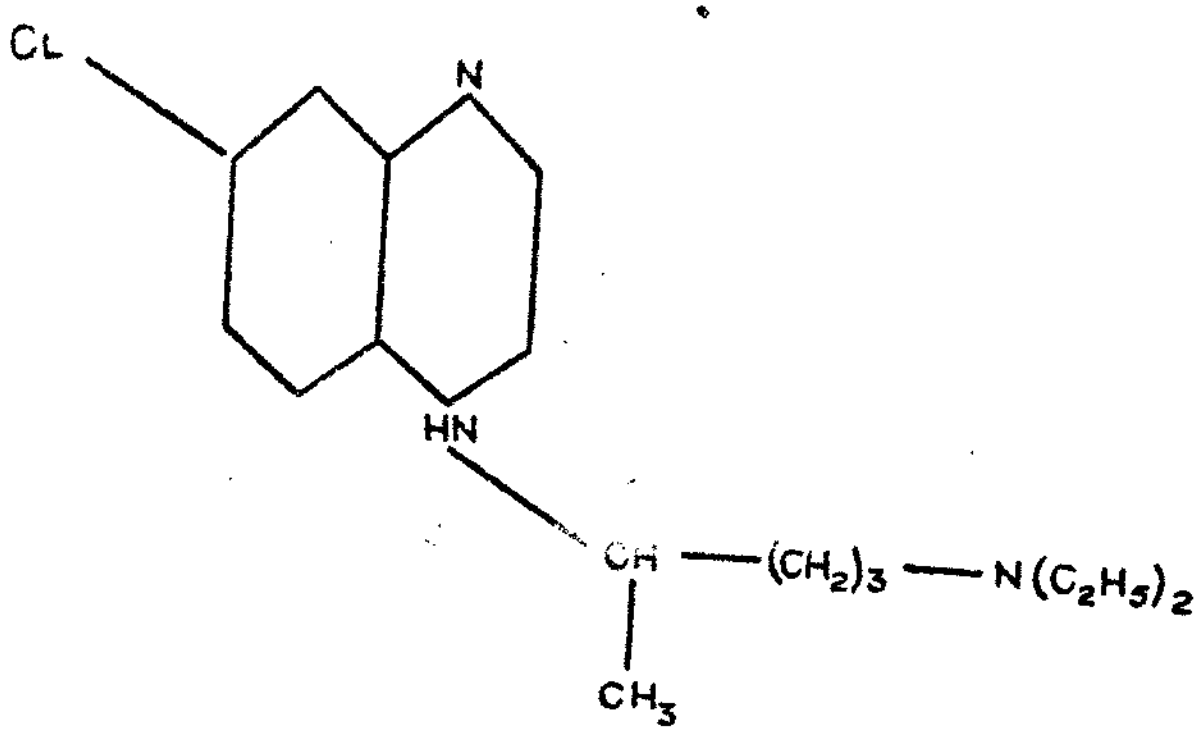
Paludrine exerts no obvious primary effect on either the number or microscopical appearance of gametocytes in the patients' blood, but mosquitoes feeding on individuals taking the drug are unable to transmit the infection.

Paludrine is remarkably free from toxic complications, its range of activity measured as the ratio between the effective therapeutic and the toxic dose being far greater than with any other antimalarial drug yet known. This property, together with its action in controlling the clinical attack with a single dose and effecting complete causal prophylaxis in malignant tertian infections, render it particularly suitable for widespread use under both rural and urban conditions throughout India.

As regards the prevention of relapse in benign tertian and quartan malaria, paludrine possesses little, if any, advantage over other antimalarials. Since however the occurrence of a relapse can be prevented by administering a small dose of this apparently harmless drug once a week, there seems no reason why this should not be continued until the infection has completely died out.

CHLOROQUINE (SN 7618 : RESOCHIN : ARALEN).

Chloroquine was first synthesized in Germany some years ago, but was considered too toxic for general use and was slightly modified under the name of sontochin. During the recent war, supplies of the latter drug were captured in North Africa by the Allies and were subjected to detailed investigation in the U. S. A. The Americans found sontochin effective in human malaria but did not



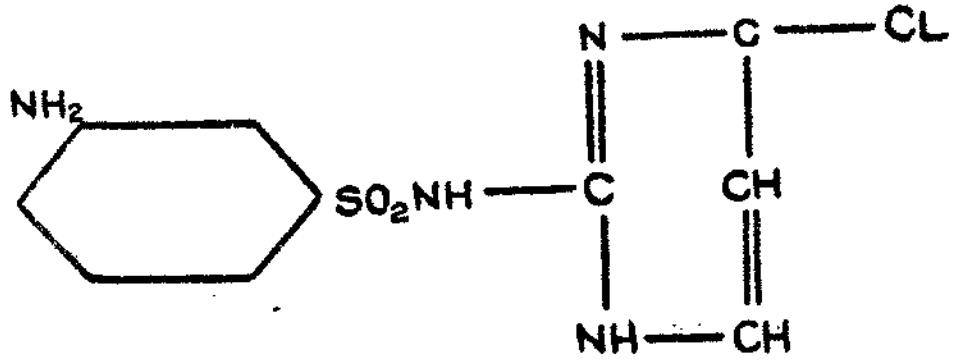
CHLOROQUINE

agree with the original German verdict on chloroquine, and thought the latter superior and worthy of further development.

Chloroquine is a member of the 4-aminoquinoline series and has the formula 7-chloro-4-(4-diethylamino-1-methyl-butyl-amino) quinoline. Large-scale trials have proved that it will terminate a clinical attack of benign tertian malaria more abruptly and cure malignant tertian malaria more promptly than mepacrine. It appears to act in the same way as mepacrine but to be more effective, and is said to be less apt to cause disagreeable gastro-intestinal symptoms. It is an effective suppressive drug when administered in a single dose once weekly.

METACHLORIDINE (S.N. 11437).

The formula for this drug is 2-metanilamido-5-chloro-pyrimidine, which is somewhat similar to that of sulphadiazine. It is very active against several species of avian malaria. In human malaria, it has been disappointing in the treatment of malignant tertian infections, but is said to be active in quartan. As mentioned above, there is some evidence to suggest that paludrine is less effective in quartan infections than in benign and malignant tertian, and should this be confirmed, metachloridine may prove of value in the treatment of quartan malaria, either alone or in combination with other antimalarial drugs. Unpublished reports on a limited series of cases indicate that it has a very low grade of toxicity, but further evidence is required before a definite opinion can be given on this point.



METACHLORIDINE

OTHER SULPHONAMIDES.

Attention was drawn to the possibilities of sulphonamides in the treatment of malaria by the observation of Coggeshall and Maier (1941) that a single dose of sulphanilamide completely eradicated the highly fatal *P. knowlesi* infection in *rhesus* monkeys. Proseptasine (the benzyl derivative of sulphanilamide) was found by Sinton *et al.* (1939) to be a true causal prophylactic in 5 out of 8 cases of malignant tertian malaria in man. Several other members of the sulphonamide

group of drugs have been shown to possess plasmodicidal properties, but for the treatment of human malaria none are as effective as quinine, mepacrine or paludrine. They have no effect on sporozoites, nor do they reduce the relapse rate in benign tertian and quartan infections. Moreover, they are not free from toxic effects, notably hæmaturia and leucopenia. There appears to be little future for such drugs in the treatment of human malaria.

ARSENICAL AND BISMUTH PREPARATIONS.

Many of these drugs have been subjected to intensive investigation in the hope that they may reduce the relapse rate in benign tertian and quartan malaria, but though some of them, e.g. neoarsphenamine, mapharsen, carbarsone and certain preparations of bismuth, have at times some effect on clinical symptoms, they neither eradicate the infection nor prevent relapse. It is now generally considered that such drugs have little, if any, value in the treatment of the disease.

INDIGENOUS DRUGS.

A vast number of indigenous drugs have been credited with antimalarial properties and a very great deal of intensive investigation has been undertaken to test their therapeutic value both in India and in many other countries. Many of them have antipyretic or diaphoretic properties and thus relieve symptoms, but their reputation as malaria specifics rests on the fact that persons who have suffered from malaria repeatedly, and who consequently possess a certain degree of immunity against the disease, will recover from their attack by the administration of any drug which will mitigate these symptoms, or even without medication of any sort whatsoever. With the sole exception of the cinchona alkaloids, none of these drugs has been shown to possess any plasmodical value.

SUMMARY.

In this brief review of the history and development of antimalarials, it will be seen that although the ideal drug has not yet been attained, notable progress towards that ideal has been made in recent years.

The problem of effecting a radical cure of benign tertian and quartan malaria still remains unsolved, but the discovery of a [illegible] which will control the clinical attack by a single dose and cure malignant tertian infections completely, whilst exhibiting so wide a margin between the effective therapeutic and toxic doses that its distribution can be left safely in the hands of non-medical personnel, represents a notable advance in the treatment of malaria among both village and urban populations.

The two great wars which have devastated the world during the last 30 years have had at least one beneficent effect, in that they have provided a powerful stimulus for the development of synthetic antimalarials which bid fair to rob malaria of most of its terrors, and perhaps even lead to its eventual eradication from the Indian sub-continent.

REFERENCES.

COGGESHALL, L. T., and MAIER, J. (1941). Determination of the activity of various drugs against the malaria parasite. *J. Infect. Dis.*, **69**, p. 108.

COVELL, G. (1943) ... ... The prophylaxis and treatment of malaria in war. *J. Mal. Inst. Ind.*, **5**, p. 129.

CURD, F. H. S., DAVEY, D. G., and ROSE, F. L. (1945). Studies on synthetic anti-malarial drugs. Part X. *Ann. Trop. Med. Paras.*, **39**, p. 208.

FAIRLEY, N. H. (1946) ... Researches on paludrine in malaria. *Trans. Roy. Soc. Trop. Med. Hyg.*, **40**, p. 105.

FILLIS, J. W. (1939) Notes on the chemotherapy of malaria. *Bull. Inst. Med. Res.*, F. M. S., No. 2 of 1938.

HAGGIS, A. W. (1941) ... Fundamental errors in the early history of malaria. *Bull. Hist. Med.*, **10**, p. 417.

JOHNSON, J. (1818) ... The influence of tropical climates, more especially the climate of India, on European constitutions. London.

MALGRAITH, R. G., VOASS, A. D. R., KING, J. D., TOTLEY, M. M., RIGBY, J. D., and SLADDEN, R. A. (1946). Paludrine in the treatment of malaria. *Brit. Med. J.*, **1**, p. 966.

MAUSS, H., and MIETZSCH, F. (1933). Atabrin, ein neues Heilmittel gegen. *Deut. Med. Wchnschr.*, **58**, p. 1276.

PHEAR, A. G. (1929) ... The treatment of malaria in Macedonia. *Lancet*, **1**, p. 195.

RUSSELL, P. F., WEST, L. S., and MANWELL, R. D. (1946). Practical malariology. Philadelphia and London.

SCHULEMANN, W., SCHONHOFER, F., and WINGLER, A. (1932). Synthesis of plasmochin. *Klin. Wchnschr.*, **11**, p. 381.

SINTON, J. A., HUTTON, E. L., and SHUTE, P. G. (1939). Some successful trials of proseptasine as a true causal prophylactic against infection with *P. falciparum*. *Ann. Trop. Med.*, **33**, p. 37.

Indian Journal of Malariology, 1, 2, June 1947.

BATS, CLOVER, WATER LETTUCE AND MALARIA.

BY

MAJOR-GENERAL SIR GORDON COVELL, M.D., D.P.H., I.M.S.
(*Director, Malaria Institute of India.*)

[February 15, 1947.]

'The most hazardous of human tendencies is the drawing of general conclusions from limited experience' (Darwin).

THE number of suggestions which are put forward from time to time from various quarters for the eradication or control of malaria is legion. The vast majority of these are discarded at sight as impracticable. But, from time to time, some well-meaning individual, carried away by his enthusiasm, ventilates his opinions in the press and arouses the interest of legislators and others interested in the welfare of the public. The Health Department concerned thereupon institutes investigations by its experts and the merits of the case are duly assessed. As a rule, the claims put forward are shown to have no scientific basis, but after a while the protagonist of the theory, nothing daunted, more often than not returns to the charge with renewed vigour, and the drama is re-enacted before a fresh audience. One is sometimes irresistibly reminded of the words of the popular song: 'They're dead, but they won't lie down'.

It is not suggested for a moment that the sponsors of such theories are in any sense attempting to mislead the public. They are genuinely convinced of the validity of their cause, which in some cases becomes a positive obsession, not to be shaken by any adverse evidence, however convincing this may appear to others.

Three typical examples of theories which have received wide publicity in the field of malariology with very little justification form the subject of this paper. They relate to such widely diverse subjects as bats, clover and water lettuce.

BATS.

The fact that bats prey on mosquitoes has been known for centuries, and was referred to by Pliny in his work on natural history nearly 2,000 years ago. This observation was not, however, regarded as possessing any practical significance until 1909, when a certain Dr. Campbell built a bat roost at San Antonio, Texas, U. S. A., with the object of breeding bats which would destroy the local mosquitoes and would also prove a paying proposition from the sale of guano.

In a communication to the International Institute of Agriculture, Rome, Dr. Campbell affirmed that bats were the greatest enemies of mosquitoes, and urged that they should be cultivated and utilized for mosquito reduction. Bats, he said, were probably immune from the bite of mosquitoes, firstly because of the peculiar formation of the hair covering their bodies and secondly because of their peculiar odour. He pointed out that they were remarkably free from disease, as shown by the fact that although they lived in caves in vast numbers, touching one another and even hanging to one another, yet men engaged in collecting bat guano very rarely encountered a dead bat.

Dr. Campbell carried out his observations in a hunter's cabin 10 miles from San Antonio, where bats congregated in large numbers. He spread large white sheets on the floor, and so arranged the roosting places in the hut that bats could not rest except above the sheets. The bats were counted and the guano collected, the latter averaging 26 pieces to each bat. From this and other data, Dr. Campbell estimated that a structure large enough to accommodate 500,000 bats would cost considerably less than £2,400, and that this number would yield in a year 20¼ tons of guano of an average value of £121 10s. He then proceeded to construct a bat roost from his own design in a place notorious for mosquitoes. The roost was completed in April 1911, and by August the bats inhabiting it were so numerous that they took 20 minutes' flying in a constant stream to enter the roost. In the following year the numbers were so great that it took several hours for them to leave it. A short time before making his report, Dr. Campbell made inquiries of the heads of 14 families residing in the neighbourhood, all of whom declared that mosquitoes during the past 12 months had been much less numerous than in the previous year, and that fever had almost vanished.* Others said that before the roosts were erected the cattle were very thin and poor, in spite of the good food, and attributed this to the attacks of myriads of mosquitoes; and the workmen engaged on irrigation work close by, who had previously complained of being at times driven away from their work by the mosquitoes, were now scarcely troubled by them. The local duck-hunters also testified that the mosquitoes had greatly diminished in numbers. Dr. Campbell concluded from these observations that it is not only commercially, but hygienically, profitable to cultivate bats (Campbell, 1913).

As the result of Dr. Campbell's writings the matter was brought to the attention of the United States Public Health Department. Howard (1920) cited evidence to the effect that mosquitoes form only a small proportion of the diet of bats, that only a very few species of bat are gregarious, and that no diminution in numbers of mosquitoes or [illegible] had resulted in places where bats were present in abundance. He concluded that bat roosts had not proved sufficiently promising to justify the expenditure of public money on their construction.

Subsequently Dr. E. W. Nelson produced a special bulletin devoted to the subject, dealing principally with the Mexican free-tailed bat, which lives in large colonies in Mexico and the south-western United States. This was the species for which roosts had been erected in Texas. He pointed out that mosquitoes had been found in abundance in the vicinity of bat caves and bat roosts, and that they

* It has been alleged, however, that the fall in malaria incidence in this area was due principally to widespread quininization.

had not diminished appreciably in number in the one locality where a successful artificial bat roost had been made. He also stressed the point that though bats undoubtedly swallow mosquitoes when they encounter them in flight, their principal food consists of larger insects (Nelson, 1926). These conclusions were corroborated by Storer (1926) who studied the habits of *Tadarida mexicana* in California. He pointed out that this species does not ordinarily feed upon mosquitoes and that it had existed along with malaria-carrying anophelines in many parts of California without any appreciable change in the malarial index, until the introduction of appropriate sanitary measures. It is a fact, however, that [illegible] species of bat devour considerable amounts of mosquitoes, for instance, *Pipistrellus abramus* in Taihoku and Formosa (Miyamoto, 1930).

The Texas experiment was subsequently repeated in Italy, notably by a retired Italian general in the vicinity of Fiumicino, who, one suspects, was more attracted by the possibility of amassing a fortune from the sale of guano than by a desire to rid the countryside of malaria. It was thought that by constructing a roost to accommodate 50,000 bats, each of which would devour 500 mosquitoes daily, working over a range of 10 kilometres, some 25 million mosquitoes would be destroyed daily. Roosts were erected in several malarious districts, but alas, the bats refused to regard them as desirable residences, and the project was finally abandoned as impracticable (Vittorio, 1926).

This, however, was not the end of the story, a tail-piece being appended during the second world war, when a retired I. C. S. officer living in South Africa, having come across one of Dr. Campbell's original papers, wrote to the Government of India, suggesting that an attempt should be made to breed bats in large numbers in that country for the control of malaria in place of measures there in vogue in the interests of economy. On being informed by the Director, Malaria Institute of India, of the results of previous efforts in this direction, the Government decided not to pursue the matter further.

CLOVER.

The suggestion that clover might possess antimalarial properties originated from no less an authority than Dr. F. d'Herelle, best known for his classical researches on bacteriophage. d'Herelle, seeking to explain the relative immunity from malaria of certain tracts of country (Tuscany, Argentina, Holland), noted that clover was abundant in such countries, and suggested that coumarin, ingested by the female insect from the clover, might have an effect on the [illegible] harboured by it, comparable with that which quinine has on the parasite in man (d'Herelle, 1924).

Sir William Willcocks, the famous irrigation engineer and a noted publicist, was so much impressed by d'Herelle's theory that he published a pamphlet in which he suggested that the relative immunity of cultivated Egypt from malaria might likewise be due to the presence of clover, and advocated the introduction of this and other leguminous plants and trees into Palestine, Cyprus, Iraq, Northern India, the Sudan and Uganda (Willcocks, 1927). The importance of these observations was also stressed by Ziemann (1931), who compiled and published a long list of plants containing coumarin.

Mayne (1930), at the Malaria Institute of India, carried out laboratory tests with coumarin and various species of Indian anophelines, and concluded (1) that coumarin did not exert any deleterious effect on the lives of the mosquitoes feeding on it, and (2) that coumarin, taken with the liquid extracted from a clover blossom, would have no deleterious action on öocysts and sporozoites undergoing development in the infected mosquito.

Bradley (1931) observed that mosquitoes were not attracted to leguminous plants, and did not feed to any extent on their blossom or foliage. He concluded that in any case there was little chance of a mosquito ever obtaining coumarin from them. Barber and Forbrich (1933) noted that alfalfa and sweet clover were [illegible] in New Mexico, but apparently offered no hindrance to the spread of malaria. Stratman-Thomas (1931) concluded that drainage was of more importance in the epidemiology of malaria than alfalfa, and that wherever a decline of malaria coincided with the planting of alfalfa, this was due to the efficient drainage conditions necessary for the crop.

In short, there is no proof that clover has any real effect on the incidence of malaria, and the only recorded experiments which have been carried out with coumarin have indicated that it has no effect either on mosquitoes or malaria parasites under natural conditions.

So many inquiries were received at the Malaria Institute of India as the result of Sir William Willcock's advocacy of d'Herelle's theory, that it was found necessary to issue a special cyclostyled note on the subject, which has been included in all subsequent editions of one of the Government of India Health Bulletins dealing with antimosquito measures with special reference to India (Covell, 1946).

WATER LETTUCE.

The protagonist of the water lettuce theory was the late Dr. P. C. Roy, formerly District Medical Officer of Murshidabad, Bengal. The water lettuce (*Pistia stratiotes*) is widely distributed throughout this district, and Dr. Roy observed that wherever malaria was prevalent Pistia was present in the local water collections.

In 1929 and 1930, Dr. P. C. Roy read two papers before the Berhampore Medical Association in which he cited Pistia as 'the fourth factor in the aetiology of malaria'. His thesis was subsequently published as a brochure of 127 pages (Roy, 1930). He maintained that, at any rate in Bengal and in the neighbouring provinces, Pistia was present wherever malaria existed and also [illegible] healthy areas, that its introduction in previously healthy villages had caused violent outbreaks of malaria, and that the removal of the weed from highly malarious villages had completely eradicated the disease.

He ascribed the action of Pistia to the fact that it contained crystals of calcium sulphate, which he alleged were imbibed by the larvæ of anopheline mosquitoes and pierced the gut wall, producing holes which persisted in the adult insect and allowed the malaria parasite to pass through and develop outside the gut. The cost of removing Pistia from water collections three times each year was estimated at Rs. 5 per *bigha* of water surface.

Dr. Roy subsequently published three other pamphlets in which he claimed spectacular reductions in the malaria rate as the result of the removal of Pistia (Roy, 1932, 1938, 1941). The last of these was dedicated to Dr. C. A. Bentley, who is well known for his classical report on malaria in Bombay, for his memoir on blackwater fever (in collaboration with Sir Rickard Christophers), and for his monograph on malaria and agriculture in Bengal. In the preface to this work, Dr. Roy acknowledged his indebtedness to Major Senior White, Malariologist to the Bengal Nagpur Railway, and Dr. D. N. Roy, Professor of Medical Entomology, School of Tropical Medicine, Calcutta, for their assistance and advice, naively remarking however that neither of them ever agreed with him.

Dr. Roy also collaborated with his namesake, Dr. D. N. Roy, in an article recording some observations on the relationship between malaria and Pistia in two villages in Murshidabad District which was published in the *Indian Medical Gazette* (Roy and Roy, 1941).

In his later writings, Dr. Roy maintained that his theory had a world-wide application, and was not confined to Bengal and the adjacent provinces. He had been erroneously informed that Pistia occurs in Italy, and at once jumped to the conclusion that this was the cause of malaria in that country. In point of fact the plant does not exist in southern Europe, in many parts of which malaria constitutes a very serious problem. He also maintained that the removal of Pistia would cause other diseases to disappear, such as cholera, typhoid and beri-beri.

As the result of his publications, Dr. Roy's theory became known not only in India but also abroad. The late Dr. R. C. Shannon, a distinguished American entomologist, who worked in southern Europe and South America under the Rockefeller Foundation for many years, wrote to Major Senior White for a set of Dr. Roy's publications. After perusing them however he joined the ranks of those who regarded the theory as untenable.

The only malariologist of note who has given encouragement to Dr. Roy is Sir Malcolm Watson, who expressed the opinion, to which no one can take exception, that should his theory prove to be well founded, it would mark an important advance in the field of malaria control.

The investigation of the validity of the Pistia theory was taken up by the Bengal Public Health Department in the year 1933. Following a challenge by Dr. Roy, who guaranteed that there would not be a single case of malaria in a given area provided that Pistia were completely removed from it, detailed observations were carried out in certain villages near Berhampore. In spite of the removal of Pistia, however, cases of malaria continued to occur. Dr. Roy explained this by saying that either the patients had acquired their infection from some locality outside the village or that the Pistia had not been completely removed from a neighbouring tank.

In his report on this investigation Dr. Sen, Assistant Director of Public Health, Malaria Research, Bengal Public Health Department, remarked that if the presence of one or two sprouts of Pistia in a tank could cause malaria, it would be impossible for a community to become malaria-free by an attempt to remove this weed. He also noted that the incidence of malaria in new-born infants in the villages

rendered Pistia-free was higher than in the comparison villages where no such work had been carried out (Sur, 1935).

A further and more detailed report on these and other experiments of a similar nature was later submitted by Dr. J. D. Sinha, Dr. Sur's successor, who adduced evidence categorically refuting Dr. Roy's arguments, point by point. He affirmed that not only had removal of Pistia failed to eradicate malaria but that the lower incidence of the disease in the treated villages could be explained by various other factors and not by the removal of Pistia alone. He pointed out that since Pistia was a waterweed, its removal would actually tend to reduce mosquito breeding and so lower malarial incidence, but this would not justify the contention that Pistia alone was responsible for malaria throughout the world (Sinha, 1940).

In a letter forwarding the two reports referred to above, Lieut.-Colonel A. C. Chatterji, I.M.S., then Director of Public Health, Bengal, stated that Dr. Roy's assertions had been conclusively disproved as the result of the experiments undertaken by his department. Dr. M. O. T. Iyengar, Entomologist, Bengal Public Health Department, who had made an intensive study of the anopheline fauna of Bengal during the previous 20 years, pointed out in a letter written about the same period that Dr. Roy's argument regarding the penetration of the gut of anopheline larvæ by crystals of calcium sulphate was vitiated by the presence of a tubular peritrophic membrane, which completely encloses the food matter, so that the latter never actually comes in contact with the epithelium of the gut. He also stated that from the epidemiological evidence available there was no relation between the incidence of malaria and the occurrence of Pistia. He pointed out the following fallacies in Dr. Roy's experiments :—

(1) The work was carried out in an area within the jurisdiction of Dr. Roy who was naturally interested in proving his hypothesis.

(2) In the experimental villages other water plants besides Pistia were removed at the same time, and the clearing of aquatic vegetation in general has long been recognized as a valuable measure for the reduction of mosquito breeding.

(3) In regard to the diagnosis of fever in the experimental and comparison villages a certain amount of bias had been introduced, a large proportion of cases from the former being recorded as influenza, whilst this was not so in the comparison villages.*

(4) Quininization of the population had been carried out in the experimental but not in the comparison villages.

The mosquito which is almost exclusively responsible for the transmission of malaria throughout the plains of Bengal is *Anopheles philippinensis*. The association of this species with various types of aquatic vegetation has been intensively studied both by Dr. Iyengar himself and Dr. P. Sen who was also on the staff of the Bengal Public Health Department. Dr. Sen showed that, whilst almost all species of anophelines bred in association with Pistia, the larvæ of

* The number of cases of influenza diagnosed annually at the dispensary in one of the experimental villages increased progressively from nil in 1933 to 1,274 in 1937. No influenza epidemic was reported elsewhere in Murshidabad District during those years.

A. philippinensis, the chief malaria carrier, formed only a very small proportion of the total, in comparison with other water weeds, such as Spirogyra, Utricularia and Limnanthemum (Sen, 1941). These findings were in agreement with those recorded by Krishnan (1940). Iyengar (1944) showed that *A. philippinensis* prefers aquatic vegetation of the submerged type, such as Hydrilla, and confirmed Sen's and Krishnan's findings regarding the lack of association between this species and Pistia.

Actually, the only anopheline for which the presence of Pistia in its breeding places is essential is *A. bachmanni*, a species found in Panama which breeds in the crowns of the plant (Curry, 1932). This mosquito, which does not occur in Asia, is not a malaria carrier. There is one anopheline common in Bengal which shows a definite preference for waters containing Pistia, namely *A. annularis*, but this species also plays no part of any importance in the transmission of malaria.

Although in the face of the evidence available Dr. Roy's contentions are obviously untenable, one cannot but admire the persistence with which he upheld his cause over a period of so many years in the face of adverse criticism from every malariologist of any standing who has studied the problems of malaria in Bengal. It seems a pity that such abundant energy could not have been directed into a more profitable channel.

DISCUSSION.

From the above account it will be evident that all the three theories cited above contain an element of truth. Bats—or at any rate some species of bat—undoubtedly feed on mosquitoes, and among these there may be malaria-carrying anophelines. Again it is a fact that clover is usually found in non-malarious areas and not in those where malaria is prevalent. Finally, it is not disputed that Pistia is associated with the breeding of many species of mosquitoes, some of which may be malaria carriers.

On the other hand, there are many places where bats abound and where malaria is nevertheless a serious problem. It has been shown that the association of clover with freedom from malaria depends solely on the fact that this crop will grow only where the ground is well drained and therefore inimical to mosquito breeding. Also that there are many intensely malarious places in the world entirely free from Pistia, whereas others, where Pistia is abundant, are malaria-free. In other words, none of these theories has been built up on a sound scientific basis.

The lesson to be learnt from all this is epitomized in the letter of Darwin which leads this paper, namely, that the most hazardous of human tendencies is the drawing of general conclusions from limited experience. If this aphorism were borne in mind by all the enthusiastic advocates of panaceas for malaria, those who specialize in the subject would be spared a good deal of the labour entailed in confuting theories based on such slender foundations.

SUMMARY.

During the past half century many suggestions have been put forward, in all good faith, by enthusiatic individuals as panaceas for eradicating malaria with

little or no scientific basis, thereby causing considerable labour to those called upon to assess their value. Three of them, relating respectively to bats, clover and water lettuce, which have received wide publicity, are cited and discussed in this paper.

Attention is directed to the imprudence of drawing general conclusions from limited experience in the field of malariology, as in all other branches of preventive medicine.

REFERENCES.

[illegible] and Fontenot, L. R. (1933). Malaria in the irrigated regions of New Mexico. *U. S. A. Pub. Hlth. Rpts.*, **48**, 22, pp. 610–623.

[illegible] H. (1934) . Feeding tests of anopheline mosquitoes with leguminous plant. *J. Econ. Ent.*, **24**, 6, pp. 1229–1233.

[illegible] A. R. (1913) .. The eradication of mosquitoes by the cultivation of bats. *Monthly Bull. Agric. Intell. Plant. Dis.*, **6**, pp. 1175–1181.

[illegible] (1940) . Antimosquito measures with special reference to India. Health Bulletin No. 11. *Govt. Press, Delhi*, 7th ed.

[illegible], D. P. (1932) . Some observations on the Nyssorynchus group of the Anopheles (Culicidæ) of Panama. *Amer. J. Hyg.*, **15**, 2, pp. 566–572.

d'Herelle, F. (1924) .. Immunity in natural infectious diseases. pp. 187-188. Baltimore.

Idem (1932) ... Clover and malaria. *Amer. J. Hyg.*, **16**, 2, pp. 609–617.

Howard, L. O. (1920) .. Mosquitoes and bats. *U. S. A. Pub. Hlth. Rpts.*, **35**, pp. 1789–1795.

Iyengar, M. O. T. (1944) . Problems relating to malaria control in deltaic Bengal. *J. Mal. Inst. Ind.*, **5**, 4, pp. 435–447.

Krishnan, K. V. (1940) . Report of the Professor of Malariology and Rural Hygiene. *Ann. Rept. All-India Inst. Hyg. & Public Health for* 1939, pp. 32–36.

Mayne, B. (1930) ... .. The effects of coumarin on the life of the mosquito and the malarial parasite. *Ind. J. Med. Res.*, **17**, 3, pp. 963–969.

Miyamoto, S. (1930) ... On the destruction of mosquitoes by *Pipistrellus armatus* in Taihohu. *J. Med. Ass., Formosa*, No. 301, p. 19.

Nelson, E. W. (1926) ... Bats in relation to the production of guano and the destruction of insects. *U. S. A. Dept. Agric. Bull.*, No. 1395.

Roy, D. N., and Roy, P. C. (1941) Observations on the relationship between malaria and Pistia in two villages in Murshidabad District. *Ind. Med. Gaz.*, **76**, pp. 538–542.

Roy, P. C. (1930) ... ... The fourth factor in the ætiology of malaria. Nagendra Printing Works, Calcutta.

Idem (1932) ... ... Report on anti-Pistia work and its immediate effects on malaria in six towns and eighty-four villages in 1932. New Art Press, Berhampore.

Idem (1938) ... ... Report on antimalaria work by anti-Pistia method carried out jointly by District Board, Murshidabad, and Public Health Department, Government of Bengal, from 1933 to 1938. New Art Press, Berhampore.

Idem (1941) ... ... A peep into a corner of the inner life of Anopheles. Modern Art Press, Calcutta.

SEN, P. (1941) ... Aquatic plants in the ecology of anopheline mosquitoes. *J. Mal. Inst. Ind.*, **4**, 1, pp. 113–137.

SINHA, J. D. (1940) ... Report on the anti-Pistia experimental method of malaria control in some selected villages in Murshidabad District. Government Press, Calcutta.

STORER, T. I. (1926) ... Bats, bat towers and mosquitoes. *J. Mammal.*, **7**, pp. 85–90.

STRATMAN-THOMAS, W. K. (1931) ... Supposed antagonism between alfalfa and malaria. *Amer. J. Hyg.*, **14**, 2, pp. 394–410.

SUR, S. N. (1935) ... Report on the incidence of malaria in villages in the district of Murshidabad where experimental anti-Pistia work was carried out under the direct supervision of Dr. P. C. Roy. Government Press, Calcutta.

VITTORIO, V. (1926) ... Auxiliary measures in the campaign against malaria. *Ann. Med. Nav. Colon.*, **2**, pp. 273–292.

VLASSOV, J. (1927) ... On the question of mutual relations between bats and mosquitoes. *Rev. Microb. and Epidem.*, **6**, 2, pp. 260–261.

WILLCOCKS, W. (1927) ... Why is cultivated Egypt immune from malaria? Nile Mission Press, Cairo.

ZIEMANN, H. (1931) ... Possible relation between plants containing coumarin to the epidemiology of malaria. *Arch. Schiffs. Trop. Hyg.*, **35**, 7, pp. 410–420.

REPORT OF A COMMITTEE CONVENED FOR THE CO-ORDINATION OF POLICY REGARDING THE PREVENTION OF MALARIAL CONDITIONS PRODUCED DURING THE CONSTRUCTION OF ROADS AND RAILWAYS.

[February 17, 1947.]

CONSTITUTION AND PROCEEDINGS OF THE COMMITTEE.

THE Committee was convened by the Government of India as the result of an enquiry received from the Railway Board as to whether there existed any proposal for a co-ordinated policy in respect of the digging of borrowpits in order to combat the menace of malaria. The matter was referred to the Director, Malaria Institute of India, who replied that such a policy was urgently required in respect, not only of borrowpits, but also of culverts and other conditions favouring the incidence of malaria likely to be created during the construction of engineering works. He suggested the calling of a conference of senior engineers and malariologists for the purpose of laying down a policy to be adopted in regard to borrowpits, culverts, quarry-pits, cuttings, etc., during the course of railway and road construction.

The Committee was constituted as follows :—

Chairman.

COLONEL E. COTTER, C.I.E., V.H.S., I.M.S.,
Public Health Commissioner with the Government of India.

Members.

MAJOR-GENERAL SIR GORDON COVELL, C.I.E., K.H.P., I.M.S.,
Director, Malaria Institute of India.

SIR ARTHUR DEAN, C.I.E., M.C., I.S.E.,
Chairman, Delhi Improvement Trust.

DR. H. J. NICHOLS, D.Sc.,
Member, Engineering, Railway Board.

MR. G. A. D. COCHRANE, O.B.E., I.S.E.,
Consulting Engineer (Roads), War Transport Department.

LIEUT.-COLONEL. M. K. AFRIDI, C.B.E., I.M.S.,
Deputy Director, Malaria Institute of India.

MAJOR R. A. SENIOR WHITE, A.I.R.O.,
Malariologist, B. N. Railway.

Mr. W. J. Berry, M.B.E., Superintending Engineer, Health Services, Delhi Province, was present by invitation at both meetings of the Committee and Mr. M. Zinkin, I.C.S., Assistant Financial Adviser (Communications), Finance Department, and Mr. S. Imam Ahmad, Deputy Agricultural Production Adviser (Manure), Department of Agriculture, were present by invitation at the second meeting only. Major Senior White was unfortunately unable to attend either meeting. His place was taken at the opening meeting by Dr. N. G. Ganguli, Offg. Malariologist, B. N. Railway.

The Committee held two meetings, the first on May 1 and the second on November 4, 1946.

At the first meeting the Committee considered notes by Sir Gordon Covell and Major Senior White (Appendices I and II) specifying the chief features in railway and road construction likely to create conditions favouring the incidence of malaria and heard the views of the engineers present as regards the measures which might be taken to prevent such conditions from arising.

At the second meeting of the Committee the following documents were examined and discussed :—

1. Railway Board Circular No. 5233-W., dated June 24, 1946, addressed to all Government railways on the subject of antimalaria measures to be adopted during the railway construction.

2. Memorandum on borrowpits in land acquired temporarily for road construction by Mr. G. A. D. Cochrane, Consulting Engineer (Roads), prepared for the Central Roads Board meeting of September 23, 1946 (Appendix IV).

3. Minutes of a meeting of the Transport Department on borrowpits held on September 27, 1946 (Appendix V).

4. Note by Sir Arthur Dean, Chairman, Delhi Improvement Trust, on construction of road embankments without creation of borrowpits (Appendix VI).

5. Note by Lieut.-Colonel. Afridi, Deputy Director, Malaria Institute of India, on the control of malaria among parties engaged in road and railway construction (Appendix VII).

6. Railway Board Circular No. 5233-W.

Sir Gordon Covell drew attention to a number of features in the circular which were unsatisfactory as regards malaria prevention, and suggested certain amendments.

Dr. Nichols undertook to recommend to the Railway Board that the circular should be amended on the lines suggested.

As the result of these recommendations a new circular No. P466/147, dated November 21, 1946, was subsequently issued by the Railway Board in substitution

of their circular No. 5233-W., dated June 24, 1946, with directions that this should be embodied in the Manual of Instructions for Construction Engineers (Appendix III). The amended circular conforms in general with the recommendations of the Committee.

2 and 3. Memorandum on borrowpits in land acquired temporarily for road construction, dated September 23, 1946, by Mr. G. A. D. Cochrane (Appendix IV) and minutes of the meeting of a Departmental Committee of the Transport Department held on September 27, 1946 (Appendix V).

It was agreed that the issuing of a directive regarding the location, number and design of culverts in connection with road construction was desirable. Mr. Cochrane undertook to prepare such a directive for submission to the Roads Board.

The Committee adopted the conclusions reached by the Departmental Committee, adding a rider to the effect that special care be taken regarding the drainage of borrowpits at points of intersection between roads and railways and canals.

4. Note by Sir Arthur Dean on construction of embankments without creating borrowpits (Appendix VI).

It was agreed that the profile of borrowpits advocated and used by Sir Arthur Dean in road construction in Delhi Province was the method of choice, but it was noted that the Department of Agriculture did not attach importance to the replacement of top-soil in borrowpits of reasonable depth.

5 Lieut.-Colonel. Afridi's note on the control of malaria among parties engaged in road and railway construction (Appendix VII).

The measures for protection of survey parties and construction parties outlined in the note were approved.

6. The Committee adopted the following resolution moved by Sir Gordon Covell.

'No engineering project of any description should be undertaken without consideration of the malarial aspect and provision in the original estimates for necessary antimalaria works and for the protection of survey parties and of labour forces during construction.'

SUMMARY AND RECOMMENDATIONS.

The Committee considered the measures which should be taken for the prevention of the breeding of malaria-carrying mosquitoes in connection with borrowpits, culverts, quarry-pits and cuttings created during railway and road construction, and for the protection of survey parties, labour forces and other personnel engaged on such projects.

They made the following recommendations :—

A. *Culverts.*

1. The provision of culvert openings as usually made under railway and road banks should be more liberal than is the usual existing practice, wherever there

is the least question of water backing up, and should be sufficient to provide for the occurrence of periodical heavy rainfall.

2. Culverts should be so designed that a lowering of the invert levels by approximately 5 feet could be effected if and when required without endangering the stability of the structure.

3. Revised engineering specifications should be drawn up in accordance with the above recommendations. These should apply to :—

(*i*) All new engineering constructions including canal irrigation systems.

(*ii*) Existing structures which for technical engineering reasons need reconstruction.

(*iii*) A limited number of existing structures which can be definitely demonstrated to constitute a direct source of severe malaria among the local population.

4. It is desirable that a directive such as has already been circulated by the Railway Board (Appendix III) be issued by the Roads Board regarding the location and design of culverts in road construction.

B. *Borrowpits.*

5. The excavation of borrowpits within built up areas and for half a mile beyond their limits should be prohibited.

6. Elsewhere, the digging of borrowpits should be avoided wherever possible. Where earth can be obtained from no other source the following rules should be observed :—

(*i*) The profile of borrowpits advocated and used by Sir Arthur Dean in road construction in Delhi Province (Appendix VI) is the method of choice.

(*ii*) Adequate provision should be made for the drainage of all borrowpits into the nearest natural drainage channel.

(*iii*) Interconnecting drains between borrowpits should be at least 5 feet wide.

(*iv*) Margins of borrowpits should be kept straight.

(*v*) All 'dead men', 'matams', or other similar aids to measurement of earth excavated should be removed.

(*vi*) Particular care is necessary as regards the siting and depth of borrowpits in hilly country, on account of the danger of tapping seepage outcrops.

(*vii*) Special care should also be taken regarding the drainage of borrowpits at points of intersection between roads, railways and canals.

C. *Quarry-pits and cuttings.*

7. Adequate drainage should in all cases be provided for quarry-pits and cuttings wherever these expose seepage outcrops.

D. *Protection of survey parties, labour forces and other personnel engaged in railway and road construction.*

8. Measures for the protection of all such personnel should be enforced on the lines laid down in Lieut.-Colonel Afridi's note (Appendix VII).

E. *Financing of antimalaria works.*

9. No engineering project of any description should be undertaken without consideration of the malarial aspect and provision in the original estimates for necessary antimalaria works and for the protection of survey parties and of labour forces during construction. A definite proportion of the cost of the project should be earmarked for this purpose.

APPENDIX I.

NOTE ON MALARIA PROBLEMS CREATED DURING ROAD AND RAILWAY CONSTRUCTION.

BY

MAJOR-GENERAL SIR GORDON COVELL, C.I.E., K.H.P., I.M.S.,
Director, Malaria Institute of India.

The principal features of railway and road construction which favour the spread of malaria are :—

(1) Interference with natural drainage by the provision of an insufficient number of culverts or of culverts incorrectly placed.

(2) The creation of borrowpits without provision for their drainage, either to obtain earth for embankments or in the process of quarrying for stone or gravel.

Antimalaria drainage differs in many respects from other engineering activities, the chief being that meticulous attention to details and continuous maintenance are all-important. If these are neglected the scheme from the antimalaria viewpoint may be a total failure. In the disposal of storm-water for instance, drainage measures may fail because whilst great attention is devoted to its rapid disposal, too little is given to the removal of all water after the storm has passed. Again, whilst a system of flat bottom drains may be perfectly effective in rendering an area fit for agricultural purposes, malaria may actually be increased unless a cuneate is provided, or the bottom shaped and maintained as a shallow V.

It is only natural that such details should be entrusted to subordinates, whilst the senior engineers are apt to be engrossed by what are to them the more important phases of their work.

CULVERTS.

In a recently published American textbook on Mosquito Control by W. B. Herms, an Agricultural Entomologist, and H. F. Gray, a Consulting Civil Engineer, the following passage occurs :—

'Railroad or highway embankments with improperly placed culverts are typical obstructions. After long and sad experience the writers are convinced that it is only by accident that either a railroad engineer or a highway engineer ever places a culvert properly. Usually it is set too high, so that a pool or swampy area forms on the upper side of the embankment; occasionally it is set too low, so that water remains in the culvert itself.

'The bottom of the culvert should conform closely to the general ground surface gradient at the low point. To determine this, a profile should be taken

along the bottom of the drainage way or depression for at least 50 feet, preferably 100 feet, beyond the toes of the future embankment and the culvert elevation and grade properly fitted to this profile.'

(*a*) *Correct placing of culverts.*—The culvert should be placed along the line of natural channel or at low point. Its grade should follow the natural grade of the land. If the invert is level it will tend to become obstructed with gravel or dirt. If the grade is steeper than the natural grade a pool may form below it owing to scour. On the other hand, as noted above, if the up-stream end of the culvert is too high it will cause ponding or a marsh above the embankment. This may have been done intentionally in order to prevent silting and thereby heavy maintenance cost.

(*b*) *Provision of an insufficient number of culverts.*—Where there are no other considerations involved there is a natural tendency to provide only that number of culverts which will ensure that the road or railway will not be washed away or damaged by floods. This is insufficient for antimalaria purposes. *Any* interference with natural drainage will result in an increase of mosquito production and hence of malaria. Furthermore, it must be ensured that natural drainage will be unobstructed, not only under normal conditions, but also in years of abnormal rainfall and flooding. This applies particularly to those regions which are subject to periodic regional epidemics of malaria. A case in point is that of a triangular tract in the Punjab bounded on two sides by canals and on the third by a railway embankment. The canals were aligned parallel to the direction of natural flow and offered no obstruction to drainage. Storm-water was normally removed by the Hudiara Nala, a natural drainage channel passing under the railway line through a culvert. In 1908, a year of abnormal rainfall, a heavy precipitation falling on a soil already moistened by irrigation and previous rain resulted in a very high discharge. The culverts were insufficient to carry off the accumulation of storm-water, which headed up and inundated the greater part of the tract. The resulting inundation of obstructed storm-water soaked into the soil and raised the subsoil water table to ground level; it also filled every tank and depression with water, which provided prolific breeding places for malaria-carrying species of mosquitoes. A regional malaria epidemic of great severity associated with an exceptionally heavy mortality was the result of this combination of circumstances.

(*c*) *Design of culvert.*—Certain specifications have been laid down by American sanitary engineers to minimize the danger of mosquito breeding, e.g. that the cement used at the joints of the invert shall not be allowed to ooze up on the inside forming a dam and in consequence small pools of water, and that the floor shall have a circular cross-section with an ordinate distance of say 1/6th of the chord of the curve to provide for velocity sufficient during the dry weather to prevent mosquito breeding. But to the malariologist the views of J. L. Clarke, a distinguished sanitary engineer, put forward in the *Engineering News Record* of 1936, Vol. 117, p. 266, are of greater interest. He condemns the box culvert as a public menace on account of 'the unpardonable dereliction in the design of a bottom which, being an integral part of the structure, may not be tampered with' and favours the substitution of a bottomless culvert which will allow the deepening of the stream bed.

He also criticizes the 'equalizer' culvert, i.e. one which has no outlet but simply permits water to stand at the same level on both sides of the road. 'Its use in highway construction is an admission of failure. Standing water in borrow-pits and roadside marshes should be drained as an integral part of highway construction. There is no good reason why land should not be purchased or condemned for drainage rights of way in the same manner employed to obtain road rights of way.'

It would be of advantage from the malariologist's point of view if guiding principles could be laid down on these lines for road and railway construction engineers. It would also be helpful if a regulation were included for the provision of concrete aprons below culverts which would otherwise be likely to produce potholes.

BORROWPITS.

Much controversy has centred around this subject. Undrained or improperly drained borrowpits are always a source of mosquito breeding, and often harbour the larvæ of malaria-carrying species, more particularly in foothill tracts, and in coastal areas where they may be contaminated by salt or brackish water. They were the cause of much malaria during the Burma campaign, particularly on the Arakan front, where an enormous amount of labour was expended in filling them up. The very fact that in most cases they were eventually filled with soil locally obtained indicates that in these localities they need never have been made.

This is the first contention of the malariologist, i.e. that in many cases, perhaps in the majority of cases, the excavation of borrowpits is actually unnecessary. This has been demonstrated in the Delhi urban area which covers an area of about 65 square miles of country. At one time it was not possible to find a single borrowpit in the whole area, a claim which perhaps cannot be altogether substantiated at the present time. There is a natural tendency to take earth from a low point, because here it is softer and more easily excavated. But in many cases sufficient earth can be obtained by slicing it from elevations or hillocks. This may increase to some extent the cost of construction and maintenance, but it should be a recognized charge in the interest of public health.

If, however, the necessary earth cannot be obtained without creating borrow-pits the following suggestions are put forward :—

(*i*) The practice advocated by Sir A. W. H. Dean in road construction whereby after removing and placing on one side the upper 6 inches of soil a very broad [illegible] is made a few inches in depth and perhaps 20 feet wide. The topsoil removed which is valuable as a manure, is spread over the bottom and the whole is ploughed along with the rest of the field by the cultivator. At the end of the season little or no sign of the borrowpits remains.

(*ii*) Instead of making irregular shaped isolated borrowpits one broad pit is made alongside the road or railway in the form of a shallow drain, the water being discharged wherever possible into a natural nala or stream.

(*iii*) Where this cannot be done for reasons of scour as for instance in foothill country where the gradient is too steep, drainage should be provided for each

borrowpit into the nearest natural channel, or into one deep pit where the water can conveniently be treated with larvicide.

(*iv*) No borrowpits should be permitted within municipal limits. It is said that when the Agra-Delhi Chord Railway was diverted in order to provide the site for New Delhi two estimates were prepared for the construction of the embankment. One provided for the bringing in of earth from outside, whilst in the other it was to be obtained locally. The latter was naturally the less costly by several lakhs of rupees and was accepted on that account. A chain of enormous borrowpits was excavated on either side of the embankment which provided prolific breeding places for mosquitoes for the next 25 years. The cost of filling these pits, which was carried out in 1936 as an antimalaria measure, was considerably greater than the difference between the two original estimates.

On the other hand, the embankment carrying the branch line which carries coal to the Electric Power House from a point on the Agra-Delhi Chord line, north of Purana Qila, was constructed about 6 years ago without a borrowpit of any kind. This project, conceived purely for utilitarian purposes, was transformed into an effective antimalaria work as the result of close collaboration between the railway engineers and the malaria department, with a negligible increase in the cost of construction.

(*v*) A regulation exists on the Bengal Assam and Bengal Nagpur Railways prohibiting the excavation of borrowpits between distant signals of stations. It is suggested that this rule should be applied to all railways in India.

Quarry-pits and cuttings.

Both of these are likely to expose seepages and thus produce ideal breeding places for malaria-carrying mosquitoes. It is most important that adequate drainage be provided under such circumstances.

It may be objected that the adoption of the above suggestions will add to the cost of road and rail construction. It is contended that the inclusion of provision for antimalaria work is a legitimate charge on such projects and indeed on all forms of engineering construction, particularly in regard to canal irrigation, and that no engineering schemes should ever be undertaken without such provision. Antimalaria sanitation should be looked upon in the same light as the provision of water supplies, sewers and other essential public health requirements.

APPENDIX II.

NOTE REGARDING MALARIOGENIC CONDITIONS CREATED DURING ROAD AND RAILWAY DEVELOPMENT.

BY

MAJOR R. A. SENIOR WHITE,
Malariologist, Bengal Nagpur Railway.

1. *Borrow pits.*—The General Manager, East Indian Railway, made a reference to me through my General Manager some months ago. To the best of my recollection I pointed out that the malariogenic status of borrowpits differed in various parts of India. In hilly country borrowpits are particularly dangerous as they frequently tap sub-soil water, and in such seepages the virulent vectors of the *fluviatilis-minimus* group breed. *Per contra*, *A. philippinensis*, the vector of deltaic Bengal, is said not to breed in borrowpits, though I am not disposed to regard this as proven beyond dispute. Between these two extremes, borrowpits however where surface-clear produce *culicifacies*, the vector of most of India other than the eastern side, and, where weedy, *annularis* the vector in particular of the Orissa Coastal plain. Borrowpits within 10 to 20 miles of the Bay of Bengal coast are frequently the breeding places of that most dangerous vector *A. sundaicus*, whether such are clean or weedy: in fact newly excavated pits appear to be especially favoured by this species.

Borrowpits, therefore, are nearly always dangerous, and if any other method of providing spoil for embankments can be devised, this is highly desirable. Village spleen rates on the Raipur-Vizianagram Railway, constructed 1926–31, appear to have risen considerably after the original surveys tabulated in Railway Board Technical Paper 258; and this must almost certainly be a borrowpit caused phenomenon. However the financial code dealing with earthwork measurements calls for measurable sized borrowpits with 'matams' in proof of depth. The matams provide additional 'breeding edge'. I believe that earth obtained by any other method of excavation has to be paid for at more expensive daily labour rates. If an alternative method of building and *maintaining* banks can be devised, its general acceptance will involve a change in the Financial Code.

2. The official Bengal Nagpur Railway construction manual of 1939 lays down 'no borrowpits between the outer signals of stations'. Henceforth this will simplify the problem of protecting individual stations but will not greatly ameliorate the general public health problem of any district through which a railway may in the future be built.

3. Provincial Health Departments and Local Boards frequently issue notices in respect of malaria and mosquito nuisance attributed to railway borrowpits whilst

ignoring those created by road building authorities, provincial or local. Considerable malaria hazards have during the war been created by the Aerodrome Branch of the Central Public Works Department. Any regulation of earthwork enforced on the railway department must therefore be simultaneously made applicable to other authorities.

4. Schemes are at times produced by Agricultural and Fishery Departments for utilizing borrowpits for food production. I have seen borrowpits utilized for rice cultivation on both the Oudh and Tirhut and the East Indian Railways. Whilst rice cultivation is seldom as dangerous as weedy borrowpits, a reference by the Bengal Nagpur to the Oudh and Tirhut Railway evoked the reply that the system had grave objections and was to be deprecated. I have recently raised the matter again in respect of East Indian Railway borrowpits in Western Bengal. My report has not yet, however, been taken into consideration. I do not see how, under such conditions, banks can be periodically 'made up'.

5. Railway borrowpits are frequently leased out for fishing. This involves the objection that the lessees have the right to object to any form of larvicidal treatment, either by chemicals or by utilizing the newly announced method of planting water-hyacinth for the control of *philippinensis* and *sundaicus*.

6. Draining or filling borrowpits is liable to evoke village objection, as the contained water is often bailed out to save a crop or to serve a second one in the dry season. If borrowpits do not exist *ab origine*, this difficulty cannot arise.

7. In my reply to General Manager, East Indian Railway, mentioned in paragraph 1, I referred to the British railway construction method of 'cut and fill'. It was pointed out to me that this system is too costly for use other than where land is very expensive, which is not often the case in India. Even in England borrowpits, probably potentially malariogenic, exist on such lengths as Whitstable-Birchington (S. R.) and Bourne-Sutton Bridge (M. & G. M. Jt. Ry.) where there are no cuttings to provide the 'fill'.

8. *Culverts.*—The cost of a culvert under an embankment is directly related to its length. Engineers therefore tend to place the sill of a culvert higher than ground level, thus creating a dangerous pool on the up-stream side. They excuse this by pleading that with time the area below the sill will silt up to its level. Even when, which is not invariably the case, this ultimately occurs, malariogenic conditions are created that last some years. There is a good illustration of such a misplaced culvert in a book by Van Hovenberg, Antimalaria Engineer, St. Louis-South Western R. R., indicating that the Indian engineers are not unique in this respect.

9. *Cuttings.*—These often expose seepages of the most dangerous kind. Only on the Federated Malay States Government Railway have I seen these dealt with by lateral and by vertical sub-surface drainage.

APPENDIX III.

To be substituted for Railway Board's Letter No. 5233-W., dated 24-6-1946.

GOVERNMENT OF INDIA.

RAILWAY DEPARTMENT (RAILWAY BOARD).

No. P46G/147. *Dated New Delhi, the 21st Nov., 1946.*

To

ALL INDIAN GOVERNMENT RAILWAYS.

ANTIMALARIAL MEASURES TO BE ADOPTED DURING RAILWAY CONSTRUCTION.

1. THE Board have had under consideration the principles to be formulated for the avoidance of conditions which favour the spread of malaria produced as a result of rail constructions :—

(*a*) by the creation of borrowpits, either to obtain earth for embankments or in the process of quarrying for stone or gravel, without proper provision for their drainage ; and

(*b*) by the provision of culverts either insufficient in number, or placed incorrectly in respect to natural drainage.

BORROWPITS.

2. They, therefore, desire that in new line construction where the necessity arises for earth to be obtained by excavation of borrowpits for making up new embankments or for repairs to existing banks, the borrowpits should be so cut as to ensure that water does not remain stagnant in them. Where possible and practicable, the borrowpits should be left clean, free from 'dead men' and sharp-edged, and extra expenditure not exceeding 1 per cent of the cost of the earthwork in any project may be incurred to achieve this. The bed level of these borrowpits should be so graded and profiled that water will drain off by drainage channels connecting one pit with another till the nearest natural drainage nala is met with.

No borrowpits should be made anywhere within station or municipal limits or in the vicinity of station yards and it is presumed that most of the railways have already issued instructions to this effect.

In regard to quarries, the Board desire that new quarries should, wherever possible, be so worked as to leave a natural drainage fall and that pockets where water may be accumulated should be avoided.

CULVERTS.

3. The floors of culverts and minor bridges should be so designed as to avoid the formation of stagnant water on their up-stream side.

The Board desire that where culverts have to be provided in new line constructions or the existing ones have to be rebuilt, they should be so designed that the lowering of the invert levels by about 3 to 5 feet could be done if and when required without endangering the stability of the structure. The additional expenditure to be incurred for providing deeper founds to culverts should not however exceed 2 per cent of the cost of structures.

Provision of adequate waterways should continue to be made in accordance with the present practice.

Care should continue to be bestowed in placing culverts suitably as regards location, elevation and grade.

STAFF FOR ANTIMALARIAL WORK.

4. The Board have also considered the necessity for antimalaria officers to accompany survey parties and the provision for these officers and staff should be considered on the merits of each case—especially in bad countries where malaria is known to be prevalent.

When submitting estimates, necessary provision should be made for these officers and staff if considered necessary. If, however, the country through which the new line construction is undertaken is free from malaria or it is accepted by the local medical authorities as country in which the incidence of malaria is low, no provision should be made for such officers.

5. The above instructions of the Board should be embodied in the Manual of Instructions for Construction Engineers.

APPENDIX IV.

Consulting Engineer (Roads), Memorandum by Mr. G. A. D. COCHRANE, meeting of 23-9-46.

BORROWPITS IN LAND ACQUIRED TEMPORARILY FOR ROAD CONSTRUCTION.

1. THE earth required for embankments in road construction is obtained from one or more of three locations, namely :—

(*a*) By transfer from adjacent 'cuttings' along the road ;

(*b*) By the excavation of drains at the roadland boundaries, or removal of local high spots between the embankment toe and the boundary ;

(*c*) From 'borrowpits' dug in land lying outside the roadland boundaries.

This reference relates to item (*c*) namely, BORROWPITS.

2. Whilst the land required for the functional purposes of the road is usually acquired outright, that needed for purely construction purposes, i.e. for borrowpits, (and quarries), is either leased temporarily or acquired outright according as by the removal of such earth (or in the case of quarries other minerals) the land remains fit or becomes unfit for use for its original purpose.

This reference chiefly relates to what is known as temporary 'acquisition'.

3. Borrowpits can be objectionable in three main respects :—

(*a*) Unless they can be, and are, properly drained they increase the hazard of the incidence of malaria :

(*b*) When in cultivated, or cultivable land, they reduce the fertility of the land by—

(*i*) removing the valuable surface tilth ;

(*ii*) reducing the depth of the soil layer suitable for root development ; and

(*iii*) increasing the liability to water-logging (though in the more arid tracts, the extra water held may actually be advantageous).

(*c*) They produce an unsightly appearance, though careful layout and control can reduce the effect.

This reference relates to effects (*a*) and (*b*).

4. For any given quantity of earth required in the road embankment, the deeper the borrowpit, the less the area of land that has to be operated upon. The cost rate per unit quantity of earth is usually constant down to depths of about 4 feet (assuming the nature of the soil does not change in that depth). On the other hand such deep pits would—

(*a*) render the land unfit for further use, and therefore

(*b*) necessitate outright acquisition instead of temporary acquisition, thereby depriving the cultivator of his land forever ; and

(*c*) generally increase the malaria hazard.

On the whole we may say that deep pits are the most economical but should not be encouraged.

5. We have therefore to go in for shallow pits which—

(*a*) in any type of land, namely cultivated, uncultivated but cultivable, or non-cultivable waste, shall not increase the malaria menace; and

(*b*) in cultivated and cultivable lands shall, as far as possible, preserve the cultivability.

In regard to (*a*), everything depends on the general level-speed of the country, the location of the pits, and the feasibility of draining them. In some areas a depth of 2 feet might be a reasonable average; in others a lesser depth would have to be prescribed if the hazard is to be avoided. Less depth means more land, and longer carriage, and therefore more cost. The point is, however, supported in the Nagpur Report which classed as deserving of particular attention on provision in a Highways Act 'to discourage deep borrowpits as malaria inducing and dangerous to public health; to enforce shallow pits in land temporarily acquired'.

At least one Province (Central Provinces) already goes one step further by prohibiting (through an Executive Instruction) the digging of any borrowpits at all within a town or village, while the railways have a similar rule applicable to areas adjacent to railway colonies or railway stations. These health measures cause additional cost to the road authority through the extra cost of carriage involved.

In regard to (*b*) and more particularly in respect of land that is already under cultivation, we need not only relatively shallow pits which can generally be effaced into shallow depressions by ploughing, but we should also try to conserve the top-soil to a depth of, say, 6 inches.

(*Note.*—It is not easy to *dig* to less than 6 inches depth: anything appreciably less amounts to *scraping*.)

The process would then be:—

dig to 6 inches depth and remove to spoil banks;

excavate further to say 12 inches to 18 inches depth and deposit the earth in the road bank; replace the spoil (surface) earth in the pit, leaving a net depth of 6 inches to 12 inches. This is relatively a costly process. Land acquisition officers, in taking cognizance of the reduction in damage accruing to the land, [illegible] area rate of compensation payable, but use will have to be made not only of the area allotted to excavation but also of additional area on which the spoil earth can be temporarily stacked. This reference relates mainly to (*b*) of this item.

6. The effect of these combined measures of shallow borrowpits, and preservation of tilth in cultivable ground, is shown in the attached statement where four cases are compared. The rates approximate to some of those quoted by Bihar in their recent estimates for certain National Highways. It has, however, been assumed that there will be some reduction in the compensation payable for agricultural land when the top-soil is to be replaced, and that the rate payable for land used for stacking only will be reduced even further.

It will be seen that the process involving the replacing of the surface soil can be an expensive proposition. On the other hand, if it is not replaced, the cultivator stands a good chance of incurring continued loss over a protracted period.

7. The Board is asked to consider this question of '*borrowpits in land acquired temporarily for road construction purposes*'. It may readily agree that, as against the malaria hazard—

(a) shallow pits should be the rule, whether in cultivated or in uncultivated land;

(b) a depth of 12 inches is considered to be the maximum suitable in open country except in purely waste land and where the pits can be thoroughly drained;

(c) in areas within say ½ mile of a built up area, the depth of pits should not exceed 6 inches, and in fact, except in cultivated ground, the digging of any pits within such zones should be discouraged altogether.

The Board may advise on the even more important principle of *replacement of top-soil in cultivated areas used temporarily for borrowpits.* The extra cost is appreciable, and in the case of National Highways, it will fall on the Centre. The Board has to decide whether to recommend the principle for general adoption on National Highways in all Provinces (and States), whether with or without the proviso that Provinces will follow the same principle when constructing their own roads. If the Board is unable to come to an immediate decision on this matter (a reference to the Department of Agriculture may, for instance, be necessary) it is asked to advise on the particular case of Bihar in whose estimates for land and earthwork for National Highways such provision is now being made; these estimates cannot be approved and work cannot start unless a decision is reached. An unfavourable decision is apt to produce undesirable repercussions. An alternative is to ask Bihar to prepare a proper case by going into the financial and community effects in more details and by defining their own general policy in this regard.

Borrowpits in Temporary Land

Alternative costs per mile of road, assuming an average earth 'borrow' of 120 c.ft.

Serial No.		Case I. (Deep pits.)	Case II. (Shallow pits—replacement.)	Case III. (Shallow pits cultivated, rural.)	Case IV. (Very shallow pits—cultivated, near urban.)
1	Average gross depth of pit.	1·0	1·0	1′ 6″ } Effective depth 1′ 0″	1′ 0″ } Effective depth 6″
2	Depth of surface soil replaced.	*Nil*	*Nil*	6″	6″
3	Area of land affected—	$\frac{120}{4} \times 5{,}280 = 158{,}400$ FS	120 5,280 633,600 FS	14·5 acres	14·5 × 2 29·0
	(*a*) by excavation ;	= 3·62 Ac.			
	(*b*) by stacking surface soil to say 3 ft. height.	*Nil*	*Nil*	$\frac{14·5}{6}$ 2·4	$\frac{29·0}{6}$ = 5·0 say
4	Acquisition, temporary or permanent.	Permanent	Temporary	Temporary	Temporary
5	Rate per acre (per year for temporary)—				
	Type 3(*a*) ...	1,145/-	165/-	140/- } Assumed	140/- } Assumed
	Type 3(*b*) ...	...	...	100/-	100/-
6	Number of years of occupation of temporary land.	...	2	2	2
7	Total cost of land—				
	Type 3(*a*) ...	4,145/-	2 × 165 × 14·5 4,788/-	2 × 140 × 14·5 4,060/-	2 × 140 × 29·0 = 8,120
	Type 3(*b*) ...	...	...	2 × 100 × 2·4 480/-	2 × 100 × 5·0 = 1,000
	Total ...	4,145/-	4,788/-	4,540/-	9,120

BORROW PITS IN TEMPORARY LANDS—*contd.*

Serial No.		Case I. (Deep pits.)	Case II. (Shallow pits—replacement.)	Case III. (Shallow pits—cultivated, rural.)	Case IV. (Very shallow pits—cultivated near urban.)
8	Quantity of earthwork—				
	(*a*) placed in road ...	120 × 5,280 = 633,600	633,600	633,600	633,600
	(*b*) placed in spoil	*Nil*	*Nil*	316,800	633,600
9	Cost of this earthwork—				
	(*a*) in road @ Rs. 10 per 0/00 c.ft.	6,336/-	6,336/-	6,336/-	6,336
	(*b*) in spoil @ Rs. 7 per 0/00 c.ft.	...	...	2,118/-	4,236
	(*c*) from spoil back to pit @ Rs. 7 per 0/00 c.ft.	...	...	2,118/-	4,236
	(*d*) Total (*a*) to (*c*)	6,336/-	6,336/-	10,572/-	14,808/-
10	Total cost land plus earthwork 7+9 (*d*).	10,481/-	11,174/-	15,111/-	25,928
11	Per cent excess on Case I.	...	6·6 per cent	44 per cent	148 per cent

APPENDIX V.

Extract from minutes of a meeting held on the 27th September, 1946, in room No. 146, North Block, Imperial Secretariat Buildings, to discuss the question of borrowpits in land acquired temporarily for road construction.

The following were present :—

MR. D. D. WARREN, C.I.E., M.C., I.C.S.,
Secretary to the Government of India, Transport Department.

MR. M. K. SEN GUPTA, C.I.E.,
Financial Adviser, Communications.

MR. G. A. D. COCHRANE, I.S.E.,
Consulting Engineer to the Government of India (Roads), Transport Department.

MR. K. S. MISRA, I.C.S.,
Deputy Secretary to the Government of India, Transport Department.

MAJOR-GENERAL SIR GORDON COVELL, C.I.E., K.H.P., I.M.S.,
Director, Malaria Institute of India, Health Department.

RAI BAHADUR K. C. MAZUMDAR,
Director, Agricultural Machinery, Agriculture Department.

MR. H. D. AWASTY,
Deputy Director, Civil Engineering, Railway Department (Railway Board).

MR. K. RANGANATHAN,
Assistant Secretary to the Government of India, Transport Department.

* * * * * *

CONCLUSIONS.

(a) *on cultivable land* :—

(*i*) if the depth of borrowpits was limited to a maximum of 9 inches, the productivity would not ordinarily be seriously impaired for any undue period ;

(*ii*) where the circumstances were such as to necessitate deeper pits, a net depth of about 1 foot might be permissible in open country, provided the rate of compensation was adjusted to suit the additional period over which the productivity might be impaired. In special circumstances it might be a suitable and economical proposition to retain the top-soil for replacement in the pits ;

(*iii*) the net depth of pits within half a mile of a built up area in a town should ordinarily be limited to six inches;

(*iv*) the beds of the borrowpits should be left clean, and free from all 'dead men', 'matams' or other similar aids to the measurement of the depth of earth excavated;

(*v*) from the aspect of the incidence of malaria, a depth of 6 to 9 inches would not be objectionable, provided the pits were of regular shape and properly drained.

(*b*) [illegible] :—

(*i*) from the aspect of the incidence of malaria the pits in open country should be either relatively shallow, so that they would dry out quickly, or relatively very deep and narrow so as to keep the length of shore line to the minimum: deep pits should, however, be capable of being flushed and drained; physical objections to deep pits were that they were dangerous to cattle and that they soon become unsightly through the sides slipping in.

(*ii*) pits within half a mile of a built up area in a town should ordinarily not exceed 6 inches in depth;

(*iii*) no borrowpit should be dug within a built up area;

(*iv*) particular care was necessary in the siting and depth of borrowpits in hilly country against the possibility of tapping seepage water.

(c) *In deltaic areas and areas liable to inundation* :—

Fairly deep borrowpits were unobjectionable, provided they could be easily drained.

APPENDIX VI.

NOTE

BY

SIR ARTHUR DEAN,
Chairman, Delhi Improvement Trust,

ON

CONSTRUCTION OF ROAD EMBANKMENTS WITHOUT CREATING BORROWPITS.

The method which has been successfully followed in Delhi Province for the construction of many miles of new metalled and painted road consists of determining the quantity of earth needed for the embankment. The quantity was got out for every furlong or more closely if the height of the embankment changed rapidly. The formation width was 30 feet made up of 12 feet metalled and painted surface and 8 feet earthen berms on each side. The side slopes were at 1 : 5. This gentle slope was adopted (*a*) to reduce the danger to carts forced off the formation by motor traffic and (*b*) to reduce the damage caused by rain in cutting gullies in the bank. The average height was 2 feet 6 inches above field level. As however most of the roads followed pre-existing village cart tracks which had worn well below the natural surface extra earth was needed.

The nature of the land either side of the acquired road width was noticed on the plan, waste, dry cultivation, wet cultivation, etc., and the width needed to get the required quantity assuming a uniform depth of cut of 1 foot only was wanted. A decision was then taken as to whether the amount required should be taken equally from both sides or whether particularly valuable land should be omitted. Waste land and high mounds were naturally first choice.

The upper 6 inches of soil which carries the accumulated manure of years of cultivation was removed and stacked outside the area to be excavated in stacks 10 feet average width and 4 feet high finished with 1 : 1 slopes and as long as necessary (cross-section 40 s. ft.).

The soil below this was excavated 1 foot deep and the clods spread on the formation width of the road; broken and spread in 6 inches layers consolidated with rammers or sheep foot rollers until the formation height was attained.

As lengths of 1 mile or other convenient lengths of the road width were completed the whole excavated area was ploughed up and the top-soil spread over it and harrowed in. This was done by the local cultivators on a piece-work basis; they did not like having it done for them by outside contractors.

By postponing the work so that it started after the crops had been gathered in and taking care to complete the work before the preparation of the tilth and

spreading of manure for the next harvest had to start, no very serious interference with agricultural operations took place and instead of payment having to be made for temporary or even permanent acquisition, only compensation for loss of use of the land for at most one season was necessary. This went a good way towards meeting the higher cost of excavating in this manner.

For the small quantities of earth needed to make up the embankment as it is washed and worn away under the influence of the monsoon and traffic, collecting the earth dug out during the regular clearance of drains designed to intercept drainage running off the fields and bringing it to the nearest culvert was found sufficient. This was done to a template so as to avoid low-lying spots holding water.

APPENDIX VII.

CONTROL OF MALARIA IN PARTIES ENGAGED ON ROAD AND RAILWAY CONSTRUCTION.

BY

LIEUT.-COLONEL M. K. AFRIDI, I.M.S.,
Deputy Director, Malaria Institute of India.

1. RESPONSIBILITY.

MALARIA protection should be laid down as a policy of the administration and all officers should be instructed to co-operate.

The engineer-in-charge of construction should be made responsible for initiating all measures for the prevention of malaria. For this purpose he should make adequate provision for the requisite antimalaria personnel, equipment and stores.

2. ANTIMALARIA STAFF.

The size and composition of the antimalaria staff will vary with the magnitude of the project and the degree of malaria existing in the area in which road or railway construction is contemplated. In most projects traversing malarious regions it will be necessary to provide not only for the control of malaria but for a preliminary malaria survey. This survey may be entrusted to a railway malaria officer or to an officer borrowed from the provincial antimalaria organization. Alternatively it may be necessary to appoint a whole-time medical officer trained in malaria work, who after conducting the survey would take charge of the control measures approved by the engineer-in-charge. In case of any special difficulties, the Director, Malaria Institute of India, should be approached for assistance.

The essential point is that the survey should be carried out in the earliest possible phase of planning, preferably at the time when the engineering survey is in operation. This will enable the engineer-in-charge and the malariologist to prepare their plans in unison and to decide as to the order in which work is to be carried out, relegating the work on sections traversing highly malarious areas to months when the malaria season is at its lowest. It will also ensure that the staff, equipment and stores, which normally take time to collect, are in full working order before the actual construction begins.

3. METHODS OF CONTROL.

The following are the principal measures of control which apply particularly to the conditions under which parties engaged on road and railway constructions are normally housed :—

(*a*) *Site selection.*—The importance of selecting a proper site for a camp cannot be over-emphasized. In many instances, a careful search is rewarded by

the discovery of a site relatively free from malaria, though it may be situated only a few miles away from a highly malarious one. In areas where malaria is uniformly high certain sites may be easier to control than others.

While a decision on these points can be arrived at only after a consideration of the local terrain, etc., the following principles should invariably be observed :—

(*i*) Camps should be fixed at least one mile away from the nearest local habitations.

(*ii*) The sites for camps should be selected well in advance so that the antimalaria staff can initiate spraying and other preventive measures in each camp before it is occupied. For the same reason the malaria officer should be informed about the closing and opening of different camps at least one to two weeks in advance.

(*iii*) The sites should be clearly defined and no one allowed to erect shelters or tents outside the perimeter previously fixed.

(*iv*) If in the selection of a site the antimalaria requirements conflict with other needs such as of water-supply, food, etc., the antimalaria viewpoint should be given preference, especially in camps located in malarious regions.

(*b*) *Spraying with D.D.T.*—It is envisaged that in the construction of roads and railways, camps will have to be opened and closed frequently. Under these conditions, spraying with D.D.T. should be looked upon as one of the most important measures of control. The exact method of applying D.D.T., namely, whether in the form of indoor residual or outdoor barrier spray, will depend upon the length of time a camp is expected to be occupied. The former would be the method of choice if the camp is stationary for longer than 3 months, while the barrier spray should be reserved for camps occupied for a shorter period. Barrier spray consists of applying D.D.T. solution lightly once a fortnight at a dosage of 5 gallons per acre to (*i*) the outer surface of the buildings and tents. (*ii*) the ground surface between buildings and tents, and (*iii*) vegetation and ground surface for a distance of 50 yards around the camp.

(*c*) *Antilarval measures.*—These are indicated only in large camps which are likely to remain occupied for a period of six months of the malaria season or longer. Antilarval measures should be carried out along the usual lines, but drainage should be restricted to such breeding places as cannot be effectively dealt with by larvicides.

(*d*) *Suppressive treatment.*—Suppressive drugs are effective only if they are regularly taken. Their use in the first instance should therefore be confined to the superior staff, and to those who can be relied upon to take the drug as instructed. The labour force may however be placed on suppressive treatment, if arrangements for the strict supervision of administering the drug exist, particularly if an epidemic has broken out and is hampering the progress of the project.

(*e*) *Personal protection measures.*—The practical difficulties in enforcing these measures in a large contractor's labour force are so many that attempts to enforce them are unlikely to succeed. In the case of superior staff however it should be possible to instruct them to use mosquito-nets and repellents correctly and regularly.

4. THE SELECTION OF APPROPRIATE MEASURES OF CONTROL.

Factors which influence the selection are :—

(*a*) the size of the party ;

(*b*) the length of occupation of a camp and the stage of the malaria season at which it is occupied ; and

(*c*) the habits of the local malaria carrier mosquitoes.

For small mobile survey parties who are not expected to remain in one camp for longer than 10 to 14 days at a time, the selection of a site one mile away from the nearest local habitation should afford adequate protection, provided all members of the party remain inside the camp and are not allowed to visit local villages and houses from dusk to sunrise. In these parties the use of mosquito-nets and suppressive drugs could also be enforced, as it would be possible to provide the necessary supervision. The application of D.D.T. will necessitate a supply of sprayers and stores and the instruction of spray-gangs into the proper method of application. If the above conditions can be fulfilled this method of protection could also be utilized. Antilarval measures, on the other hand, would be impracticable and are not recommended.

In labour camps of any size which are likely to be occupied for less than 2 to 3 months, chief emphasis should be laid on proper selection of the camp site and efficient application of D.D.T. Personal protection and suppressive treatment would be applicable only to the superior staff. Antilarval measures should not be attempted. If labour is accommodated in ballast trains the latter should be treated as a camp, both in regard to its siting for the night and the application of D.D.T.

If labour is working at night, the site of the work should similarly be treated with D.D.T. on the principle of a barrier spray.

In large camps accommodating a considerable labour force which are stationary for six months or longer, the aim should be to provide control by antilarval measures, supplemented by the regular use of D.D.T. either over the entire camp or in the tents and shelters situated on the periphery. Should a camp be occupied in the middle or towards the end of the malaria season, it may not be possible to enforce antilarval measures in time to be effective. In these circumstances, it would be advisable to concentrate on D.D.T. spraying and to provide for the necessary antilarval control for the next malaria season.

Indian Journal of Malariology, **1**, 2, June 1947.

MALARIA CONTROL OF VILLAGES AROUND QUETTA (BALUCHISTAN) WITH D.D.T.

BY

LIEUT.-COLONEL M. K. AFRIDI, M.D., D.T.M. & H., I.M.S.,

AND

M. L. BHATIA, M.Sc. (Punj.), Ph.D. (Cantab.).

(*Malaria Institute of India.*)

(March 1, 1947.)

IT is unnecessary to describe in detail the epidemiology of malaria in the Quetta Vale as this has already been comprehensively dealt with by Mulligan and Baily (1936). The findings of these workers, amply confirmed by subsequent observations, were that malaria was highly endemic in the villages around Quetta and was carried by *A. superpictus*, *A. culicifacies* and *A. stephensi* whose favourite breeding habitats were springs, irrigation channels, rivers and perennial streams.

In April 1946, one of us (M. K. A.) was called upon to advise the Government of Baluchistan on the methods of controlling malaria in villages which formed a part of their plan for rural development and reconstruction. In the course of this visit, it was noted that the villages around Quetta possessed several particular advantages for an experiment on D.D.T. spray for the control of malaria. In the first place, the villages were situated at fairly long distances from each other so that each group of villages could be subjected to a specified differential treatment without its effects being interfered with by the spraying of a neighbouring group. Secondly, the construction and layout of the houses in all the villages was more or less uniform. Thirdly, although the intensity of malaria varied from year to year, its incidence even in a mild season was fairly high. Finally, as malaria transmission normally lasted from mid-July to mid-September it was reasonable to expect that the trial would yield definite and clear-cut results in a relatively short period of time.

Originally, the investigation was planned to be integrated with the D.D.T. spraying programme which the provincial antimalaria organization was to initiate in the villages around Quetta. The creation of the latter organization was, however,

delayed for administrative reasons, and we were obliged therefore to execute pilot control scheme in a limited number of villages independently. This fa greatly curtailed the scope of the investigations, as the investigatory staff had to diverted to supervise and to conduct the actual spraying operations. None t less it is felt that an account of how the control scheme was organized and wi what results might be of interest to workers similarly engaged.

AIMS AND OBJECTS.

In planning the control scheme the following objectives were kept in view :

(*a*) Whether malaria in a rural population in Baluchistan could be controll simply by killing adult mosquitoes by periodic D.D.T. spraying ;

(*b*) Whether the cost *per capita* on such control measures would be wit reasonable economic bounds ; and

(*c*) Whether spraying operations could be conducted in a community which purdah system (seclusion of women) rendered entry into hou difficult.

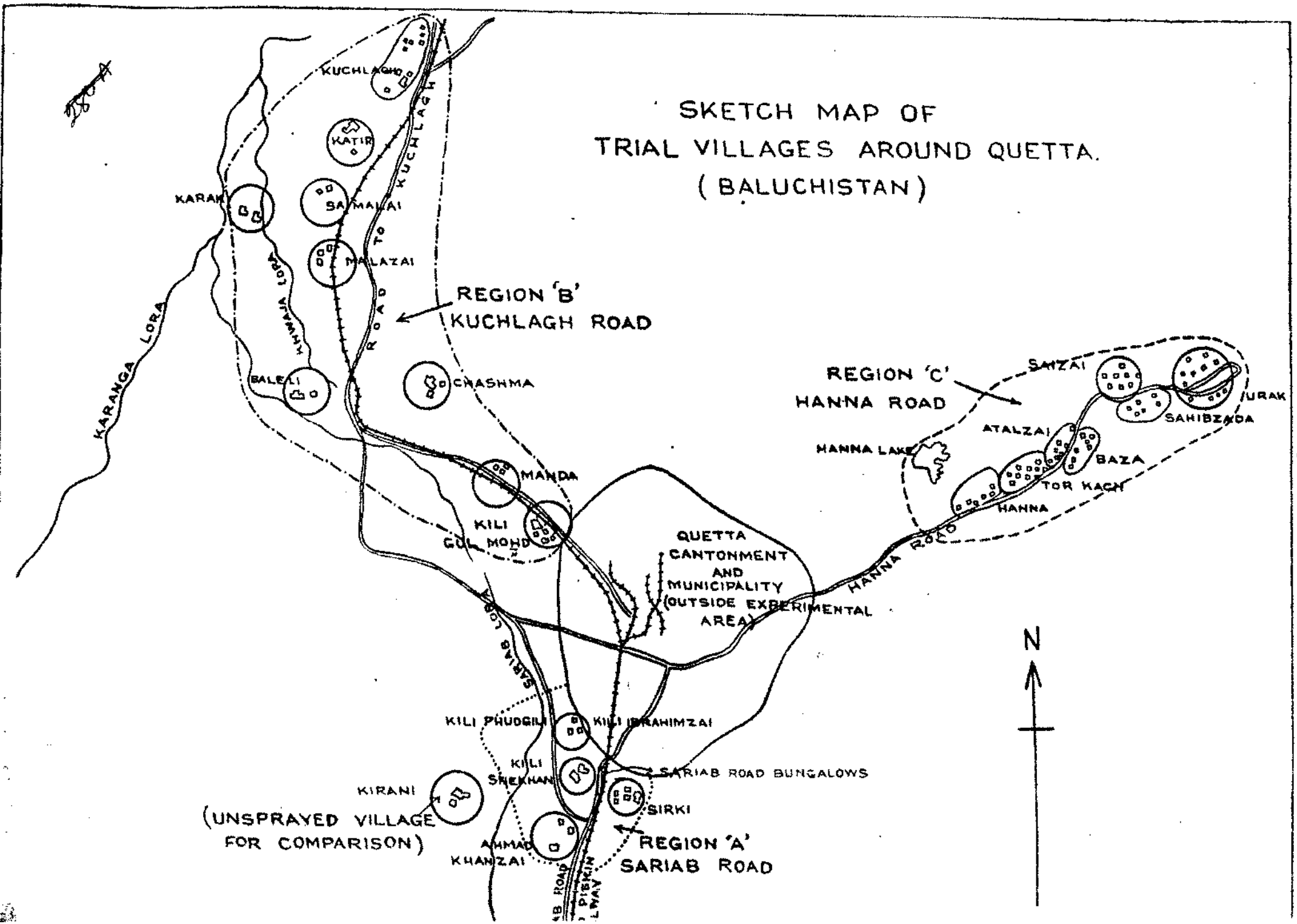
DESCRIPTION OF THE VILLAGES UNDER CONTROL.

The villages selected for experimental control were within easy reach of Que and were located along three roads radiating from the town (*vide* sketch ma Villages occurring in the immediate vicinity of Quetta Cantonment were howe excluded as the army antimalaria organization had already sprayed them w D.D.T. solution prior to the commencement of the trial.

Houses in these villages consisted of a perimeter wall enclosing a central co yard on three sides of which were living rooms for the family, covered sheds the cattle and open pens for the sheep. In some villages we encountered a gue house or a school-building made of burnt bricks with a corrugated iron roof the great majority of the houses were made of mud brick and mud plaster. only exception were the buildings on either side of Sariab Road which were bungalows made of burnt brick each having a separate compound containing small fruit garden, out-houses for servants and stables. Even so, these bungalo were limited to the two sides of the road, the villages further away being exac like those in the rest of the experimental area.

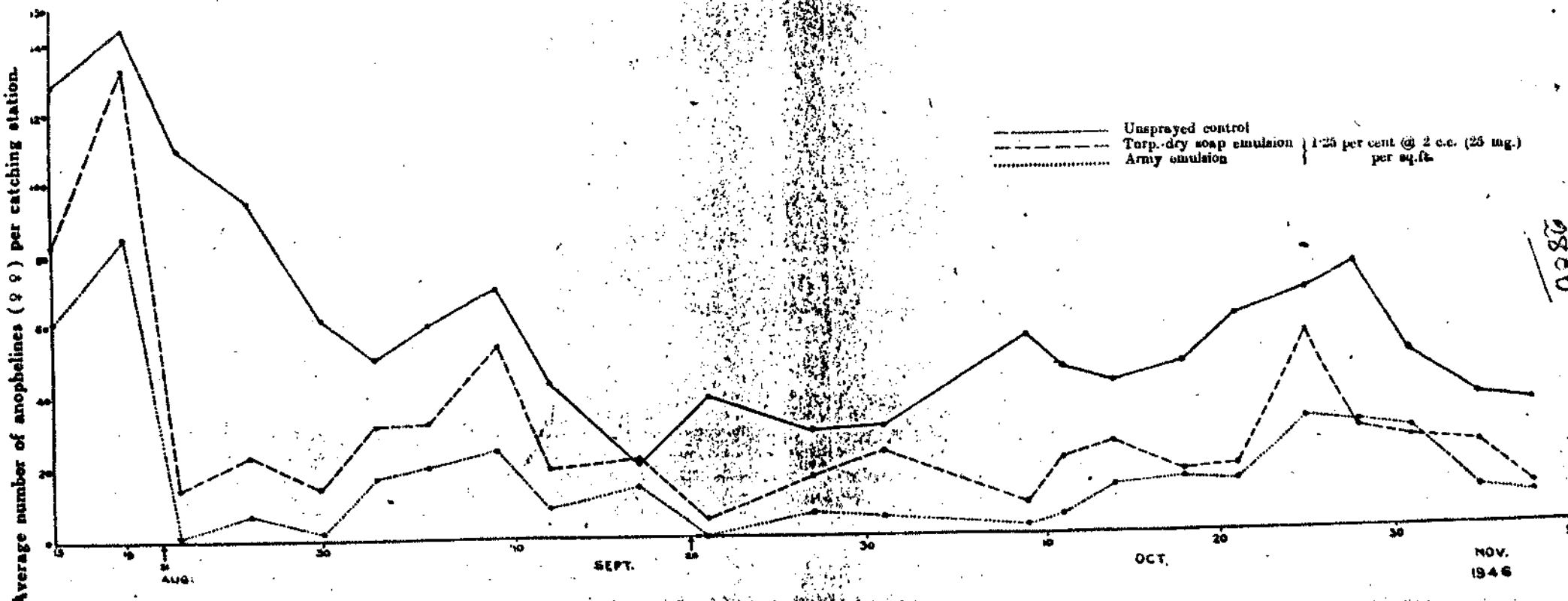
Around most of the villages were encampments of nomads who move up ev summer from southern Baluchistan in search of labour. They live gypsy fash in canvas or horsehair tents surrounded by their domestic animals tethered open ground.

Except for the nomads, the population of the villages is static, their m occupation being agriculture, sheep, goat, and cattle farming. The land is irriga from springs and karezes, the latter, fully described by Mulligan and Baily (*loc. ci* being a device for tapping subsoil water through an underground tunnel wh begins at the foot of the hills and ends in the central section of the valley. bed of the tunnel is aligned at a lesser slope than that of the ground surface so t eventually the subsoil water from the hills comes to surface as an open watercou in the low-lying part of the valley.


SKETCH MAP OF
TRIAL VILLAGES AROUND QUETTA.
(BALUCHISTAN)
KUCHLAGHO
KATIR
KARAK
SAMALZAI
MALAZAI
KUCHLAGH ROAD
REGION 'B'
KUCHLAGH ROAD
KHWAJA LORA
KARANGA LORA
BALELI
CHASHMA
MANDA
KILI GUL MOHD
QUETTA CANTONMENT AND MUNICIPALITY (OUTSIDE EXPERIMENTAL AREA)
REGION 'C'
HANNA ROAD
SAHZAI
URAK
SAHIBZADA
ATALZAI
BAZA
HANNA LAKE
TOR KACH
HANNA
HANNA ROAD
N
SARIAB LORA
KILI PHUDGIL
KILI IBRAHIMZAI
KILI SHEKHAN
SARIAB ROAD BUNGALOWS
SIRKI
KIRANI
(UNSPRAYED VILLAGE FOR COMPARISON)
AHMAD KHANZAI
REGION 'A'
SARIAB ROAD

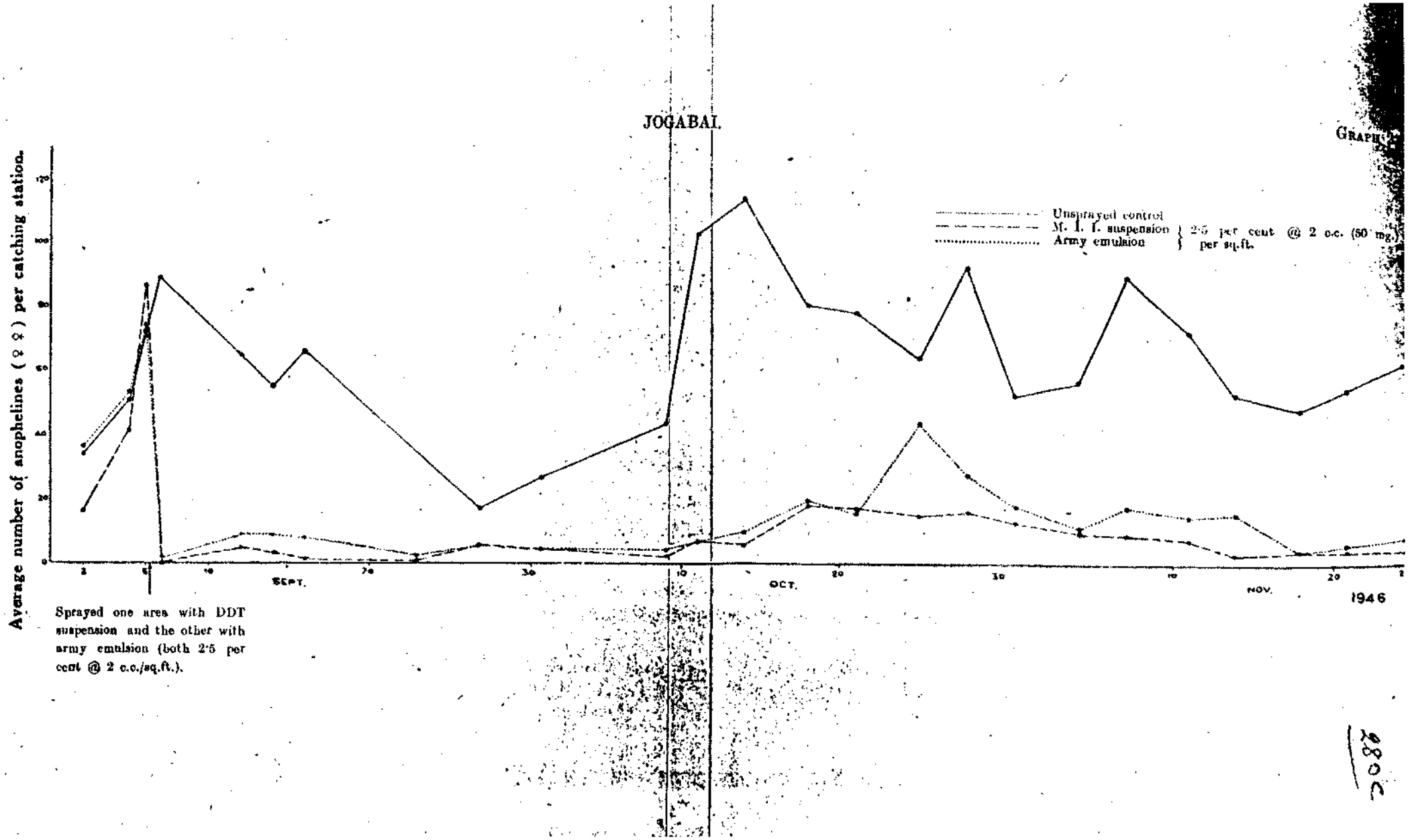
GRAPH 1.

OKHLA.

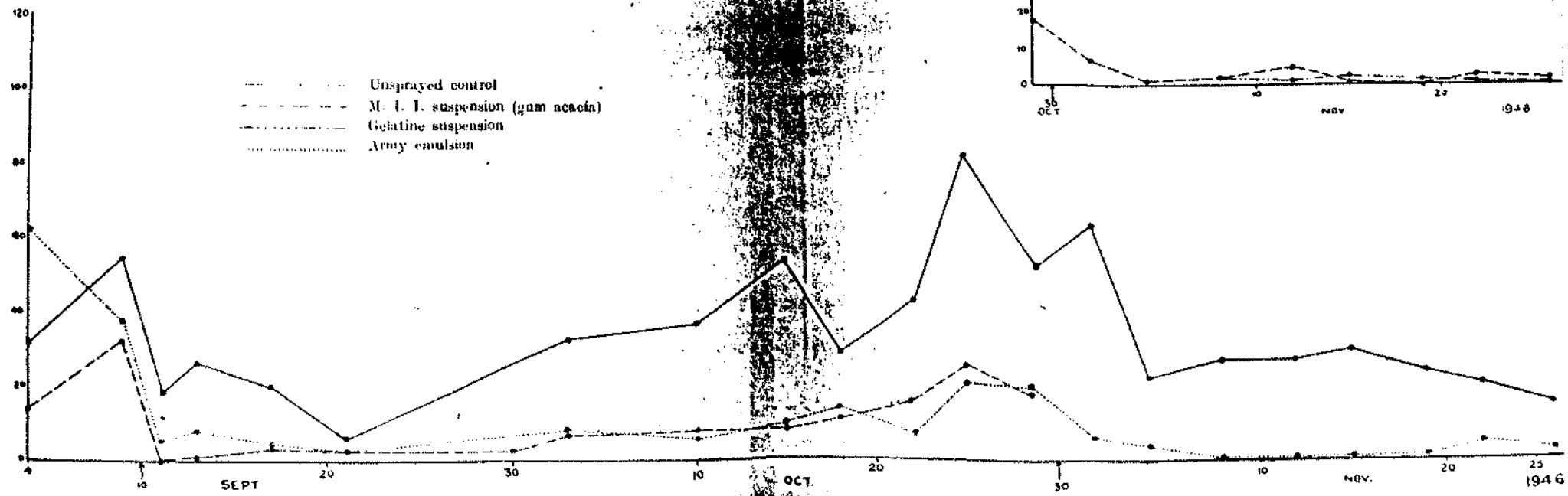


Sprayed one area with turp.-lux soap emulsion and the other with army emulsion (both 1·25 per cent @ 2 c.c./sq.ft.).

Re-sprayed (as before).


JOGABAI.
GRAPH
Average number of anophelines (♀♀) per catching station.
Unsprayed control
M. I. I. suspension
Army emulsion
2·5 per cent @ 2 c.c. (50 mg.) per sq.ft.
SEPT.
OCT.
NOV.
1946
Sprayed one area with DDT suspension and the other with army emulsion (both 2·5 per cent @ 2 c.c./sq.ft.).

GRAPH 3.

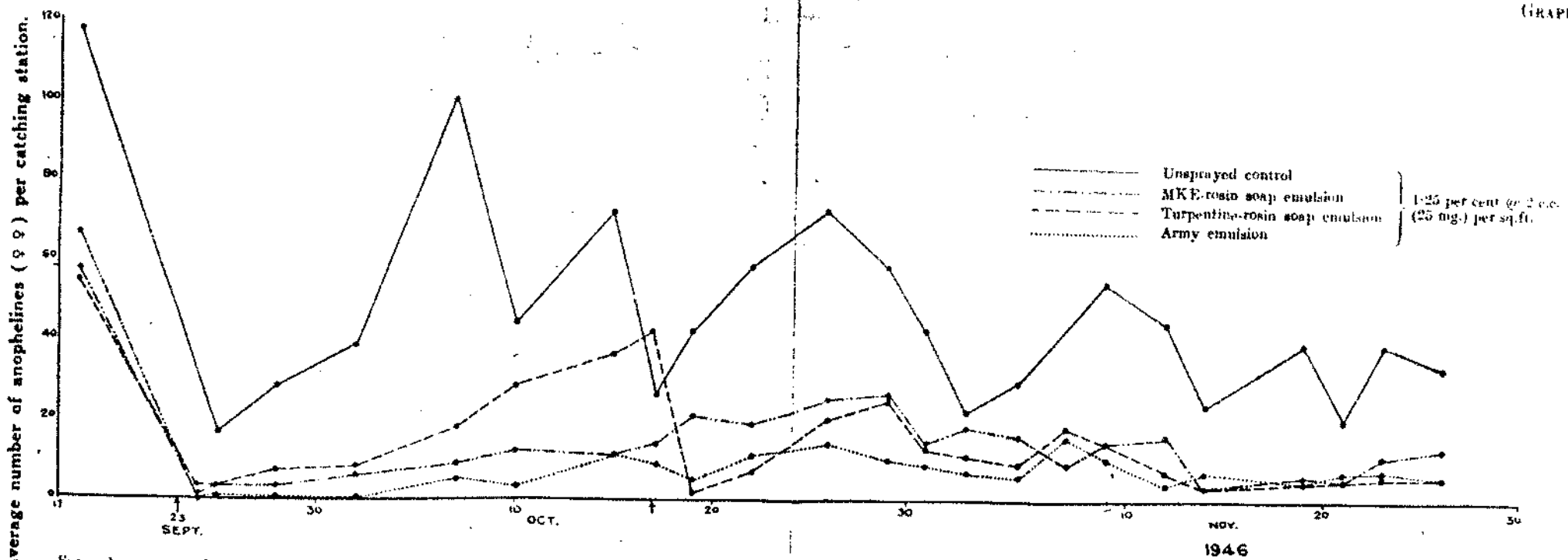


Sprayed one area with gum-acacia suspension and the other with army emulsion (both 1·25 per cent @ 2 c.c./sq.ft.).

Re-sprayed @ 1 c.c./sq.ft. Area II, one half with gum-acacia suspension and the other half with gelatine suspension (see line 1 Graph).

GRAPH 4.

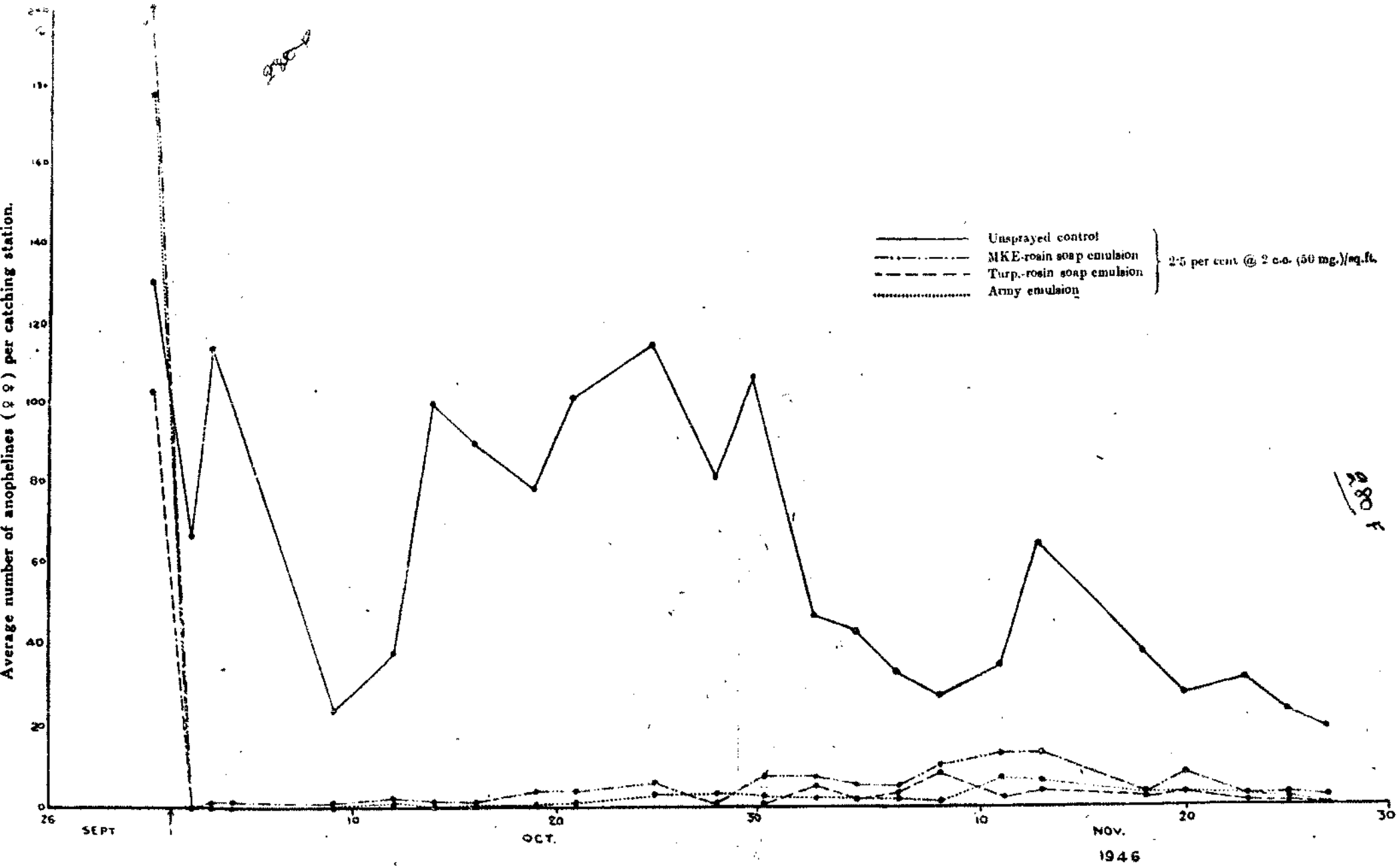
SILAMPUR.



Sprayed one area with turp.-rosin soap emulsion, the other with army emulsion, and the third with MKE-rosin soap emulsion (all 1·25 per cent @ 2 c.c./sq.ft.).

Re-sprayed turp.-rosin emulsion (as before).

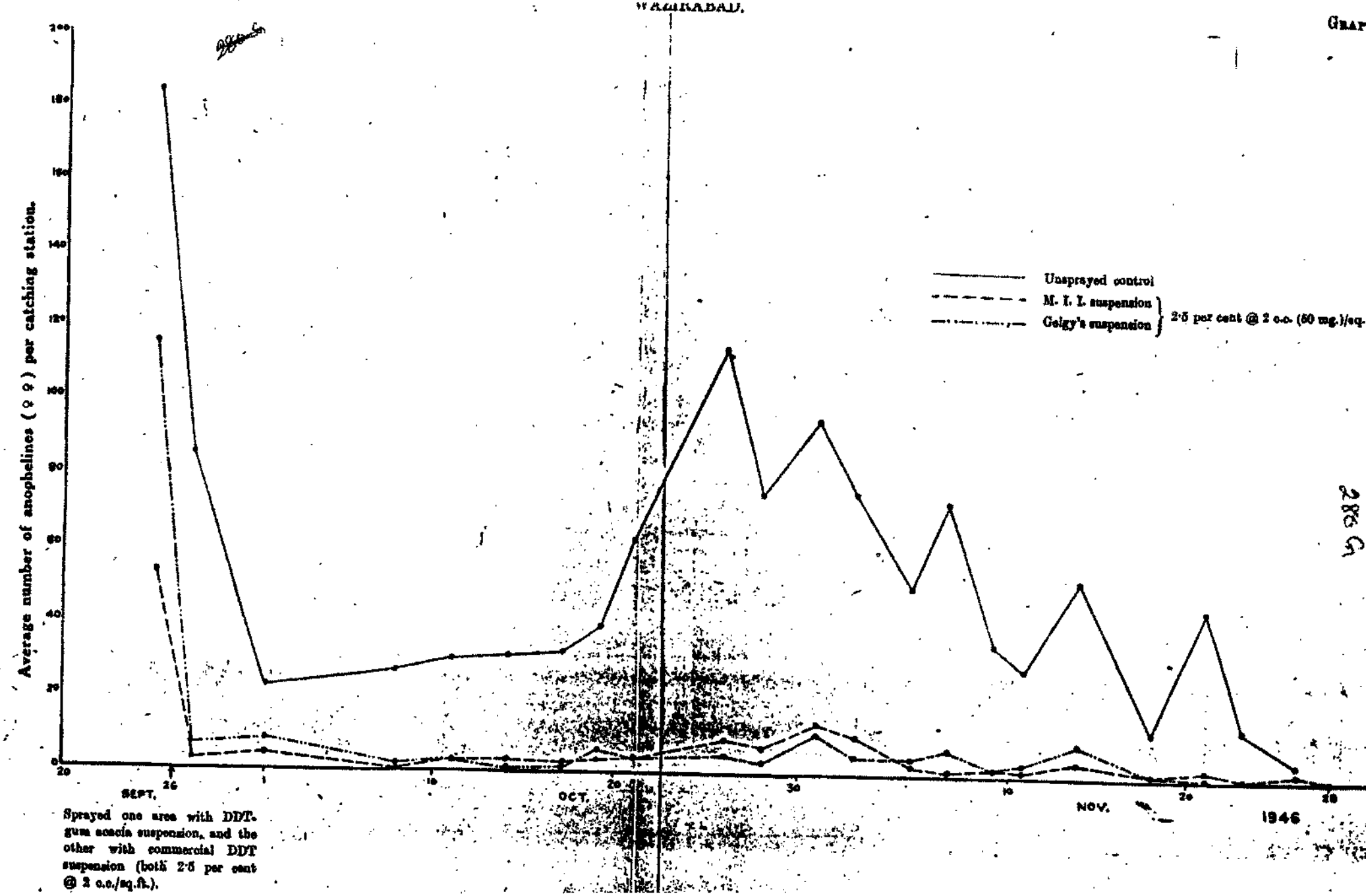
280 E



Sprayed one area with turp.-rosin soap emulsion, the other with army emulsion, and the third with MKE-rosin soap emulsion (all 2·5 per cent @ 2 c.c./sq.ft.)

WAZIRABAD.

GRAP

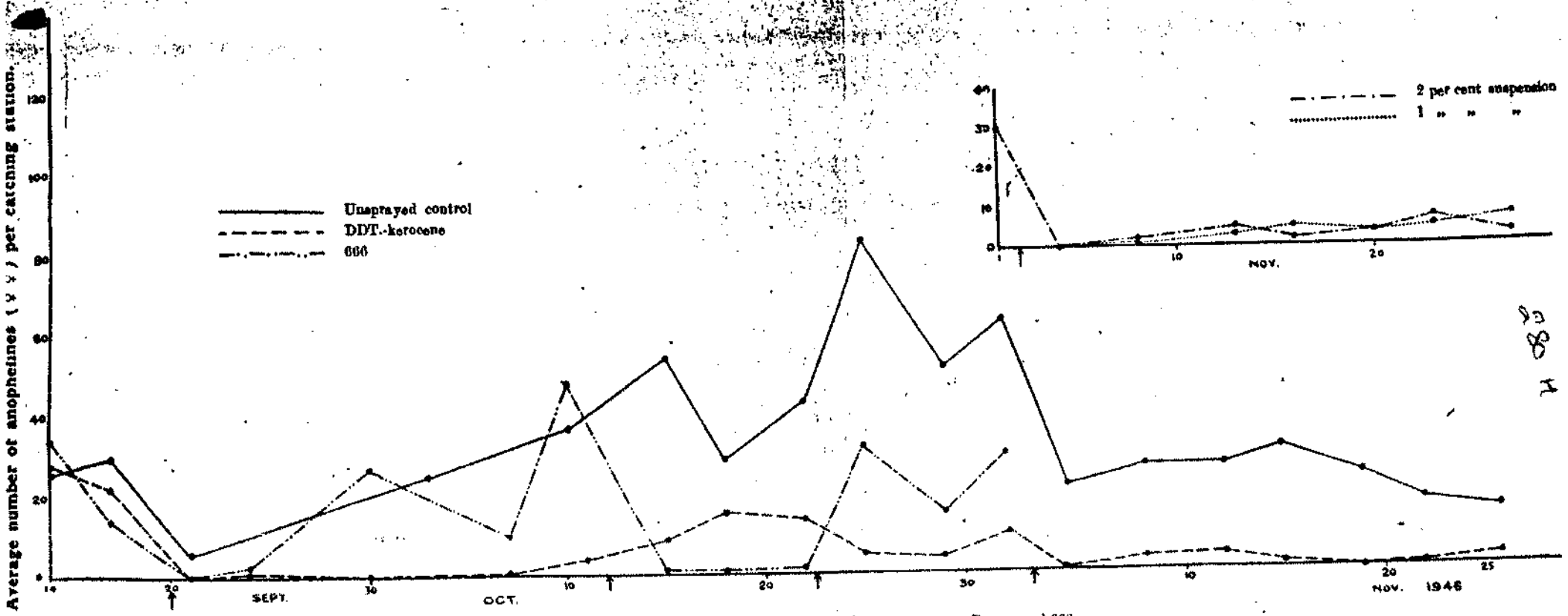


Sprayed one area with DDT. gum acacia suspension, and the other with commercial DDT suspension (both 2·5 per cent @ 2 c.c./sq.ft.).

286 G

GRAPH 7.

MASSIGARH.



Sprayed 2·5 per cent DDT and 0·5 per cent 666 (LG140) @ 2 c.c./sq.ft.

Re-sprayed with 1 per cent 666 (LG140) in kerosene @ 2 c.c./sq.ft.

Re-sprayed DDT area.

Re-sprayed 666 area half with 1 per cent and half with 2 per cent suspension of 666 (D939) (*see* Inset Graph above).

DESCRIPTION OF SPRAYING OPERATIONS.

(*a*) *Preparation of D.D.T. emulsion.*—Throughout our experiment we used an emulsion concentrate containing 25 per cent D.D.T. supplied to us through the courtesy of the Medical Directorate, General Headquarters (India). This emulsion was developed by the Chemical Warfare Laboratory, Jubbulpore, and is manufactured under military supervision to the following formula :—

D.D.T. (commercial)	... ...	25·00 parts.
Toluene	... ...	33·35 ..
Turpentine	... ...	33·35 ..
Rectified spirit	... ...	4·90 ,,
Dry soap	... ...	2·80 ,,
Distilled water	... ...	0·60 ,,
		100·00 parts.

For use in the field, one part of the concentrate was diluted with 9 parts of water to make a spraying emulsion containing 2·5 per cent D.D.T. In the early stages of the trials, the dilute emulsion was prepared in bulk and carried to the villages ready made for spraying. Later, this procedure was modified and arrangements were made to dilute the concentrate in the village itself. The correct strength of the diluted emulsion was ensured by the fact that one of us invariably accompanied the spraying party and supervised its dilution on the spot. To save time which would otherwise be wasted in searching out water locally, sufficient water was carried in four-gallon drums to prepare the first lot of spraying solution immediately on arrival.

(*b*) *Dosage of D.D.T. and spraying equipment.*—The diluted emulsion was carried in buckets and sprayed by means of stirrup pumps fitted with a special nozzle which emitted a coarse droplet spray at the rate of about 25 ounces of emulsion per minute. Wall surfaces were sprayed till they displayed a degree of wetness which on trial had previously been found to represent an approximate dosage of 1 to 1·5 c.c. per square foot, i.e. about 25 to 38 mg. of D.D.T. per square foot. Doorways, windows and other openings were treated more liberally, the dosage there being approximately twice that applied to the blind wall surfaces.

It is not claimed that every section of the buildings uniformly received the prescribed dosage of D.D.T. as it was impossible to attain such exactitude in a large-scale field trial. Care was however taken to keep a strict and constant watch on the spraying gangs to ensure that spraying was carried out as prescribed.

(*c*) *Methods of application of D.D.T.*—As already stated, the villages selected for experimental control were located along three roads radiating from Quetta, the group of villages along each road forming a distinct region as follows :—

Region A	...	5 villages and 15 bungalows astride Sariab Road.
Region B	...	13 villages astride Kuchlagh Road.
Region C	...	7 villages astride Hanna Road.

The first round of spraying commenced on July 22, and was completed on August 2, 1946. On this occasion only outdoor spraying was practised in all three

regions. The second round with D.D.T. lasted from August 19 to 28 in rotation so that each region was sprayed four weeks after the first. The application of D.D.T. in this round was however varied in the three regions as follows :—

Region A	...	Outdoor and indoor spraying.
Region B	...	Indoor spraying only.
Region C	...	Outdoor spraying only.

(*d*) *Organization of field work.*—Labour and transport were secured through the help of Major H. A. Ledgard, I.M.S., Chief Medical Officer in Baluchistan, who was kind enough to place at our disposal the services of two supervisors, 25 field workers and one three-ton lorry. Ten spraying equipments each consisting of a bucket and a stirrup pump were obtained on loan from the local military authorities. This number of sprayers ensured that on an average seven units were available in good working order for daily use. Originally, three men were allotted to each sprayer but later this number was reduced to two men, employing the remainder of field workers on preparing spraying emulsion on the spot and distributing it to the spraying gangs.

The possibility of employing local labour recruited for the day from the village earmarked for spraying was explored but was found to be impracticable for the reason that as the same individuals could not always be available it would have been necessary to train new hands at each spraying turn, an obviously unsatisfactory arrangement.

It was found easier therefore to work with men recruited for a season who readily became proficient and interested in their work. The usual routine was to load up the lorry in the morning with men, D.D.T. emulsion concentrate, spraying equipment and tools for immediate repairs to spray nozzles and hose connections. On arrival at a village, the medical officer would explain to the supervisors the limits of the outlying buildings which had to be included in the spraying operation. He would then seek out the headman of the village, and after explaining the purpose of his visit, would secure his assistance in gaining admission into the houses. The supervisors would then obtain permission from each householder and detail the necessary number of spraying units to spray the house, the two supervisors covering the adjoining sections of the village in a leap frog manner. With these precautions, we encountered no difficulties in obtaining permission to enter houses. We found it necessary however to keep the spraying gangs concentrated over a limited section of the village to ensure that no houses were missed and that spraying was adequately supervised. Each supervisor kept a running daily account of the number of rooms or tents sprayed in each village and the amount of D.D.T. emulsion expended.

SUMMARY OF DATA OBTAINED FROM SPRAYING OPERATIONS.

A statement showing the number of rooms and tents sprayed and the amount of D.D.T. emulsion and man-hours expended in the process is set forth in Table I.

This table brings out a number of interesting points of practical importance. Taking the results of the first treatment when D.D.T. was applied outdoors in all

three regions, it will be observed that in region C (Hanna Road) time taken in spraying was longer and the amount of solution expended per room was less than in the other two regions.

The explanation for this apparent paradox was that the villages on Hanna Road consisted of small groups of houses scattered over a wide area but the individual rooms and courtyards were relatively smaller in size. It follows therefore that the economy of all such spraying operations would be influenced not only by the average dimension of the rooms but also by the circumstance whether the villages are compact or spread out.

Secondly, comparing the results of the two treatments in region B, it will be seen that indoor spraying proved more economical than outdoor both in respect of the amount of D.D.T. used and the time taken in spraying. Finally, in so far as villages in Baluchistan are concerned, the average expenditure per village was 20 gallons of 2·5 per cent emulsion (about 5 pounds of D.D.T. powder) for each round of spraying applied at a dosage of 25 to 38 mg. per square foot.

COST OF SPRAYING.

Since the latest census report compiled in 1941 does not contain figures for population by villages, we had to arrive at an approximation after making local enquiries, and consulting the provincial rationing authorities. From these sources, the total static and nomadic population of the sprayed villages was reckoned to be not less than 20,000.

The actual cost of two sprayings with D.D.T. is given below :—

Wages :		
Two supervisors for 21 days ...	Rs. 88·2	
Twenty-five men ,, ,, ...	,, 595·0	Rs. 683·2
Transport :		
Hire of lorry for 21 days at Rs. 18/- per day		,, 378·0
D.D.T. emulsion :		
Cost of 103·2 gallons of concentrate emulsion at Rs. 18/- per gallon ...		,, 1,857·6
Spraying equipment and incidental expenses :		
Depreciation of 10 sprayers and repairs, etc.		,, 81·2 approx.
Total ...		,, 3,000·0 ,,
Cost per capita		Annas 2·4

Notes :—

(*a*) Wages for holidays during each spraying round have been included but not the period intervening between the first and the second treatment as the spraying staff was then diverted to spray buildings in the Quetta municipal area.

(*b*) The cost of D.D.T. emulsion is based on the cost of ingredients plus reasonable manufacturing charges and not on the actual book price which is inexplicably high.

THE EFFECT OF SPRAYING ON MALARIA.

The original plan was to make detailed observations on the effect of spraying in the treated villages on (*a*) the density of and infection rates in anophelines, (*b*) actual morbidity figures obtained from periodical visits to the villages, and (*c*) spleen and parasite rates amongst children. But, as already explained, this programme had to be curtailed owing to the fact that the investigatory staff was diverted to supervise spraying operations. Efforts were therefore concentrated exclusively on conducting the last-named set of observations, namely, spleen and parasite rates amongst children between 2 and 10 years of age, the results of which are given in Table II.

From this table it will be observed that :—

(*a*) In the unsprayed village, the spleen and parasite indices followed the normal course indicative of a moderately high degree of malaria transmission. Thus, the rise in parasite rate in August was followed a month later by a rise in spleen rates and the size of the average enlarged spleen.

(*b*) In the sprayed villages in regions B and C there was a noticeable rise in the parasite rates indicating a mild degree of malaria transmission not sufficient however to influence the spleen rates which instead of showing a rise were actually lower in September than at the beginning of the malaria season in June.

(*c*) In the sprayed village in region A, the results were disappointing inasmuch as both the spleen and parasite rates in September showed a significant increase over the June figures. This was an unexpected finding particularly as in the second round of spraying D.D.T. was applied more liberally in this region than in the other two, when it was sprayed both indoors and outdoors. It is highly improbable, therefore, that the unfavourable results denote a failure of D.D.T. spraying. A more likely explanation is that as this region adjoined an uncontrolled area, the controlled population contracted malarial infection during visits to the neighbouring unsprayed villages. In this respect the other two regions were more favourably placed in that the nearest unsprayed village on Kuchlagh Road (region B) was 10 miles away whereas on Hanna Road (region C) no villages were left unsprayed.

Dr. S. Dakshinamurthy was kind enough to subject the combined results of the sprayed and unsprayed villages to X^2 test on the spleen rates and 't' tests on the average enlarged spleen. His conclusions were as follows :—

(1) Spleen rates in the experimental and comparison villages were significantly different to start with but after spraying they were much more so showing that spraying had significantly reduced the spleen rates.

(2) Average enlarged spleens in the experimental and comparison villages were not significantly different to start with, but after spraying they were significantly different, showing that spraying had prevented a rise in the size of the spleens in the experimental villages.

CONCLUSIONS.

The successful outcome of D.D.T. spraying in this trial is particularly noteworthy in view of the fact that :—

(*a*) The dosage of D.D.T. applied was unusually low (25 to 38 mg. per square foot).

(*b*) The first round of D.D.T. spraying was made at a time when infections in *A. superpictus* had actually started. This is borne out by the results of investigations conducted concurrently by Puri and Bhatia (1947) in a comparable village near Quetta.

(*c*) Sprayings were successfully carried out in a part of India where owing to the purdah system (seclusion of women) this method of control is commonly thought to be impracticable.

The cost *per capita* of 2·4 annas after two rounds of sprayings is low but this figure could be reduced to 1·4 annas in Baluchistan if future spraying programmes are based on our results and the findings of Puri and Bhatia (*loc. cit.*), namely, that spraying is done only once a year with D.D.T. suspension applied indoors at a dosage of 50 mg. per square foot. Indoor spraying is recommended for economic reasons only having been found cheaper both in respect of man-hours and the amount of D.D.T. solution. From the malaria control point of view the results obtained from outdoor sprayings in region C in both rounds of sprayings were as satisfactory as in the other two regions where in the second round indoor spraying was practised alone or combined with outdoor.

It should be mentioned that the cost *per capita* given above does not take into account the cost of supervision by a medical officer. If this item be included, the cost would approximate 2 annas, a figure estimated by Puri (1947) for rural control of malaria by one spraying only.

SUMMARY.

1. An organization set up to control malaria in villages around Quetta, Baluchistan, with a total population of about 20,000 is described in detail. Evidence is produced to show that malaria was effectively controlled by two sprayings of D.D.T. emulsion at a dosage of 25 to 38 mg. per square foot.

2. The actual cost *per capita* over two sprayings was 2·4 annas but effective control could be secured by indoor spraying applied once a year with D.D.T. suspension at 50 mg. per square foot. The cost in that case would approximate 1·4 annas exclusive and 2·0 annas inclusive of supervision by a medical officer.

3. No insuperable difficulties were encountered in gaining entry into the house for spraying despite the local custom of purdah system (seclusion of women).

ACKNOWLEDGMENT.

We are greatly indebted to Major A. H. Ledgard, I.M.S., Chief Medical Officer, Baluchistan, but for whose assistance and help this trial could not have been carried out. We are also grateful to Drs. S. P. Ramakrishnan, A. Goswami, and M. K. Menon, for their assistance in determining the spleen and parasite rates in the villages.

REFERENCES.

MCLEAN, H. W., and BAILY, J. D. (1936). Malaria in Quetta, Baluchistan. *Rec. Mal. Surv. Ind.*, **6**, 2, pp. 289–385.

PURI, I. M. (1947) ... The practical application of D.D.T. for malaria control in rural and urban areas in India. *Ind. J. Mal.*, **1**, 1, pp. 211–220.

PURI, I. M., and BHATIA, M. L. (1947). Studies on some insecticides against anopheline adults and larvae. Part III. Experiments with D.D.T. as a residual spray in some villages in Baluchistan. *Ibid.*, **1**, 1, pp. 183–191.

TABLE I.

D.D.T. and man-hour expenditure in spraying.

Date.	Region.	Number of			Man-hours expended in total spraying.	Man-minutes taken in spraying one room/tent.	Amount of 2·5 per cent D.D.T. emulsion expended.		Method of applying D.D.T.
		Rooms.	Tents.	Total.			Total in gallons.	Per room/tent in oz.	
July 22 to 24	A	1,148	435	1,583	361	13·7	226	22·84	Outdoor.
July 25 to 29	B	1,522	225	1,747	457	15·7	211	19·32	Do.
July 30 to August 2.	C	476	56	532	225	25·4	58	17·44	Do.
				Second round of spraying.					
Aug. 19 to 21	A	1,148	435	1,583	390	14·8	316	31·94	Outdoor and indoor.
Aug. 22 to 26	B	1,522	225	1,747	362	12·4	160	14·65	Indoor only.
Aug. 27 to 28	C	476	56	532	230	25·9	61	18·35	Outdoor only.

TABLE II.

Spleen and parasite rates.

	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	A.E.S. in cm.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.
Unsprayed village.							
Karani—							
June ...	64	23	36·0	11·0	64	4	6·2
August ...	55	21	38·1	10·6	55	23	36·3
September ...	32	21	65·6	7·5	25	7	28·0
Sprayed villages.							
Region A—							
June ..	145	14	9·7	7·8	145	8	5·5
September ...	86	18	20·9	10·6	86	13	14·0
Region B—							
July ...	132	41	31·1	10·9	111	11	9·9
September ..	112	31	27·7	10·7	81	5	6·1
Region C—							
July ...	33	15	45·5	10·6	...	...	...
September ...	57	20	35·0	9·3	28	3	10·7
Total sprayed villages—							
June/July ...	310	70	22·6	10·08	256	19	7·8
September ...	225	69	27·1	10·25	195	21	10·8

A.E.S.=Average enlarged spleen.

Indian Journal of Malariology, **1**, 2, June 1947.

PRELIMINARY NOTE ON INVESTIGATION OF MALARIA IN BENGAL-ORISSA BORDER, SOUTH OF KHARGPUR.

BY

N. GANGULI, M.B., D.P.H., D.T.M.

(*Malaria Section, Medical Department, Bengal Nagpur Railway.*)

(March 3, 1947.)

INTRODUCTION.

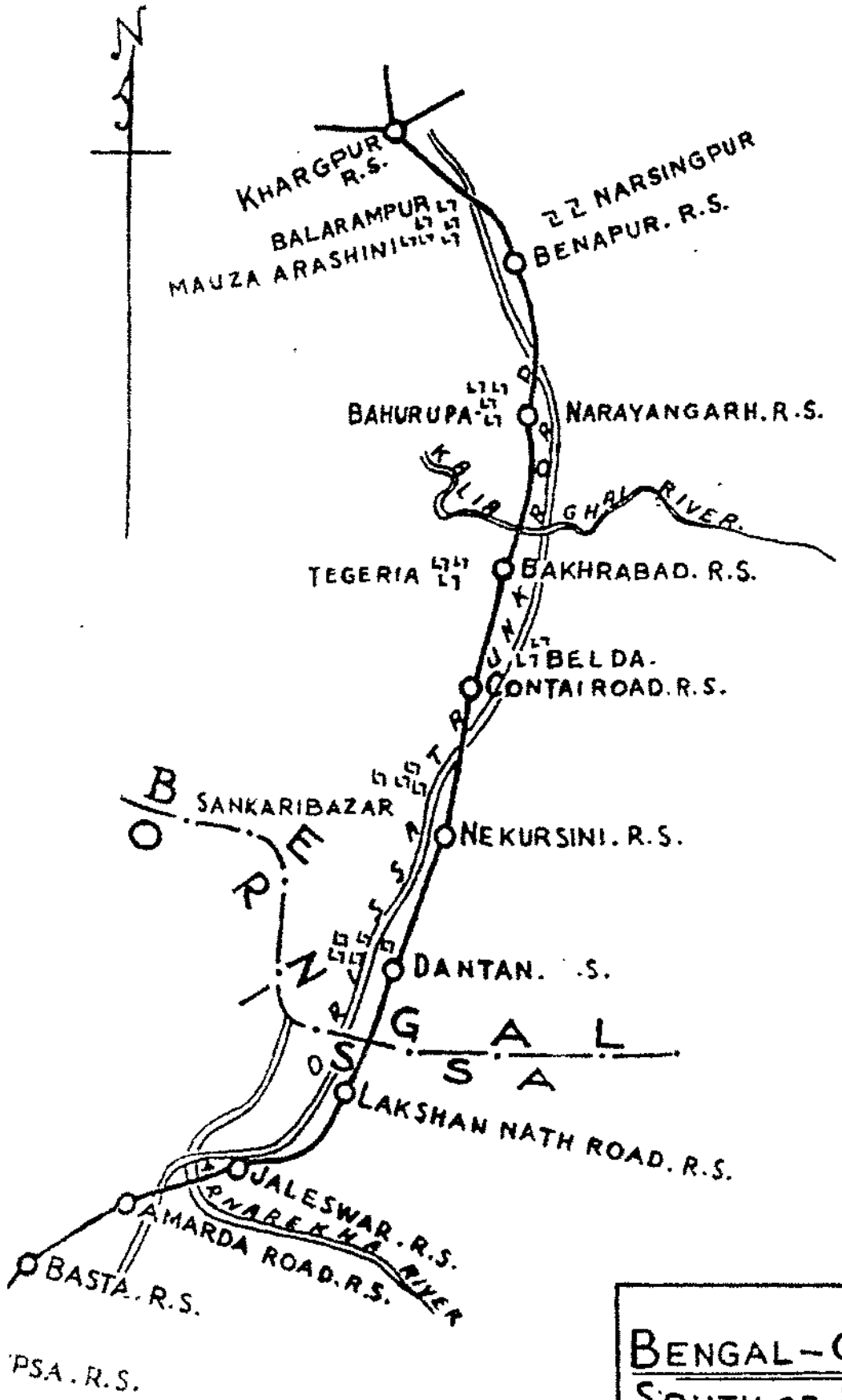
MALARIA is endemic in the area adjacent to the important railway colony of Khargpur on the Bengal Nagpur Railway and a preliminary investigation about the malaria prevalence in that area was instituted from April 1944 to December 1945, on the Madras line between Khargpur and Rupsa junction (Map 1) before making a systematic attempt at its control. The investigation primarily aimed at determining the species responsible for the transmission of malaria in this area. The railway colonies and the villages in close proximity to the railroad were selected for this purpose.

The area selected lies on the border of Bengal and Orissa and has a laterite soil intermingled with alluvium. A change-over in the nature of the soil is known to effect a corresponding change in the vector species as pointed out by Sen (1933) and Biswas (in a private communication in 1943), who, working in Asansol area on the borders of Bengal and Bihar, found that *A. philippinensis*, the chief carrier of malaria in the alluvial deltaic Bengal, gave place to *A. culicifacies* as the vector in the laterite area. Similarly, Senior White *et al.* (1943) working further south of the area under our investigation consider *A. philippinensis* to be of no epidemiological importance, *A. annularis* being the main carrier of local malaria there.

The object of the present survey was, therefore, mainly directed towards obtaining definite information about the respective rôles of *A. philippinensis* and *A. annularis* as carriers of malaria in this part of the country.

PHYSIOGRAPHY.

The laterite vein runs south to within 75 miles of Howrah, and then turns as a continuous formation westward. The soil in this area is therefore mainly



BENGAL-ORISSA BORDER
SOUTH OF KHARGPUR.

NOT TO SCALE.

old alluvium with an occasional laterite outcrop. The general slope of the land is from west to east, and is traversed by two rivers Kaliaghai and Subarnarekha, running parallel to each other from west to east up to the Bay of Bengal.

CLIMATE AND POPULATION.

The climate is generally warm and humid throughout the greater part of the year. The rainy season usually starts about the middle of June and lasts till the end of October, the average annual rainfall varying from 60 to 70 inches, the maximum precipitation occurring in July and August.

The local inhabitants of the villages are mostly of Bengalee and Oriya stock, mainly engaged in rice cultivation. The race composition of the railway population is varied consisting principally of Bengalees, Oriyas and Telegus.

MALARIA MORBIDITY.

The malaria cases at Rupsa, which is 65 miles south of Khargpur, and at intermediate stations for the period 1943–45 are given in Table I and are graphically represented in Chart I. These show that the seasonal incidence of malaria is from August to December with a peak in October.

MALARIA ENDEMICITY.

Spleen examination of children between 2 and 10 years of age on the railroad between Khargpur and Dantan was carried out in April 1944 (Table II). At Balarampur (Mauza Arashini of Ordinance Survey), Narsinghpur and Benapur, spleen rates were very high and varied from 82 to 85 per cent. As one proceeds southwards beyond Benapur, there is a considerable fall in the spleen rate and figures range between 36·6 and 48·5 per cent. The majority of the children with enlarged spleens had a spleen size varying between 2 and 3 fingers' width below the costal margin.

ANOPHELINE SURVEY.

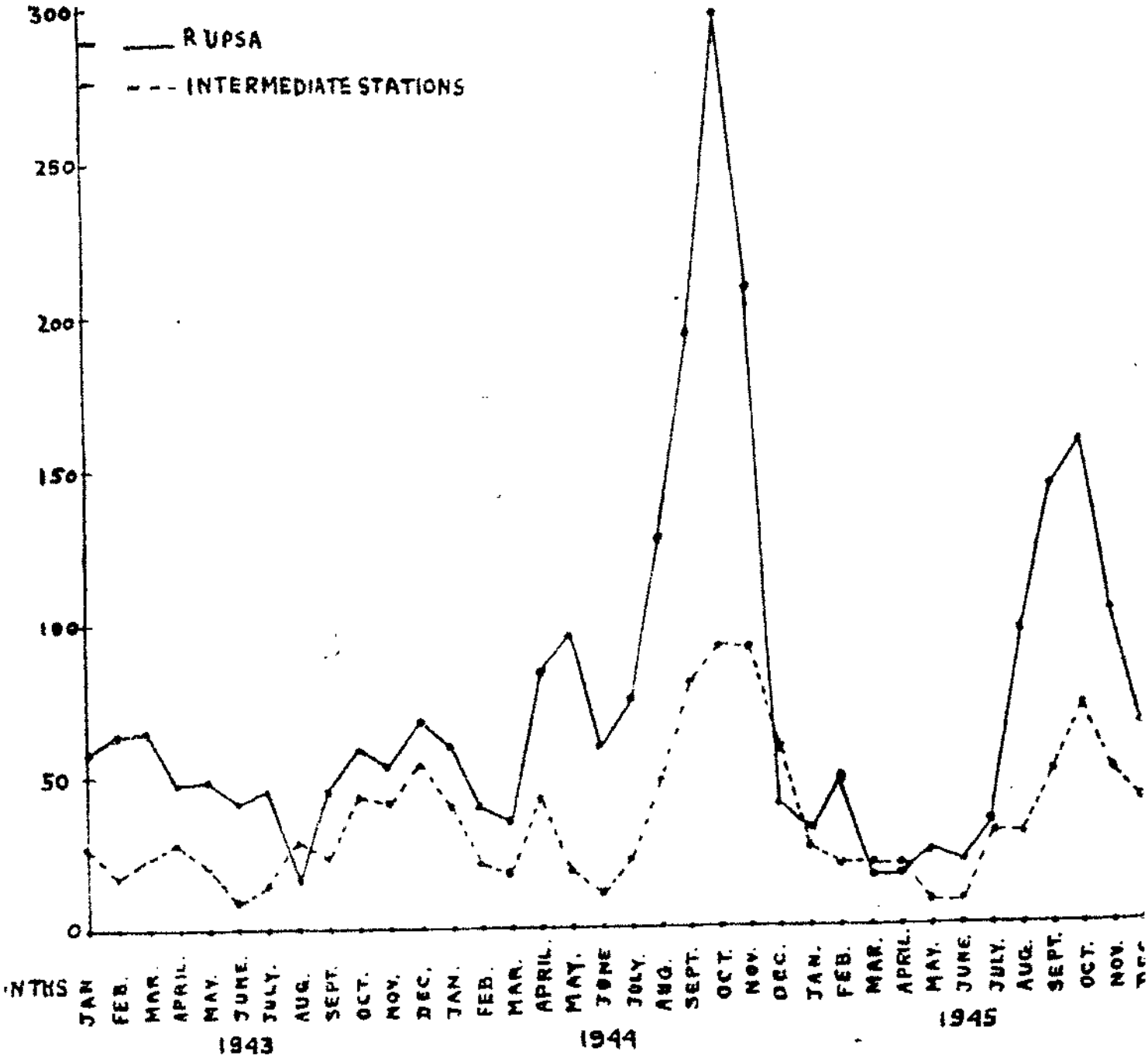
Routine adult anopheline catches from selected catching stations in the area between Khargpur and Rupsa were started in the month of August 1944, once a fortnight, and were continued till the end of December 1945, with a break of a month in January and June 1945. The following species of adult anophelines were identified and the results of actual catches are tabulated in Table III.

A. hyrcanus var. *nigerrimus* Giles, 1900.
A. barbirostris van der Wulp, 1884.
A. culicifacies Giles, 1901.
A. varuna Iyengar, 1924.
A. aconitus Dönitz, 1902.
A. subpictus Grassi, 1899.
A. vagus Dönitz, 1902.
A. ramsayi Covell, 1927.
A. annularis van der Wulp, 1884.
A. philippinensis Ludlow, 1902.
A. pallidus Theobald, 1901.

A systematic search of cowsheds between Balarampur and Rupsa failed to reveal a single specimen of *A. philippinensis* (Table III). It may be noted that in this area *A. philippinensis* is known to display a decided preference for human

habitations rather than cattlesheds. Thus, Timbres (1935) working in Birbhum found it 8·6 times more common in houses than in cattlesheds, and Krishnan (1940) in Burdwan district found it 14·1 times more frequent in houses.

CHART I.



Malaria cases at Rupsa and at stations between Khargpur and Rupsa.

A. philippinensis rested in the daytime mostly on the walls of dark rooms from about 4 feet above the floor, hanging clothes, umbrellas, etc., and were

neither encountered too near the floor nor in the kitchens. The popular conception that *A. philippinensis* disappears from the walls with the advance of day was not confirmed, as specimens were caught in fair numbers even at and after midday during the present survey.

DISSECTIONS.

Regular dissections of *A. annularis* and *A. philippinensis* caught from both houses and cattlesheds were made during the present survey and the results have been tabulated (Table IV). Table V shows the results of dissections of *A. philippinensis* in the whole area month by month. While no infection was found in a total of 792 *A. annularis* dissected during 1944 and 1945, *A. philippinensis* was found naturally infected on as many as twelve occasions, out of a total of 294 dissections. In 1944, specimens of *A. philippinensis* dissected during the months of August, September and October showed infections in both gut and gland, while in 1945 infection was met with in September and October only. First year's work yielded an oöcyst rate of 2·2 per cent and a sporozoite rate of 3·4 per cent, while the corresponding rates for the second year were 0·9 and 0·9 per cent respectively.

DISCUSSION.

The results of dissections carried out during the years 1944 and 1945 show that *A. philippinensis* plays a significant rôle in the causation of malaria in the area concerned. The sporozoite rate in this species, which at the beginning of the malaria season in August 1944 was found to be 2·3 per cent, rose to a peak of 5·2 per cent in September and thereafter gradually declined to zero in November. In 1945, however, October was the only month when a sudden rise in sporozoite rate from zero to 5·5 per cent was noticed. No gland infections were encountered in the earlier months. Sur (1929) also found a sporozoite rate of 3·5 per cent in *A. philippinensis* during the month of September at Chandrakona, about 40 miles to the north-east of Khargpur. According to Iyengar (1944), *A. philippinensis* in deltaic Bengal has a limited seasonal activity, viz. from July till December, when the species is not only abundant but is heavily infected. Our findings in this area corroborate his observations. The rise in the infectivity rate in *A. philippinensis* is followed by a rise in the number of malaria cases. It is of interest to note that all the infected mosquitoes were obtained from Balarampur (Mauza Arashini), near Khargpur and Dantan bordering on Orissa, whereas no infections were found in mosquitoes caught from localities further north, although malaria there is equally severe. The question whether *A. philippinensis* can be held responsible for malaria in the latter area can only be answered after further investigation.

SUMMARY.

(1) *A. philippinensis* has been found naturally infected for the first time in portions of the area under investigation during the months of August, September and October, with a peak in September–October.

(2) The malaria season coincides with the increase in density and infectivity rate of *A. philippinensis*.

REFERENCES.

..ENGAL, M. O. T. (1941)	...	Problems relating to malaria control in deltaic Bengal. *J. Mal. Inst. Ind.*, **5**, pp. 435–447.
..ISHNAN, K. V. (1940)	...	Annual Report, All-India Institute of Hygiene & Public Health, 1939, pp. 32–36.
..N, L. (1933) ...	...	Annual Report, Asansol Mines Board of Health, 1933-34.
..NOR WHITE, K., ADHIKARI, A. K., RAMAKRISHNA, V., and ROY, B. B. (1943).		On malaria transmission on the Orissa coastal plain. *J. Mal. Inst. Ind.*, **5**, pp. 159–186.
..R, S. N. (1929) ...	...	Malaria problem of Bengal. Bengal Government Press.
..MBRES, H. G. (1935)	...	Studies on malaria in villages in western Bengal. *Rec. Mal. Surv. Ind.*, **5**, pp. 345–370.

TABLE I.

Statement showing malaria cases at Rupsa and stations between Kharagpur and Rupsa during the years 1943, 1944 *and* 1945.

Month.	Rupsa.			Intermediate stations.		
	1943.	1944.	1945.	1943.	1944.	1945.
January ...	58	60	31	27	40	26
February ...	64	40	38	17	21	20
March ...	65	34	16	23	48	18
April ...	47	83	16	27	42	20
May ...	49	96	25	20	19	8
June ...	41	58	21	9	11	7
July ...	46	74	28	14	22	33
August ...	16	127	96	29	48	30
September ...	46	194	142	23	80	50
October ...	59	299	158	43	97	72
November ...	53	214	103	41	96	50
December ...	69	40	64	53	59	41
TOTAL ...	613	1,319	738	326	553	375

TABLE II.

Statement showing spleen rates of localities between Khargpur and Dantan in April 1914.

Locality.	Station.	Number examined.	V_0	V_1	V_2	V_3	V_4	V_5	V_6	V_7	Percentage.	Average enlarged spleen in fingers' breadth.
Balarampur ... (Mauza Arashini)	Khargpur	34	6	0	8	12	2	4	0	2	82·5	3·4
Narsinigpur ...	Benapur	14	2	0	2	6	2	2	0	0	85·7	3·3
Benapur ...	Benapur	13	2	1	3	3	2	2	0	0	84·6	3·1
Bohurupa ...	Narayangarh	21	11	2	2	1	2	0	3	0	47·6	3·2
Tegeria ...	Bakhrabad	30	19	2	5	3	1	0	0	0	36·6	2·3
Belda ...	Contai Road	33	17	6	5	2	2	0	0	1	48·5	2·3
Sankaribazar ...	Nikurseni	28	15	2	4	4	1	1	1	0	46·4	2·7
Dantan ...	Dantan	84	52	13	5	2	5	4	2	1	38·1	2·7

O = A search was made, but no specimens found.

TABLE III.

Collections of adult anopheline mosquitoes during 1944 and 1945.

Month.	House catch.												Cattleshed catch.											
	A. hyrcanus.	*A. barbirostris.*	*A. culicifacies.*	*A. varuna.*	*A. aconitus.*	*A. subpictus.*	*A. vagus.*	*A. ramsayi.*	*A. annularis.*	*A. philippinensis.*	*A. pallidus.*	Total.	*A. hyrcanus.*	*A. barbirostris.*	*A. culicifacies.*	*A. varuna.*	*A. aconitus.*	*A. subpictus.*	*A. vagus.*	*A. ramsayi.*	*A. annularis.*	*A. philippinensis.*	*A. pallidus.*	Total.
1944.																								
August ..	2	0	1	0	0	31	8	3	3	43	4	95	6	2	2	0	2	90	10	76	6	0	28	222
September ..	5	0	0	0	0	45	11	1	10	77	0	149	10	0	0	0	18	102	24	38	56	0	30	278
October ..	3	0	0	3	1	32	14	6	23	27	58	167	8	0	0	2	0	48	8	54	76	0	94	290
November ..	5	0	0	0	5	26	6	4	43	6	8	101	4	0	0	0	0	27	7	18	20	0	48	124
December ..	2	0	0	1	0	20	14	3	25	6	4	75	5	1	0	0	0	22	9	16	20	0	36	109
Total ..	17	0	1	4	6	153	52	17	104	159	74	587	33	3	2	2	20	289	58	202	178	0	236	1,023
1945.																								
February ..	2	0	0	0	2	31	26	4	46	9	6	126	..	..	..	..	..	..	..	..	..	..	..	..
March ..	4	0	0	1	2	15	11	0	47	0	2	82	..	..	..	..	..	..	..	..	..	..	..	..
April ..	3	0	0	0	16	23	10	2	39	4	3	100	..	..	..	..	..	..	..	..	..	..	..	..
May ..	0	0	0	0	2	18	11	0	34	2	0	67	..	..	..	..	..	..	..	..	..	..	..	..
June ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
July ..	0	0	0	2	0	16	5	65	23	6	7	124	4	1	0	1	3	55	12	88	29	0	36	229
August ..	3	1	0	2	0	17	10	27	64	21	24	169	14	2	0	4	8	114	26	80	66	0	66	380
September ..	4	0	0	3	10	45	11	20	98	18	31	240	10	1	0	2	9	99	20	59	95	0	30	316
October ..	3	1	0	4	1	31	14	81	33	19	27	214	9	3	0	3	7	101	18	77	88	0	43	349
November ..	6	0	0	3	10	25	7	22	29	21	53	176	..	..	..	..	..	..	..	..	..	..	..	..
December ..	4	0	0	11	15	20	15	8	74	17	36	200	..	..	..	..	..	..	..	..	..	..	..	..
Total ..	29	2	0	26	58	241	120	229	487	117	189	1,498	37	7	0	10	27	360	76	304	278	0	175	1,274

0 = A search was made, but no specimens found.
.. = No collection.

Page-296

TABLE IV.

Results of dissections of A. annularis *and* A. philippinensis *from human habitations and cowsheds during the years* 1944 *and* 1945.

Month.	HOUSE CATCH.											
	BALARAMPUR (MAUZA ARASHINI).						DANTAN.					
	annularis.			*philippinensis.*			*annularis.*			*philippinensis.*		
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1944.												
August ..	3	0	0	43	1	1	..	..	..	..	..	..
September ..	1	0	0	62	2	3	3	0	0	15	0	1
October ..	16	0	0	22	1	1	2	0	0	5	0	0
November ..	43	0	0	6	0	0	..	..	..	..	..	..
December ..	25	0	0	6	0	0	..	..	..	..	..	..
Total ..	88	0	0	139	4	5	5	0	0	20	0	1
Infection rate, per cent.	..	0	0	..	2·9	3·6	..	0	0	..	0	5·0

Month.	HOUSE CATCH.						CATTLESHED CATCH.					
	RUPSA.						BALARAMPUR (MAUZA ARASHINI).					
	annularis.			*philippinensis.*			*annularis.*			*philippinensis.*		
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1944.												
August ..	..	..	..	..	..	..	3	0	0	0	0	0
September ..	6	0	0	0	0	0	12	0	0	0	0	0
October ..	5	0	0	18	0	0	15	0	0	0	0	0
November ..	..	..	..	..	..	..	20	0	0	0	0	0
December ..	..	..	..	..	..	..	20	0	0	0	0	0
Total ..	11	0	0	18	0	0	70	0	0	0	0	0
Infection rate, per cent.	..	0	0	..	0	0	..	0	0	..	0	0

G+ = Gut infected. Gl+ = Salivary glands infected.
0 = A search was made, but no specimens found. .. = No collection.

TABLE IV—*contd.*

CATTLESHED CATCH.

Month.	Dantan.						Rupsa.					
	annularis.			*philippinensis.*			*annularis.*			*philippinensis.*		
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1944.												
August ..	..	..	..	..	..	..	..	..	..	..	..	..
September ..	12	0	0	0	0	0	4	0	0	0	0	0
October ..	15	0	0	0	0	0	8	0	0	0	0	0
November ..	..	..	..	..	..	..	..	..	..	..	..	..
December ..	..	..	..	..	..	..	..	..	..	..	..	..
Total ..	27	0	0	0	0	0	12	0	0	0	0	0
Infection rate, per cent.	..	0	0	..	0	0	..	0	0	..	0	0

HOUSE CATCH.

Month.	Balarampur (Mauza Arasgini).						Contai Road.					
	annularis.			*philippinensis.*			*annularis.*			*philippinensis.*		
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1945.												
February ..	46	0	0	9	0	0	..	..	..	..	..	..
March ..	47	0	0	0	0	0	..	..	..	..	..	..
April ..	39	0	0	4	0	0	..	..	..	..	..	..
May ..	34	0	0	2	0	0	..	..	..	..	..	..
June ..	..	..	..	..	..	..	..	..	..	..	..	..
July ..	5	0	0	6	0	0	3	0	0	0	0	0
August ..	46	0	0	6	0	0	3	0	0	14	0	0
September ..	12	0	0	15	1	0	14	0	0	0	0	0
October ..	14	0	0	19	0	1	11	0	0	0	0	0
November ..	4	0	0	18	0	0	7	0	0	3	0	0
December ..	17	0	0	13	0	0	12	0	0	1	0	0
Total ..	264	0	0	92	1	1	50	0	0	18	0	0
Infection rate, per cent.	..	0	0	..	1·1	1·1	..	0	0	..	0	0

G+ = Gut infected.
O = A search was made, but no specimens found.
Gl+ = Salivary glands infected.
.. = No collection.

TABLE IV—*contd.*

HOUSE CATCH.

Month.	Lakshnath Road.						Rupsa.					
	annularis.			*philippinensis.*			*annularis.*			*philippinensis.*		
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1945.												
February ..	..	..	..	..	..	..	..	..	..	..	..	..
March ..	..	..	..	..	..	..	..	..	..	..	..	..
April ..	..	..	..	..	..	..	..	..	..	..	..	..
May ..	..	..	..	..	..	..	..	..	..	..	..	..
June ..	..	..	..	..	..	..	..	..	..	..	..	..
July ..	12	0	0	0	0	0	3	0	0	0	0	0
August ..	6	0	0	0	0	0	9	0	0	1	0	0
September ..	39	0	0	0	0	0	33	0	0	3	0	0
October ..	10	0	0	0	0	0	18	0	0	0	0	0
November ..	15	0	0	0	0	0	3	0	0	0	0	0
December ..	16	0	0	1	0	0	29	0	0	2	0	0
Total ..	98	0	0	1	0	0	95	0	0	6	0	0
Infection rate, per cent.	..	0	0	..	0	0	..	0	0	..	0	0

CATTLESHED CATCH.

Month.	Balarampur (Mauza Aras ini).						Contai Road.					
	annularis.			*philippinensis.*			*annularis.*			*philippinensis.*		
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1945.												
July ..	12	0	0	0	0	0	1	0	0	0	0	0
August ..	18	0	0	0	0	0	14	0	0	0	0	0
Total ..	30	0	0	0	0	0	15	0	0	0	0	0
Infection rate, per cent.	..	0	0	..	0	0	..	0	0	..	0	0

G+ = Gut infected.
O = A search was made, but no specimens found.
Gl+ = Salivary glands infected
.. = No collection.

TABLE IV—*concld.*

CATTLESHED CATCH.

Month.	Lakshnath Road.						Rupsa.					
	annularis.			*philippinensis.*			*annularis.*			*philippinensis.*		
	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.	Number dissected.	G+.	Gl+.
1945.												
July ..	14	0	0	0	0	0	2	0	0	0	0	0
August ..	2	0	0	0	0	0	9	0	0	0	0	0
Total ..	16	0	0	0	0	0	11	0	0	0	0	0
Infection rate, per cent.	..	0	0	..	0	0	..	0	0	..	0	0

G+ = Gut infected. Gl+ = Salivary glands infected.
0 = A search was made, but no specimens found. .. = No collection.

TABLE V.

Combined data of seasonal incidence of natural infection in A. philippinensis *between Balarampur (Mauza Arashini) and Rupsa.*

Month.	1944.					1945.				
	Number dissected.	G+.	Gl+.	Oöcyst rate, per cent.	Sporozoite rate, per cent.	Number dissected.	G+.	Gl+.	Oöcyst rate, per cent.	Sporozoite rate, per cent.
February ..	..	..	..	..	..	9	0	0	0	0
March ..	..	..	..	..	..	0	0	0	0	0
April ..	..	..	..	..	..	4	0	0	0	0
May ..	..	..	..	..	..	2	0	0	0	0
June ..	..	..	..	..	..	..	..	..	..	..
July ..	..	..	..	..	..	6	0	0	0	0
August ..	43	1	1	2·3	2·3	21	0	0	0	0
September ..	77	2	4	2·6	5·2	18	1	0	5·5	0
October ..	45	1	1	2·2	2·2	19	0	1	0	5·5
November ..	6	0	0	0	0	21	0	0	0	0
December ..	6	0	0	0	0	17	0	0	0	0
TOTAL ..	177	4	6	2·2	3·4	117	1	1	0·9	0·9

G+ = Gut infected. Gl+ = Salivary glands infected.
0 = A search was made, but no specimens found. .. = No collection.

Indian Journal of Malariology, 1, 2, June 1947.

MEASUREMENTS OF MALARIA.*

Part I.

INTRODUCTORY: 'SAY IT WITH NUMBERS'.

BY

S. DAKSHINAMURTY, M.B.B.S., B.S.Sc., D.P.H., D.T.M. & H.
(*Malaria Institute of India.*)

[March 15, 1947.]

'When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind.'—LORD KELVIN.

THE subject of statistics affects everyone in the modern world whether they like it or not. Our very entry and exit, health and sickness, marriages and divorces are all recorded statistically. Advertisers and propagandists either try to convince or fool us by statistical facts and arguments every day of our lives. In any country, Government and local bodies are the largest collectors of statistical data. The former are responsible for the periodical census while the latter record our births, deaths and marriages—the three vital events of life—while business and trade, banks and life insurance companies, the very planning of our economic and social life all depend on statistical information.

We are here concerned with statistics as scientists, as experimental biologists, as malariologists trying to understand the science of malariology better by gathering facts in a malaria survey—which we are endeavouring as far as possible to translate into figures. We are also very much concerned with the planning and designing of experiments, in the collecting, sorting and arranging of raw material in a malaria survey and in the interpretation of results of experiments which may be in the field—where perhaps the treated group may be compared with the untreated group to judge the efficacy of an antimalaria measure or an antimalaria

* Based on lectures given at the malaria course for medical officers at the Malaria Institute of India, Delhi.

drug. Or again, we may be engaged in the type of research works conducted in a laboratory where the significance of the results as merely due to chance must be eliminated. A statistical sense or tact is required from the very start, whether in the field or in the laboratory, whether doing routine or research work, whether engaged in investigation or control, so that the malariologist may feel quite at home with facts and figures and arrive at correct conclusions when the data warrant such conclusions to be drawn, and at the same time avoid what is more dangerous and the common experience of a novice to jump at conclusions with insufficient data. Such accurate knowledge gained by a malariologist which can be measured and expressed in numbers will promote the orderly progress of the science of malaria, taking us a step forward in the advancement of that science.

Approach to the subject.—How shall we approach the subject of statistics? As public health workers initially our unit is a population and not just individuals. While the physician or surgeon counts his patients in terms of individuals, public health workers give rates per mille of the population : so many out of a thousand. It has fallen however to the lot of the malariologist to deal with three animal populations, viz. the man, the mosquito and the malaria parasite, all belonging to the same animal kingdom at various levels, and forming the closed-triple-linked chain of malaria.

Malaria is a 'local problem', and this is due to the extreme variability of the three animal populations in diverse ways under a variety of environmental conditions, giving a final picture of malaria of any locality not unlike the kaleidoscope which gives a different vision at every turn. We have to analyse these multiple causes and disentangle the puzzling effects which are produced by these causes on the three populations that are so variable, and it is here that statistics can help a malariologist.

Statistics is a science and an art.—Statistics is not mere common sense as some think. It is certainly innate with a few amongst us : but the vast majority must acquire it by patient study of the basic principles of simple statistical methods. Among the common folk there are some overcritical persons who think that statistics can prove anything. These misuse statistics, which has thereby earned the odium that it is the 'superlative of lies'. At the other extreme, there are others who think that statistics prove nothing. Among these are the biologists who go to the statistician at the end of a badly designed experiment with data for interpretation of results, and the statistician is expected to perform the unpleasant task of a post mortem on his experiments. The truth lies perhaps midway between the two.

Statistics is a science like any other science and statistical methods are part of general scientific methods based on the same fundamental ideas and processes which give a scientific outlook to figures. It is an art in that their successful application depends to a considerable degree on the skill and special experience of the statistician and on his knowledge of the field of application. Like the musician, the statistician must learn the science and practise his art. Statistics is not a mere calculating machine into which figures can be put and perfect results obtained. Statisticians must have data to work upon and obtain results like any

other science. Like many sciences statistics may be pure or applied. The pure science interests only a small group of statisticians who specialize in the mathematical theory underlying statistical methods or while the large majority of applied statisticians are those who are able to use with confidence only simple statistical methods, but who have a very wide and deep knowledge of their particular field of application. It is to the latter class that malariologists belong, and they should study simple statistical methods and acquire a statistical mind to apply them to their intricate problems.

No pure statistician can be expected to be familiar with all the factors that are or may be relevant to any malaria problem. At the most he may by general experience be able to suggest certain broad disturbing causes, but with factors that are narrowly specific he cannot be expected to be familiar. It is therefore necessary for malariologists to study simple statistical methods, rather than for statisticians to study malariology, in contradiction to the classes which we hold for engineers to teach them the main principles of malariology on a background of engineering which they already possess.

Scope and jurisdiction.—Statistics deal with populations or aggregates and not with individuals. Statistics are concerned with events that happen on the average or in the long run rather than those which happen on particular occasions. Statistics help us to make estimates when exact measurements are not possible; and this does not make it in any way more inexact than other sciences. Statistical methods can deal with observations which are subject to a multiplicity of causes as well as show an extreme variability as we meet with in biological sciences like malariology. It is the function of statistics to break and disentangle this multiplicity of causes and present a clear picture of cause and effect.

Experimental and statistical methods.—Methods of scientific enquiry may be classified in two broad classes, viz. experimental and statistical. The experimental method consists in isolating the factors that are under investigation—perhaps varying only one or two controlled factors at a time in a determinate manner and keeping all other irrelevant factors relatively constant; observations are then made on the resulting system. This method serves for most physical and chemical investigations. The so-called statistical method is applied in biological sciences where the variations in the factors cannot be controlled but at the same time have essentially to be taken into account and the observer has to take observations of things as they are. In short, statistics deal with figures which are subject to uncontrollable variation, such factors *we cannot control* but at the same time *cannot ignore*. The planning of experiments in physics and chemistry is comparatively simple, but in biological sciences special methods of reduction and interpretation are necessary. These are the methods of statistics applied to investigation in sciences like malariology.

The observations to which the application of statistical methods is necessary are those, it has been pointed out, which are influenced by numerous causes—the object being to disentangle that multiple causation. It must also be recognized that the observations utilized in biological sciences are nearly always a sample of the possible observations that might have been made. The question that

immediately arises is how far is the sample representative of the population from which it is drawn and bound up with: and to what extent may the values calculated from the sample be regarded as a true estimate of the values of the population sampled. This problem is fundamental to all statistical work and reasoning; and a clear conception of its importance is necessary from the very start.

Statistical problems in malariology.—Statistical problems in malariology are broadly speaking:—(1) those dealing with malaria surveys, (2) those dealing with experiments on research work. If we regard malaria surveys as a piece of research work, then both these merge into one another. A statistical sense or tact is necessary at every stage of a malaria survey. First, the raw material should be carefully selected. Accuracy and reliability of data are important, because their lack cannot be supplied later by elaboration and care in the subsequent statistical treatment. On the other hand, it is a mistake to think that inaccurate and unreliable figures as one often meets with in India should not be given careful treatment. They may not merit it but they certainly need it: and extra care is necessary to allow for inaccuracies and avoid at arriving at false conclusions. In practice, the malariologist should do all he can to obtain data that are as precise and reliable as possible and then apply methods of analysis to make the best possible use of figures.

In the planning of an experiment care is needed in taking representative and random samples. A representative sample is one in which all factors which may influence the experiment are taken into account and are well represented in both the experimental and comparison groups. A random sample is one in which chance alone determines its individual inclusion into the sample, every individual having an equal chance of getting in or getting out. Such samples alone can be treated by statistical methods. In other words, representative samples are taken from different groups of observations that deal with all relevant factors influencing the experiment: while random samples deal with individual selection within the groups. A sample, in addition to being representative and random, should also be fairly large as to be subject to statistical treatment. A statistician can advise upon the statistical lines which an experiment should follow from the very start. A statistical approach to an experiment should be considered as part and parcel of the experiment itself. As is often the case, it is too late to call upon the statistician at the end for the mere interpretation of results and to perform a post mortem on a badly designed experiment. In spite of the fact that simple statistical methods are available during recent years, experimentors still continue to work with variable material without a statistical approach. To deal with some of the very simple methods in relation to problems commonly met with by the malariologists a short series of lectures on statistics can usefully be included in the syllabus for courses in malariology.

ACKNOWLEDGMENT.

The author wishes to acknowledge the help received by him from Mr. S. P. Jain, M.Sc., A.I.A., Statistician, Office of the Director-General, Indian Medical Service.

BIBLIOGRAPHY.

Great use has been made of the following books from which ideas as well as extracts have been freely incorporated :—

Methods of statistics by L. H. C. Tippett, 4th ed., revised and enlarged. William and Norgate, London.

Statistics by L. H. C. Tippett of the Home and University Library of Modern Knowledge, 1944.

Principles of medical statistics by Bradford Hill, 2nd ed., 1939.

How to do a malaria survey by Christophers, S. R., Sinton, J. A., and Covell G. *Health Bulletin No.* 14, Govt. Press, Simla.

Indian Journal of Malariology, 1, 2, June 1947.

EXPERIMENTS WITH PALUDRINE IN THE CHEMOTHERAPY OF MALARIA.

BY

D. K. VISWANATHAN,

AND

RAO SAHEB J. D. BAILY.

(*Malaria Organization, Bombay Presidency.*)

INTRODUCTION.

THE brilliant investigations of Fairley *et al.* (1946) at Cairns in the wake of previous researches by Curd, Davey and Rose (1945) have placed paludrine in the forefront in the chemotherapy of malaria. The Medical Research Council, London, recommended that field trials in the treatment of malaria with paludrine should be undertaken principally in India and its utility against the various strains of Indian plasmodia assessed. Free supplies of the drug were made available by the Imperial Chemical Industries (India), Ltd., London, and the co-ordination of trials in different parts of India was entrusted to Major-General Sir Gordon Covell, Director, Malaria Institute of India. The paper here presented records the results of trials made in the province of Bombay from October 1946 to January 1947, for which purpose a full-time medical officer and other field staff were sanctioned by the Government of Bombay.

The League of Nations Malaria Commission (1933) defined the 5 principal aims in the chemotherapy of malaria as (1) true causal prophylaxis, (2) clinical prophylaxis, (3) treatment of the primary attack, (4) treatment for prevention of relapses and (5) gametocidal treatment. To these may be added a sixth aim, in public health practice, the provision of treatment facilities in the rural areas of the tropics, in the absence of dispensary facilities nearby. Our experiments were restricted to a study of the second and third aims, although the data provide some clue to an understanding of the fourth and the fifth, and a definite pointer by way of fulfilment of the sixth. A study of the first aim is not possible in the endemic areas since, for one thing, it will be difficult, due to long periods of transmission, to distinguish between causal and clinical prophylaxis and, for another, the rarity of strictly non-immune persons restricts the utility of sub-inoculations for the determination of latent blood infections.

TECHNIQUE.

Three different geographical areas were selected. Ahmedabad in the north, Visapur in the centre, Belgaum and a few villages in Kanara District in the south of the province so that the efficacy of the drug may be studied against the different plasmodial strains prevalent in the province. In Ahmedabad, Visapur and Belgaum the study was confined to the jail population. Of these 3 places Ahmedabad and Visapur are moderately endemic with the malaria season from September to January and Belgaum has little *indigenous* malaria. The villages in Kanara District are hyperendemic with an almost static transmission of malaria from October to June.

Clinical prophylaxis.—In each of the 3 jails and in Manchikeri, a village in Kanara, a specified number of individuals were given weekly doses of 100 mg. of paludrine and an equal number were kept under observation for comparison. Blood slides were taken from both the experimental and comparison groups once a month. If any person in either group (except in the village) developed fever, his blood was immediately taken by the local medical officer and sent for examination. If on clinical grounds the case was diagnosed as malaria, the patient was placed on a course of paludrine treatment. Included in each of the experimental and comparison groups there were 180 persons in Ahmedabad, 100 in Visapur, 380 in Belgaum and 100 in Manchikeri. In addition to these, 3 more villages in Kanara District were included, in one of which all persons above 2 years of age were placed on weekly paludrine treatment (100 mg.), in another all persons above 5 years of age were so treated and the third was kept under observation for purpose of comparison. But, since continuity of treatment could not be maintained, these studies offer no useful data except to bring out the extreme difficulty in persuading the villagers to undertake themselves, or even to accept a weekly course of clinical prophylactic treatment. The data relating to these villages are therefore not presented in this paper. Nearly 6,000 blood slides were examined during the 4 months from October 1946 to January 1947 from the persons included in the studies on clinical prophylaxis. While both thick and thin films were taken from each, only the former was examined as a routine except when there was doubt as regards the species of plasmodium. One hundred high power fields of thick smear were examined as a routine both for determining the concentration of parasites and for determining a film as negative. This will represent approximately 1/10 of a c.mm. of blood.

Treatment of primary attack.—Any case diagnosed clinically as malaria by the local medical officer in charge of the jails was placed on one of 3 different courses of paludrine treatment. Course I consists of a single administration of 3 tablets of 100 mg. each on admission. Course II consists of 2 such tablets on admission repeated on the second day. Course III consists of 1 tablet 3 times a day for 7 days. Out of every 5 consecutive cases of clinical malaria the first received Course I treatment, the second Course II and the third, fourth and fifth Course III. Thick and thin smears were taken from each case prior to the administration of the drug and on each day until 2 days after the temperature reached and remained normal and again every week for at least 3 more weeks. Subsequently only monthly examinations were made. In the analysis of results only those cases which were positive on microscopic examination have been

TABLE I.

Results of blood examinations of prophylactic and comparison groups.

Place.	Month.	Number examined.	Prophylactic. Number with parasites. Asexual.	Prophylactic. Number with parasites. Sexual.	Parasite rate, per cent.	Number examined.	Comparison. Number with parasites. Asexual.	Comparison. Number with parasites. Sexual.	Parasite rate, per cent.
Belgaum ...	October ...	360	12	1	3·6	360	8	0	2·2
	November ...	335	4	13	5·0	327	22	3	7·6
	December ...	304	0	0	*Nil*	279	4	3	2·5
	January ...	286	0	1	0·3	267	3	4	2·6
Visapur ...	October ...	100	4	0	4·0	100	4	1	5·0
	November ...	87	1	1	2·3	78	0	3	3·8
	December ...	78	0	2	2·6	59	0	1	1·7
	January ...	61	0	0	*Nil*	37	3	1	8·1
Ahmedabad ...	October ...	180	13	6	10·6	180	3	13	8·9
	November ...	174	3	1	2·3	165	2	4	3·6
	December ...	171	0	0	0·0	161	2	4	3·7
	January ...	175	0	0	0·0	161	2	4	3·7
Manchikeri ...	October ...	100	4	2	6·0	100	2	1	3·0
	November ...	100	1	6	7·0	100	5	2	7·0
	December ...	64	0	0	0·0	67	0	1	1·5
	January ...	64	0	0	0·0	62	1	4	8·1

included. In the month of January one of us (J. D. B.) remained in Manchikeri village for 3 weeks and treated 30 cases of malaria. These have also been included in this series which represents a total of 124 cases. On the average about 10 blood films were examined from each case, an average of 4 during the primary attack and the rest to determine parasitic relapses. In all cases the temperature was recorded both morning and evening until 2 days after it reached normal. Later the temperature was taken only of those who reported sick.

ANALYSIS OF RESULTS.

CLINICAL PROPHYLAXIS.

Table I gives the results of monthly blood examinations of the clinical prophylactic and the comparison groups respectively.

TABLE II.

Incidence of malaria (clinical and parasitic) among prophylactic and comparison groups.

1. Place.	Belgaum.	Visapur.	Ahmedabad.	Manchikeri.
2. Number under prophylaxis ...	360-286	100-61	180-175	100-64
3. Number among (2) with later malaria	3	0	1	1
4. Percentage of 3 to 2	1·0	0·0	0·6	1·6
5. Number under comparison ...	360-267	100-37	180-161	100-62
6. Number among (5) with later malaria	5	6	12	5
7. Percentage of 6 to 5	1·9	16·2	7·5	8·1

Comment.—The data presented in both Tables I and II should be taken into account in assessing the efficacy of paludrine as a clinical (and possibly causal) prophylactic. The Belgaum experience has to be interpreted differently from that in the other 3 places in as much as there is little local malaria transmission in the former area. In assessing percentages, the number that received paludrine tablets every week from the beginning of October to the end of January, has been taken as the population at risk. Likewise in the comparison group only those who were available for comparative study throughout the period have been reckoned as the population at risk. This reckoning no doubt exaggerates the percentage of malaria incidence but the degree of exaggeration is almost equal in both groups except in the case of Visapur where in the comparison group only 37 persons were available all through the period whereas 61 were available in the prophylactic group, while at the beginning there were hundred in either group. That is presumably why the incidence of malaria in Visapur in the comparison group is 16 per cent as compared with about 8 per cent in Ahmedabad and Manchikeri among such groups. In any case, from the data presented in Table II, it will be seen that while there was at least 8 per cent of malaria incidence during

the period of 4 months from October to January among the comparison group in Manchikeri, Ahmedabad and Visapur, none in Visapur and only one each in Ahmedabad and Manchikeri developed malaria among the prophylactic group. Even in these two cases the malaria patient in Ahmedabad had received only tablet before he showed *vivax* infection (2 rings and 4 trophozoites in 100 high power fields). This case therefore should not strictly be reckoned among the prophylactic group. The case in Manchikeri was different in that *falciparum* infection was microscopically demonstrable even after 14 weekly doses of 100 mg. of paludrine though the concentration was very low (only 2 rings per 100 fields). If this were a fresh infection it indicates that weekly doses of 100 mg. are not absolutely certain to act as a causal prophylactic among the semi-immunes in the tropics thus confirming the experimental work of Fairley *et al.* (*loc. cit.*) among the non-immunes. On the other hand, it may be a relapse in which case such dosage of paludrine has failed to act on the late or secondary tissue (or exoerythrocytic) forms, if such exist in *falciparum* infections. In either case it has failed to act as a schizonticide. Barring this single case, however, the efficacy of weekly dosage of 100 mg. of paludrine as a causal or clinical prophylactic against *vivax*, *falciparum* and *malaria* infections is well demonstrated in the 3 different geographical areas of the province of Bombay. The exception noted above would render twice a week dosage as recommended by Fairley *et al.* (*loc. cit.*) far safer. While a weekly regimen offers far greater administrative scope in rural areas, the authors are convinced that under the conditions prevailing in the hyperendemic area of Kanara District it would be extremely difficult to carry out any mass drug therapy. It required an enormous amount of coaxing to persuade the people of Manchikeri to take their weekly dose and in 2 other villages where this was attempted it proved futile. There was, however, a very valid objection raised by these villagers. For the sake of these experiments those villages were excluded from the scheme of D.D.T. indoor residual spraying which was in progress on an extensive scale throughout the district. Since the resultant freedom from insects in general makes the use of D.D.T. immediately popular, even among a rural population, they resented their exclusion and the substitution of some other kind of experiment. Even so, the prevalence of disease is not often a sufficient stimulus for villagers to resort to treatment. It will, therefore, be futile to expect their submission to drug treatment practically continuously since malaria transmission is possible throughout the year in these parts. There is, however, ample scope for disciplined or enlightened communities to resort to a course of paludrine treatment (2 tablets of 100 mg. each per week at intervals of 3 and 4 days respectively) throughout the malaria season. Prisoners in jails, police, forest and excise staff of the Government, touring officials, industrial, plantation or constructional labour forces may all usefully resort to such treatment. While mepacrine has to be taken daily for such purposes and has the disadvantage of colouring the skin, paludrine has to be taken only for 2 days in a week and, as in the much larger experience of Fairley *et al.* (*loc. cit.*), no toxic symptoms were discovered in our series.

In the case of Belgaum, which is a healthy area, there is not, naturally, much difference between the 2 groups. The occurrence of malaria in the prophylactic as well as in the comparison group may therefore be reckoned as relapses especially as this jail accommodates prisoners from the neighbouring districts which are hyperendemic for malaria. All the 8 cases of malaria in Belgaum occurred during

the first month of experiment (3 in the prophylactic and 5 in the comparison groups) and there were no cases in the later months confirming that they were all probably only relapses. In the prophylactic group only 2 weekly courses had been administered before each of the 3 relapses occurred, 2 of which were *falciparum* and the third *vivax*. In all the 4 places 8 weekly courses of 100 mg. of paludrine have cleared the peripheral blood of demonstrable asexual parasites arising either out of fresh infections or of relapses, but gametocytes seem to persist even in the absence of multiplication of asexual parasites to the level of microscopic demonstration in the peripheral blood. In the comparison group infections show a progressive increase in Visapur and Manchikeri, a stationary level in Ahmedabad and a decline in Belgaum. As fever cases (positive on microscopic examination) have been left out of the subsequent reckoning in Table I, the progressive increase is actually of a higher order. The decline in Belgaum is naturally due to the absence of local transmission.

There were very few children included in this series, and these were confined to the villages in Kanara District. Children above 5 years of age were given half a tablet or 50 mg. and children between 2 and 5 one-quarter of a tablet or 25 mg. As these tablets were not scored to facilitate exact splitting, these doses were only approximate. The few children that were treated appeared to tolerate these doses without any untoward symptoms.

TREATMENT OF MALARIAL ATTACK (SCHIZONTICIDAL ACTION). FALCIPARUM *MALARIA.*

Altogether 73 cases were included in this group (*vide* protocol). Twenty-two among them were placed on Course I (300 mg. on admission), 21 on Course II (200 mg. on admission and 200 mg. the next day) and 30 on Course III (100 mg. thrice a day for 7 days).

TABLE III.

FALCIPARUM *MALARIA.*

Duration of fever and parasites in peripheral blood after different courses of treatment with paludrine.

	Duration of fever in *days*.						Average in *hours*.	Duration of parasites in peripheral blood in *days*.						Average in *hours*.
	0	1	2	3	4	5		0	1	2	3	4	5	
Course I ...	0	13	3	3	2	1	45	4	10	6	2	0	0	35
Course II ...	0	14	2	4	0	1	40	3	10	5	2	0	1	39
Course III ...	0	7	10	7	2	4	61	4	14	8	1	1	2	41
	0	34	15	14	4	6	50	11	34	19	5	1	3	38

The above data confirm the findings of Fairley *et al.* (*loc. cit.*) and Afridi *et al.* (1946) that single doses of paludrine have nearly as good a schizonticidal action as repeated doses, judging from clinical relief or initial disappearance of parasites from the peripheral blood. The data presented above show, if anything, a bias in favour of a single administration of 300 mg. of paludrine although the difference is not statistically significant. While in the total series slightly less than half the number of cases had their fever terminated within 24 hours, in about 59 per cent treated with Course I fever abated within that period and if Courses I and II are included as much as 63 per cent secured relief in one day. In only 23 per cent of persons on Course III treatment did fever come down within 24 hours. It has, however, to be pointed out that as many as 23 out of 24 cases treated in Manchikeri, a hyperendemic village with semi-immune population are included in a total of 34 cases showing abatement of fever within 24 hours. It seems, therefore, that the semi-immunes in hyperendemic tracts show a much readier clinical response to paludrine. Again while in Ahmedabad and Visapur the average duration of parasitic prevalence is much less than that of temperature, in Manchikeri the reverse is the case. This indicates that paludrine assists in the earlier manifestation of the mechanism of anti-toxic immunity in the hyperendemic areas.

The authors had no means of determining how many among these cases were primary attacks and how many relapses. It was possible only to follow up later parasitic or clinical relapses after a course of treatment. The medical officers of Visapur and Ahmedabad jails were very careful to select only frankly clinical cases of malaria for treatment with paludrine. Very often prisoners' complaint of an attack of fever was not implicitly relied on and they were taken up for treatment only when they again showed a rise in temperature. Hence the duration of fever or of parasites recorded above is a definite underestimate. Fairley *et al.* (*loc. cit.*) refer to volunteers in whom treatment was often withheld for a variety of reasons proving more difficult subjects for therapeutic testing. While this may be so in the case of non-immunes, in very few of our series was treatment commenced during the first febrile paroxysm and no case of paludrine resistance was encountered. The average period for the disappearance of *falciparum* parasites was 50 hours in our series as against 48 recorded by Fairley *et al.* (*loc. cit.*) but our standards of microscopic examination were less strict, in that only 100 high-power fields (as against their 1,000) were included. While due to this difference we may have failed to detect extremely low-grade infections it does not materially affect the reckoning of the average duration of parasites. The different courses of treatment seem to have exercised no significant difference in the duration of parasites in the peripheral blood. Between the duration of neither temperature nor parasitic prevalence in peripheral blood and the density of infection is there any striking correlation. Very high densities of infections, however, seem to have a slightly more protracted duration under both counts.

Vivax *malaria.*—Of 35 cases of *vivax* infections, 24 received Course III treatment, 6 Course I and 5 Course II.

No case of *vivax* malaria was treated in the hyperendemic village. If the *falciparum* malaria cases in that village are excluded, the average parasitic and temperature duration in *vivax* and *falciparum* infections remains the same, showing an equal degree of schizonticidal action in the two species. Differences between

TABLE IV.

VIVAX *MALARIA.*

Duration of fever and parasites in peripheral blood after different courses of treatment with paludrine.

	Duration of fever in *days.*							Average in *hours.*	Duration of parasitic prevalence in peripheral blood in *days.*						Average in *hours.*
	1	2	3	4	5	6	7		1	2	3	4	5	6	
Course I	4	0	1	1	0	0	0	14	4	2	0	0	0	0	32
Course II	0	2	1	2	0	0	0	72	1	2	2	0	0	0	33
Course III	5	4	8	5	1	0	1	69	7	11	4	0	1	1	52
	9	6	10	8	1	0	1	65	12	15	6	0	1	1	49

the 3 courses of treatment are not marked. In one case treated with Course III, epistaxis occurred on the third day of treatment which was stopped in order to take no chances. This is, however, reckoned as a pure coincidence and in any event it was the only case where any untoward symptom was noticed either coincidently or following the treatment.

MALARIÆ *MALARIA.*

Only 3 cases of infection with this species have been included. Three each of them received Courses I and III and the other 2 Course II. The numbers are too small to assess differences in the efficacy of the 3 courses. The average duration of temperature was 66 hours and of parasites 51 hours, almost the same as in *vivax* malaria. A point of interest, however, is that while in *falciparum* malaria in the hyperendemic village of Manchikeri the vast majority of cases had a very short duration of temperature and parasitic prevalence, in 2 out of 5 cases of *malariæ* malaria, temperature persisted for 3 days. Likewise in 2 cases in Ahmedabad the temperature was maintained for 4 days and in the only case at Visapur for 5 days.

MIXED INFECTIONS.

Out of a total of 124 cases, 8 were mixed infections, 7 with *vivax* and *falciparum* and one with *malariæ* and *falciparum*. The average duration of temperature was 54 hours and of parasites 51 hours. Numbers are too small to assess the differential efficacy of the 3 courses of treatment.

RELAPSES.

Out of 124 cases, 30 have to be left out of reckoning in considering relapses since treatment was only just concluded. Of the remaining 94 cases, 60 have been under observation for at least 2 months after completion of treatment. Among

these one was *malariæ* malaria with no relapse, 26 were *falciparum* malaria with two relapses (one clinical and the other parasitic), 26 were *vivax* malaria with one relapse (both clinical and parasitic) and 7 mixed infections with *vivax* and *falciparum*, among which there were 2 *vivax* and one *falciparum* relapses within the period of observation.

EFFECT OF PALUDRINE ON GAMETOCYTES.

It was stated earlier under clinical prophylaxis that gametocytes persisted even after 8 weekly courses of treatment. One cannot say whether these persistent gametocytes were formed after further cycles of schizogony after commencement of paludrine therapy, or whether they were already formed before the administration of the drug and had still not been withdrawn from the circulation. After treatment of acute attacks, however, and resultant disappearance of asexual forms from the peripheral blood, the concentration of gametocytes still met with is, indeed, striking. As they are almost invariably met with without even a single co-existing asexual form, the mind receives an exaggerated picture of their prevalence almost to the point of imagining increased gametocyte production after treatment with paludrine. For instance, case 2 showed 660 rings on the first day and 520 gametocytes on the eighth day, though the asexual forms completely disappeared on the third day. Case 5 showed only 16 rings on the first day but 26 gametocytes 15 days later. In case 14 gametocytes persisted for 50 days. In case 20 there were no asexual forms on the first day and only about 3 gametocytes were seen on the fifth day, but 150 were seen on the thirteenth day. In case 38 there were only 10 rings on the first day but 200 gametocytes on the fourteenth day. Fairley *et al.* (*loc. cit.*) have stated that in therapeutic dosage paludrine affects neither the morphology nor the number of *falciparum* gametocytes already formed nor directly inhibits their production. In the case of *vivax* they have recorded an increase in the number of gametocytes on the second or third day of treatment and they add that such a phenomenon was found to a lesser degree with quinine, mepacrine and pamaquin. In our experience we found gametocytes in *vivax* infections only as a small fraction of the total number of parasites in the earlier stages. It is only in *falciparum* infections that we met with this seeming high prevalence of gametocytes by themselves, not infrequently in considerable excess of the density of the asexual stage preliminary to treatment. Obviously no drug can effect an absolute increase in gametocyte production. Our data would, therefore, seem to show that, among the semi-immunes, while small doses of paludrine effectively clear the peripheral blood of demonstrable asexual parasites further cycles of schizogony apparently do take place in the internal organs, but the quantum of immunity keeps them below the point of demonstrable invasion of the peripheral blood. This mechanism, however, apparently fails to prevent the entry and development of the gametocytes in the peripheral blood. In no other way can one explain the prevalence of gametocytes unassociated with asexual parasites weeks after treatment of the primary attack in much higher concentration than the initial density of the asexual stages of the parasites. We have also noticed distinct morphological changes in the gametocytes among persons subjected to clinical prophylactic therapy. They have a definite degenerated appearance, but the numbers have however been few. In the treatment series, however, gametocytes occurring later

present their typical appearance. On the whole, we are of the view that the prevalence of gametocytes for long after stoppage of paludrine treatment requires further investigation in malarious areas, as if such be the case transmission will still be left unimpaired. The effect of paludrine inhibiting the viability of gametocytes in the mosquitoes' stomach recorded by Fairley *et al.* (*loc. cit.*) will be of no avail since such effect, according to them, disappears so early as the twelfth day after the completion of a course of 300 mg. daily for 10 days. The need for further study of this aspect in the hyperendemic tracts is rendered more important in view of the difficulty, previously stated, of subjecting them to any prolonged course of treatment.

PROVISION OF FACILITIES FOR MASS TREATMENT OF RURAL POPULATION.

The general principles of malaria therapy in relation to the development and degree of acquired immunity have been defined by Sinton (1939) as (1) radical cure in populations of individuals with little chances of reinfection, (2) *rapid clinical* cure but not of infection in populations liable to constant infection, reinfection and superinfection, (3) clinical prophylaxis for individuals exposed only temporarily to chances of frequent infection and superinfection. Commenting upon these principles as fundamentally important with regard to the antimalarial drugs hitherto known, Fairley *et al.* (*loc. cit.*) have stressed the need for further investigations on paludrine in malarious areas to ascertain (1) the effects of treating overt attacks of malaria in children and adults with single doses, (2) what single weekly dose regimen will suffice to control clinical malaria without producing radical cure in infants, children and adults with premunity, and (3) what dosage regimen is necessary to produce radical cure in such persons. While our data cannot elucidate the last point, we have shown that a single dose of 300 mg. in adults (150 mg. in children between 5 and 12 and 75 mg. in children between 2 and 5) effects rapid clinical cure among semi-immunes and the disappearance of demonstrable parasites from the peripheral blood and that the relapse rate is of a very much smaller order both in *vivax* and *falciparum* infections than among non-immunes. It has also been shown that weekly dosage of 100 mg. in adults (50 mg. in children between 5 and 12 and 25 mg. in children between 2 and 10) acts effectively, but not absolutely, as a clinical (or causal) prophylactic. Hence on these two points the behaviour of the non-immunes and semi-immunes does not seem to have a marked difference except that relapse rates in the latter are much lower. The determination of the dosage required for radical cure of infection among the semi-immunes involves superinfection experiments which will not yield as precise conclusions as sub-inoculations and these are not possibly due to the rarity of non-immunes. Such determination will doubtless be a step in the right direction in the altered perspective of malaria control in India. We strongly endorse the plea made by Fairley *et al.* (*loc. cit.*) for a change in policy in the treatment of semi-immunes and favour an attempt to effect radical cure of infections undeterred by the fear of disastrous results following in the wake of loss of premunity. Indian provinces now exhibit a far greater zeal than formerly for malaria control, in fostering which the Malaria Institute of India and the experience of antimalarial campaigns in the recent war have exerted no small part. Large-scale rural malaria control with the use of D.D.T. has not only been made possible but is actually in progress in

several parts of India and Ceylon and the time has now arrived for a world-wide perspective of application of methods of control of diseases without any regimentation as tropical and non-tropical. At best the advantage of premunity was only the last refuge of the tropical malariologist, and it is time to discard its benefits won at great odds in favour of modern advances in prevention and cure by the aid of D.D.T. and paludrine.

Pending the determination of the dosage required for radical cure the present studies make it possible to recommend that paludrine may be usefully put up in wafer paper containers with 3 tablets of 100 mg. apiece somewhat like 'aspro' so that each wafer may constitute one treatment for an attack of malaria. A single tablet of 300 mg. will perhaps become too massive to swallow. Each tablet may also have 2 cross-bars to facilitate splitting into half or quarter size for consumption by children between 5 and 12 and 2 and 5 respectively. In the case of infants and one-year-old children still smaller tablets of perhaps 10 mg. may have to be provided separately. No weekly regimen of dosage either for clinical prophylaxis or for prevention of relapses will be a practical expedient in the villages. The twin aims for the present should therefore be active prevention of malaria by the use of D.D.T. and rapid clinical cure of infections which may still occur. The enormous gap between the toxic dose and the therapeutic dose of paludrine combined with the efficacy of a single administration make its distribution by lay agents in rural parts extremely practicable.

GENERAL CONCLUSIONS.

(1) Paludrine acts as an efficient clinical (or causal) prophylactic among Indians with different degrees of acquired immunity when administered in weekly dosage of 100 mg. for adults, 50 mg. for children between 5 and 12 and 25 mg. for children 2 to 4 years of age. This dosage is not, however, absolutely effective. Hence twice a week administration of such doses (at intervals of 3 and 4 days) is recommended for adoption by the police, forest, excise and similar field staff, touring Government officials, plantation, constructional or factory labour, etc., throughout the season of transmission and for about 2 months later.

(2) A single dose of 300 mg. (and proportionate doses for children) effects clinical cure in all species of plasmodia and while relapses do occur especially in mixed infections they are of a much smaller order than in the non-immunes. Further investigations are necessary in order to determine an adequate dosage in hospital practice for the prevention of relapses, perhaps with the combined use of paludrine and plasmoquine.

(3) Gametocyte production appears to go on even after clinical relief and disappearance of asexual parasites from peripheral blood indicating an absence of radical cure after a single administration of 300 mg., 200 mg. a day on 2 consecutive days or of 300 mg. daily for 7 days. After 8 weekly doses of 100 mg. of paludrine gametocytes still appear, but they show definite degenerative changes morphologically. The gametocytes appearing long after treatment of the primary attack are normal and present no such morphological change.

(4) A regimen of weekly dosage is not considered practicable in rural areas (much less twice a week dosage) to secure clinical or causal prophylaxis. Treatment designed to bring about rapid clinical relief is alone practicable, and for this purpose a single dose of 300 mg. for adults and proportionate dosage for children are recommended and 3 tablets of 100 mg. may usefully be put up in wafer paper containers. Each tablet may have cross-bars to facilitate splitting into 2 or 4 equal pieces. For infants and one-year-old children tablets weighing 10 mg. may have to be provided. The efficacy of a single administration and the remarkable freedom from any toxicity make it possible to place these tablets in the hands of laymen in each village (e.g. village officers).

(5) Further investigations for determining the dosage required for radical cures are desirable as also a change in policy, so that less faith may be placed on the advantages of premunition won at great odds and an attempt made to effect the prevention and radical cure of tropical malaria by the use of D.D.T. and paludrine.

ACKNOWLEDGMENTS.

These investigations were undertaken with the hearty co-operation of Dr. H. S. Khanderia, M.D., M.R.C.P. (London), Medical Officer, Central Prison, Ahmedabad, and his two assistants, Messrs. J. S. Shah and V. D. Mankad, Messrs. T. N. Date and K. G. Mulkund, Subordinate Medical Service Officers in Visapur Temporary Prison, and Rao Bahadur K. V. Chipkar, Medical Officer, Belgaum Central Prison, and his two assistants, Messrs. V. R. Patil and M. R. Kulkarni. To them as well as to Messrs. S. D. Londhe and B. Raghavan, Medical Officers, Malaria Organization, and Mr. H. R. Bhat, Assistant Medical Officer, the thanks of the authors are due for assistance in the conduct of the experiments.

REFERENCES.

ALEXIDI, M. K., RAMAKRISHNAN, S. P., GOSWAMI, A., and MENON, M. K. (1946). *Ind. J. Mal.*, 1, **1**, pp. 221–229.

CURD, F. H. S., DAVEY, D. G., and ROSE, F. L. (1945). *Ann. Trop. Med. Parasit.*, **39**, p. 208.

FAIRLEY, N. H., *et al.* (1946) ... *Trans. Roy. Soc. Trop. Med. Hyg.*, **40**, 2, pp. 105–163.

LEAGUE OF NATIONS MALARIA COMMISSION (1933). *Quart. Bull. Health Organ., L. of N.*, **2**, pp. 181–285.

SINTON, J. A. (1939) ... *J. Mal. Inst. Ind.*, **2**, pp. 191–215.

APPENDIX I.

Protocol of falciparum *malaria cases (positive on microscopic examination) treated with paludrine.*

Serial number.	Case number.	Age in years.	Sex.	Place.	State and concentration.	Course of treatment.	Duration of temperature, *hours*.	Duration of asexual parasites in peripheral blood, *hours*.	Period under observation after treatment, *days*.	Fever or parasite relapse within the period of observation. Fever.	Parasite.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13
1	266	26	Male	Ahmedabad	R. 220 G. 40	III	48	24	80	*Nil*	*Nil*	Gametocytes 14 to 15 days.
2	279	40	"	"	R. 660	I	48	48	80	*Nil*	*Nil*	Gametocytes 520 8th day.
3	296	26	"	"	R. 600 G. 10	III	48	48	90	*Nil*	*Nil*	
4	357	23	"	"	G. 25	II	72	*Nil*	80	*Nil*	*Nil*	
5	362	28	"	"	R. 16	III	72	24	110	*Nil*	*Nil*	Gametocytes 96. 15 days later.
6	367	35	"	"	R. 20 G. 15	I	24	24	100	*Nil*	*Nil*	Showed *malaria* infection 2 months later.
7	368	32	"	"	R. 1 G. 1	II	48	24	20	*Nil*	*Nil*	Not available for further observation.
8	369	30	"	"	R. 400	III	120	48	90	*Nil*	14 days later	Rings 80, gametocytes 3, 14 days later.
9	370	35	"	"	R. 1200	III	120	120	90	*Nil*	*Nil*	Gametocytes 200 2nd day.

R. Rings. G. — Gametocytes.

Page-319

APPENDIX I—*contd*

Serial number.	Case number.	Age in years.	Sex.	Place.	State and concentration.	Course of treatment.	Duration of temperature, *hours*.	Duration of asexual parasites in peripheral blood, *hours*.	Period under observation after treatment, *days*.	Fever or parasite relapse within the period of observation. Fever.	Parasite.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13
10	215	32	Male	Visapur	R. 600	III	72	24	90	*Nil*	*Nil*	
11	216	20	"	"	No asexual forms G. 20, 4 days later.	III	48	*Nil*	90	*Nil*	*Nil*	
12	217	25	"	"	R. 700	III	96	48	90	*Nil*	*Nil*	
13	219	25	"	"	R. 500	II	72	120	90	*Nil*	*Nil*	Gametocytes 100—4th day.
14	222	20	"	"	R. 1800	III	72	72	90	*Nil*	*Nil*	Gametocytes 120, 20 days later, 80, 50 days later.
15	224	28	"	"	R. 1240	II	48	48	90	*Nil*	*Nil*	
16	225	25	"	"	R. 460	III	48	120	90	*Nil*	*Nil*	Gametocytes 10, 12 days later.
17	226	30	"	"	R. 440	III	48	48	90	*Nil*	*Nil*	
18	233	25	"	"	R. 540	II	120	48	80	16 days later.	*Nil*	Gametocytes 1, 40 days later. Relapse treated with Course 1.
19	234	30	"	"	R. 1250	III	72	24	20	*Nil*	*Nil*	Gametocytes 140—4th day.
20	236	30	"	"	No asexual forms G. 3 (5 days later).	I	96	*Nil*	80	*Nil*	*Nil*	Gametocytes 150—13th day.
21	238	50	"	"	R. 1780	III	96	24	80	*Nil*	*Nil*	Gametocytes 300, 7 days later.
22	243	40	"	"	R. 420	III	120	48	70	*Nil*	*Nil*	
23	247	25	"	"	R. 600	III	72	48	70	*Nil*	*Nil*	
24	249	25	"	"	R. 25	I	120	24	70	*Nil*	*Nil*	

Page C-3

25	102	30	,,	Belgaum	R. 10	I	48	48	90	Nil	Nil	
26	511	30	,,	,,	G. 20	II	24	24	90	Nil	Nil	
27	453	35	,,	,,	R. 400	III	48	24	90	Nil	Nil	
28	233	32	,,	,,	No asexual forms G. 26	II	24	72	90	Nil	Nil	
29	248	30	,,	Visapur	No asexual forms	III	48	Nil	70	Nil	Nil	Gametocytes 3, 20 days later.
30	255	30	,,	,,	R. 900	I	72	48	40	Nil	Nil	
31	256	20	,,	,,	R. 500	III	72	24	40	Nil	Nil	
32	257	40	,,	,,	R. 260	I	24	24	60	Nil	30 days later	Rings 140.
33	258	25	,,	,,	R. 20	II	24	24	40	Nil	Nil	
34	260	25	,,	,,	R. 1200	III	72	96	10	Nil	Nil	Not available for further observation.
35	261	25	,,	,,	R. 220	I	96	72	30	Nil	Nil	Gametocytes 24, 23 days later.
36	262	40	,,	,,	R. 1100 G. 42	II	72	72	30	Nil	Nil	
37	264	30	,,	,,	R. 120	III	48	24	30	Nil	Nil	
38	265	37	,,	,,	R. 10	III	48	24	30	Nil	Nil	Gametocytes 200, 14 days later.
39	266	40	,,	,,	R. 2240	I	48	48	30	Nil	Nil	Gametocytes 120, 20 days later.
40	267	25	,,	,,	R. 1 G. 20	II	24	24	10	Nil	Nil	
41	271	38	,,	,,	No asexual forms	I	24	Nil	10	Nil	Nil	Gametocytes 300, 2 days later.
42	273	30	,,	,,	,,	III	24	Nil	10	Nil	Nil	Gametocytes 20—2nd day.
43	275	25	,,	,,	R. 220	III	24	24	10	Nil	Nil	
44	276	35	,,	,,	R. 40	I	24	24	10	Nil	Nil	
45	277	30	,,	,,	R. 20	II	72	48	10	Nil	Nil	

R. = Rings. G. = Gametocytes.

Page 321

APPENDIX I *concld.*

Serial number.	Case number.	Age in years.	Sex.	Place.	State and concentration.	Course of treatment.	Duration of temperature, *hours.*	Duration of asexual parasites in peripheral blood, *hours.*	Period under observation after treatment, *days.*	Fever or parasite relapse within the period of observation. Fever.	Parasite.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13
46	270	40	Male	Visapur	[illegible]	III	48	48	10	*Nil*	*Nil*	
47	198	25	"	Ahmedabad	R. 20	III	24	24	50	*Nil*	*Nil*	
48	331	30	"	"	R. 360	I	72	24	40	*Nil*	*Nil*	
49	332	30	"	"	No asexual parasites	III	120	*Nil*	10	*Nil*	*Nil*	Gametocytes 120 to 260. Everyday of observation.
50	1	13	"	Manchikeri	R. 600	I	72	72	..	..	..	Treatment just completed.
51	2	20	"	"	R. 15	II	24	24	..	..	..	Later period of observation too short in this and all the cases that follow.
52	3	12	Female	"	R. 420	III	24	48	..	..	..	
53	4	33	Male	"	R. 250	III	24	24	..	..	..	
54	5	32	"	"	R. 2	III	24	24	..	..	..	
55	6	22	"	"	R. 10	III	24	24	..	..	..	
56	7	3	"	"	R. 2	I	24	24	..	..	..	
57	8	6	"	"	R. 2	II	24	24	..	..	..	
58	9	7	Female	"	R. 10	I	24	24	..	..	..	
59	10	42	"	"	R. 15	I	24	24	..	..	..	
60	11	6	Male	"	No asexual parasites G. 1	II	24	*Nil*	..	..	..	

Page e - 322

61	12	34	Female	,,	No asexual G. 1	I	24	*Nil*	..	..	..	
62	13	12	Male	,,	R. 2	II	24	24	..	..	..	Has had 14 weekly doses of paludrine of 100 mg. each.
63	17	33	,,	,,	R. 10	II	24	24	..	..	..	
64	20	2	Female	,,	R. 1020	II	24	48	..	..	..	
65	22	30	Male	,,	R. 60	II	24	21	..	..	..	
66	3	17	Female	,,	No asexual forms G. 8	I	24	*Nil*	..	.	..	
67	24	20	,,	,,	No asexual parasite G. 200	II	24	*Nil*	..	..	..	
68	25	3	Male	,,	R. 600	I	24	48	..	..	..	
69	26	16	,,	,,	R. 510	I	24	24	..	..	..	
70	28	10	,,	,,	R. 106	I	24	24	.	..	..	
71	29	6	,,	,,	R. 220	II	24	24	..	..	..	Gametocytes 200—4th day.
72	31	3	,,	,,	R. 1200	II	24	48	..	..	..	
73	32	7	,,	,,	R. 600	I	24	48	..	..	..	

R. = Rings. G. = Gametocytes.

APPENDIX II.

Protocol of vivax *malaria cases (positive on microscopic examination) treated with paludrine*

Serial number.	Case number.	Age in years.	Sex.	Place.	Stage and concentration.	Course of treatment.	Duration of temperature, *hours*.	Duration of asexual parasites in peripheral blood, *hours*.	Period under observation after treatment, *days*.	Fever or parasite relapse within the period of observation.		Remarks.
										Fever.	Parasite.	
1	2	3	4	5	6	7	8	9	10	11	12	13
1	102	35	Male	Ahmedabad	R. 2 T. 4	III	120	24	110	*Nil*	*Nil*	
2	236	42	"	"	T. 1	I	72	24	90	*Nil*	*Nil*	
3	254	35	"	"	R. 22 T. 10	III	72	48	130	*Nil*	*Nil*	
4	348	43	"	"	R. 140	II	72	48	110	*Nil*	*Nil*	
5	364	50	"	"	All stages 800	II	96	48	110	*Nil*	*Nil*	
6	201	30	"	Visapur	R. 220	I	24	24	110	40th day	40th day	R. 40. Relapse treated with Course III. No further relapse up to 60 days later.
7	202	38	"	"	R. 12 T. 6	III	24	24	110	*Nil*	*Nil*	
8	206	27	"	"	T. 4	III	72	24	100	*Nil*	*Nil*	
9	210	26	"	"	T. 600	III	72	120 (afterwards not examined).	20	*Nil*	*Nil*	Not available for further observation.
10	211	22	"	"	T. 600	III (only 3 days stopped due to epistaxis).	72	48	90	*Nil*	*Nil*	

11	220	30	,,	,,	R. 500 T. 660	III	72	48	90	*Nil*	*Nil*	
12	221	35	,,	,,	T. 60	III	24	48	90	*Nil*	*Nil*	Showed *falciparum* gametocytes 21 days later. Negative since.
13	223	25	,,	,,	T. 220	I	24	24	10	*Nil*	*Nil*	Not available for further observation.
14	230	22	,,	,,	All stages 1780	III	72	48	10	*Nil*	*Nil*	Do.
15	232	24	,,	,,	All stages 2560	I	96	48	80	*Nil*	*Nil*	
16	235	28	,,	,,	T. 1500	III	96	48	80	*Nil*	*Nil*	
17	239	60	,,	,,	T. 125	III	96	24	80	*Nil*	*Nil*	
18	240	33	,,	,,	Asexual forms appeared on 3rd day. T. 1.	III	72	72	80	*Nil*	*Nil*	
19	242	60	,,	,,	All stages 1240	II	48	72	80	*Nil*	*Nil*	
20	250	22	,,	,,	T. 280	III	48	48	70	*Nil*	*Nil*	
21	251	30	,,	,,	T. 240	II	96	24	70	*Nil*	*Nil*	
22	252	21	,,	,,	T. 280	III	168	48	70	*Nil*	*Nil*	
23	57	40	,,	,,	T. 140	III	96	72	60	*Nil*	*Nil*	Shows *falciparum* gametocytes 14 days later.
24	83	22	,,	,,	T.14850	III	96	144	30	*Nil*	*Nil*	
25	85	21	,,	,,	T. 400	III	96	48	70	*Nil*	*Nil*	Shows *falciparum* gametocytes persistent for six weeks.
26	97	22	,,	,,	T. 800	I	24	48	30	*Nil*	*Nil*	
27	682	30	,,	Belgaum	T. 25	I	24	24	110	*Nil*	*Nil*	
28	81	35	,,	,,	T. 125	III	24	72	110	*Nil*	*Nil*	
29	452	30	,,	,,	T. 400	II	48	72	100	*Nil*	*Nil*	

R. = Rings. T. = Trophozoites.

APPENDIX II—*contd.*

Serial number.	Case number.	Age in years.	Sex.	Place.	Stage and concentration.	Course of treatment.	Duration of temperature, *hours.*	Duration of asexual parasites in peripheral blood, *hours.*	Period under observation after treatment, *days.*	Fever or parasite relapse within the period of observation.		Remarks.
										Fever.	Parasite.	
1	2	3	4	5	6	7	8	9	10	11	12	13
30	451	30	Male	Bolgaum	All stages 1280	III	48	72	110	*Nil*	*Nil*	
31	254	30	,,	Visapur	T. 400	III	72	48	60	*Nil*	*Nil*	
32	259	45	,,	,,	R. 10	III	24	24	30	*Nil*	*Nil*	
33	268	28	,,	,,	T. 60	III	24	24	10	*Nil*	*Nil*	
34	51	25	,,	,,	T. 8	III	48	24	40	*Nil*	*Nil*	
35	52	25	,,	,,	T. 360 G. 29	III	48	48	10	*Nil*	*Nil*	

R. = Rings. T. = Trophozoites. G. = Gametocytes.

APPENDIX III.

Protocol of mixed infection malaria cases (positive on microscopic examination) treated with paludrine.

Serial number.	Case number.	Age in years.	Sex.	Place.	Stage and concentration.	Course of treatment.	Duration of temperature, *hours*.	Duration of asexual parasites in peripheral blood, *hours*.	Period under observation after treatment, *days*.	Fever or parasite relapse within the period of observation. Fever.	Parasite.	Remarks.
1	210	42	Male	Ahmedabad	(F) R. 440 (V) R. 82	II	48	48	110	30 days later.	30 days later.	*Vivax* T. 600 treated with Course III. No relapse—80 days later.
2	363	47	"	"	(F) R. 700 R. 220 (V) T. 60	I	96	48	110	45 days later.	45 days later.	F. R. 144 treated with Course III. No relapse 60 days later.
3	365	26	"	"	(F) R. 620 (V) T. 1	III	24	24	110	*Nil*	*Nil*	F. G. 66 12 days later.
4	366	30	"	"	(V) R. 220 T. 6 (F) R. 4	III	24	48	110	*Nil*	*Nil*	F. G. 120 8 days later.
5	372	40	"	"	(V) T. 120 (F) G. 40	II	48	24	70	*Nil*	*Nil*	
6	218	20	"	Visapur	(V) T. 120 (F) R. 1240	I	72	144	90	24 days later.	25 days later.	V. R. 60 treated with Course III. No relapse 60 days later.
7	237	40	"	"	(V) T. 1 (F) G. 20	II	72	24	80	*Nil*	*Nil*	
8	30	12	"	Manchikeri	(F) R. 220 (M) T. 2240	I	48	48	..	..	..	Treatment just completed.

(F) = *Falciparum*. (V) = *Vivax*. (M) = *Malaria*. R. = Rings. T. = Trophozoites. G. = Gametocytes.

APPENDIX IV.

Protocol of malaria *malaria cases (positive on microscopic examination) treated with paludrine.*

Serial number.	Case number.	Age in years.	Sex.	Place.	Stage and concentration.	Course of treatment.	Duration of temperature, *hours.*	Duration of asexual parasites in peripheral blood, *hours.*	Period under observation after treatment, *days.*	Fever or parasite relapse within the period of observation.		Remarks.
										Fever.	Parasite.	
1	244	30	Male	Visapur	T. 160	III	120	72	80	*Nil*	*Nil*	
2	367	35	„	Ahmedabad	T. 540 G. 40	III	96	72	30	*Nil*	*Nil*	
3	319	28	„	„	T. 12	II	96	24	30	*Nil*	*Nil*	
4	16	14	Female	Manchikeri	T. 120	I	24	24	..	..	..	Treatment just completed and period too short to determine recrudescence or relapse.
5	18	4	Male	„	T. 20	I	24	24	..	..	..	
6	19	2	„	„	T. 1260	II	72	96	..	..	..	
7	21	30	Female	„	T. 40	I	24	24	..	..	..	
8	27	3	„	„	T. 2000	II	72	72	..	..	..	

T. = Trophozoites. G. = Gametocytes.

MALARIA IN THE MALABAR SQUIRREL

BY

LIEUT.-COLONEL H. W. MULLIGAN, M.D., D.SC., I.M.S.,

AND

MAJOR T. SOMMERVILLE, M.B., CH.B., I.M.S.
(From the Central Research Institute, Kasauli.)

(April 21, 1947.)

INTRODUCTION.

EXPERIMENTAL studies on malaria would be greatly facilitated if a plasmodial strain could be established in one of the small mammals commonly used in the laboratory. Interest in this problem led the authors to re-investigate the occurrence of a malarial infection in the Malabar squirrel originally reported by Donovan (1920). The work was carried out at the Pasteur Institute of Southern India, Coonoor, in 1940, and although considerable progress had been made it was terminated abruptly by the authors' sudden recall to military duty. The material which had been collected, together with the relevant records, were left in the care of Mr. C. S. Swaminath, a colleague on the Protozoal Parasites Inquiry under the Indian Research Fund Association, but owing to his death while the authors were on active service overseas most of the material and records were lost. As the subject is one which might well repay renewed investigation, the authors have considered it worth while to record their findings, incomplete as they are, as they can foresee no opportunity of resuming it themselves. In doing so it has been necessary to rely on memory for the details of some of the experiments but the description of the parasite has been prepared from the limited material still available for study.

MATERIAL STUDIED.

The proper name of the Malabar squirrel is given as *Sciurus indicus malabaricus* (Blanford, 1888) but it is variously recorded as *Sciurus malabaricus*, *Sciurus maximus* and *Ratufa indica malabarica*. The head and body of the adult squirrel measures about 18 inches and the bushy tail is of approximately the same length. The dorsal aspects of the head, back and rump, and the whole of the tail are a rich.

deep maroon colour, while the ventral surfaces are yellowish-brown or buff. These animals abound in the dense forests of the Nilgiri-Wynaad where they inhabit tall trees, living among the branches and rarely coming to the ground. The young are reared in nests built of twigs and leaves near the top of lofty trees.

Ruthless hunters seeking its handsome and valuable pelt at one time threatened the extinction of the Malabar squirrel so that strict regulations for its preservation had to be introduced. Through the co-operation of the Nilgiris Game Association, special permission was obtained to procure a sufficient number of squirrels for this investigation. These were obtained in the Game Reserve near Teppikadu on the main road between Ootacamund and Mysore City, that is, in the same locality in which Donovan's observations had been made twenty years earlier. Six squirrels were shot on the first expedition and, later, three were captured alive. Seven out of the nine squirrels examined showed the presence of a malaria parasite in their blood.

DESCRIPTION OF THE PLASMODIUM.

General.—The same species of plasmodium was present in all of the seven squirrels found to be infected. Although gametocytes were more or less plentiful in most of these animals, asexual forms were always scanty. All of the squirrels examined were full-grown adults. The investigation was terminated before it was possible to study the infection in young animals in which heavier infections might occur.

The following description refers to parasites seen in blood films stained with Giemsa stain.

Asexual cycle.—Trophozoites were invariably scanty and true schizogony was not observed either in the peripheral blood or in the internal organs. The prevalence of gametocytes makes it probable that at least some of the developing forms to be described were immature sexual forms. No characteristic changes were observed in the size, shape or staining reactions of the infected red cells at any stage of development of the parasite.

The smallest trophozoites seen consisted of a single, round chromatin dot and a semi-lunar or oval wisp or blob of blue-staining protoplasm (Plate X, figs. 1 and 2). Small signet-ring forms were not observed but larger rings measuring $\frac{1}{2}$ to $\frac{2}{3}$ the diameter of the red cell were occasionally seen (Plate X, figs. 3 to 5); in these, the chromatin nucleus occurred as a single mass placed opposite to the thickened portion of the protoplasmic ring; in the larger forms a few discrete granules of dark-brown pigment were seen. Forms showing little or no vacuolation but which otherwise appeared to be at a similar stage of development probably represented developing gametocytes (Plate X, figs. 6 and 7). Amœboid forms presented a variety of appearances (Plate X, figs. 8 to 11); the protoplasm was very irregular and appeared to be fragmented; the chromatin nucleus occurred as a single mass (Plate X, figs. 9 and 11) or as several fragments (Plate X, figs. 8 and 10); a few small dark-brown pigment granules were sometimes seen. Larger forms (Plate X, figs. 12 to 20) were more regular in outline and contained more numerous and somewhat coarser pigment granules; as a rule there was considerable vacuolation and when this was single the parasite appeared as a large ring occupying the greater

part of the red cell (Plate X, figs. 12 to 14); the chromatin nucleus usually occurred as a single mass which was more or less dense and compact, or consisted of an aggregation of chromatin granules. Although trophozoites measuring 5μ to 6μ in diameter were frequently observed, forms showing true schizogony were not seen.

Sexual cycle.—Mature gametocytes, which were plentiful in most of the blood films examined, occurred as more or less spherical bodies free from all traces of the original host red cell. The sexes were readily distinguishable, and females were rather more numerous than males: a differential count made on one blood film showed the male : female ratio to be 4 : 5.

Macrogametocytes (Plate X, figs. 21 to 25) were slightly larger than a normal red cell and commonly measured about 8μ in diameter. The protoplasm stained deep blue and usually presented a somewhat granular appearance: as a rule the protoplasm was seen as a more or less solid (Plate X, figs. 21 to 23) but not infrequently it was vacuolated (Plate X, figs. 24 and 25). The chromatin nucleus was characterized by its relatively small size, its granular appearance and vivid red staining; the nucleus was situated centrally or peripherally and was composed of a single mass, or of two or even three small masses lying close together: the shape of the nucleus was very variable being round, oval, linear or irregular: occasionally the nucleus consisted of one or two small dense compact masses. The pigment granules were dark-brown in colour and were more or less evenly scattered through the protoplasm which, by reason of its deep staining, tended to obscure them.

Microgametocytes (Plate X, figs. 26 to 30) were readily distinguished by the faint staining of the protoplasm, the large size of the nucleus and the clarity with which the pigment granules stood out. There was greater disparity in size than in the case of the macrogametocytes and forms varying in size from 6μ to 8μ in diameter were commonly seen. The nucleus which was composed of an outer faintly staining zone and an inner deeply staining zone (karyosome) occupied a considerable proportion of the parasite. The karyosome was larger and more homogeneous than the nucleus of the macrogametocyte and often stained a deep dull red or purple colour; the outer zone of the nucleus which stained a pinkish colour tended to merge almost imperceptibly into the protoplasm. The protoplasm which was seldom vacuolated stained a faint bluish or greenish-grey colour against which the dark-brown pigment granules were very clearly seen. The pigment granules were more or less evenly scattered through the protoplasm but tended to be coarser and more plentiful towards the periphery: the size of the granules was variable in different parasites.

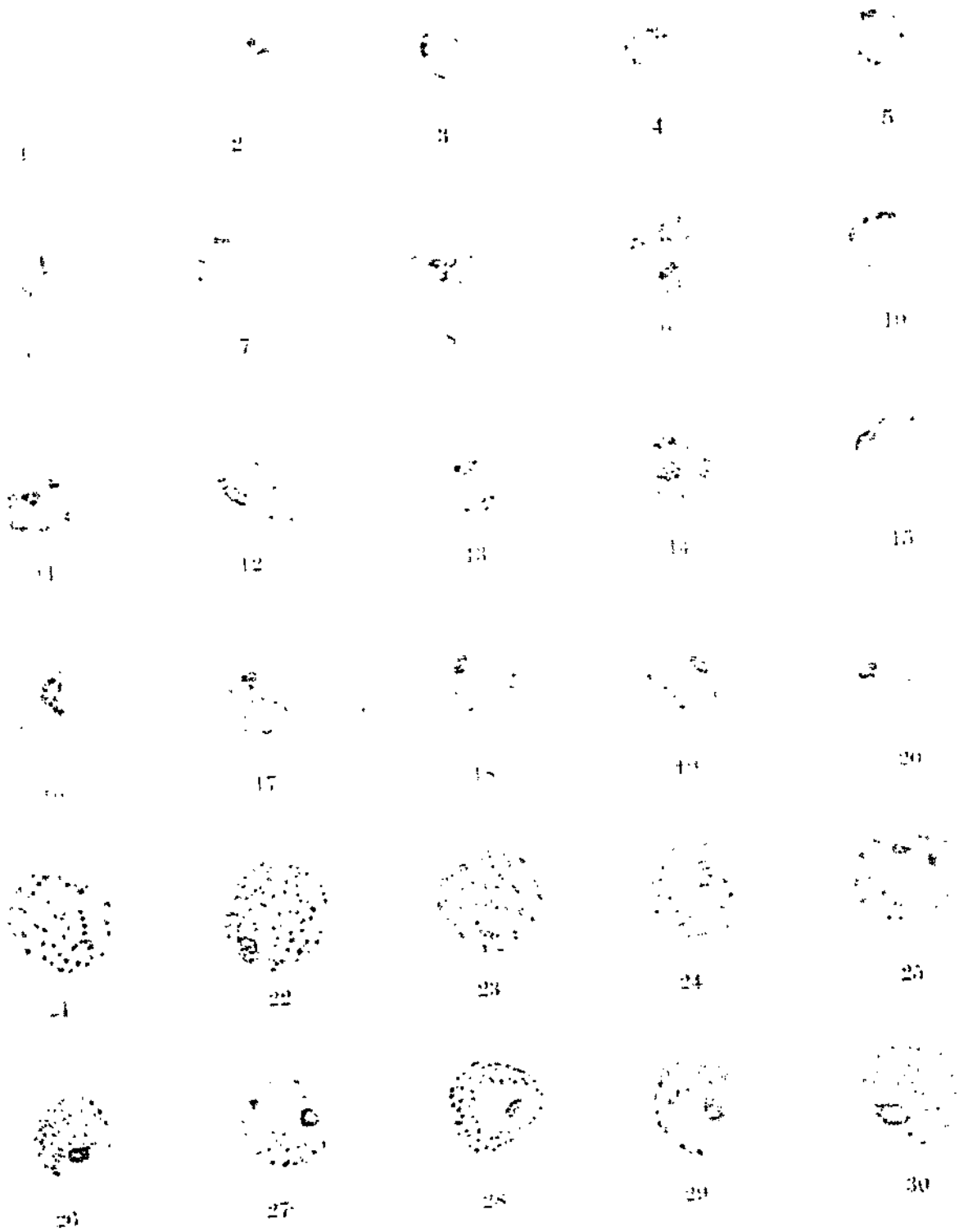
Duration of schizogony cycle.—It has not been possible to work out the duration of the schizogony cycle on the material now available.

Exo-erythrocytic development.—A detailed search of sections of spleen, liver, kidney, lung and intestine of infected squirrels revealed no evidence of an exo-erythrocytic development of this plasmodium.

Pathogenicity.—The extreme activity and agility of the animals in their natural habitat in spite of a high incidence of infection suggest that the disease in the adult is of very low pathogenicity. Further, the two infected adults which were

Page - 331 A

PLATE X



H. W. MULLIGAN *del.*

Scale.

10 μ

Explanation of Plate X.

Plasmodium cassdi var. *ratufæ*.

(From a blood film stained with Giemsa stain.)

Fig. 1. Normal red blood cell of the Malabar squirrel.

" 2. Youngest trophozoite observed.

Figs. 3, 4 and 5. Large ring forms showing early pigmentation.

" 6 and 7. Trophozoites showing little or no vacuolation: possibly developing gametocytes.

" 8 to 11. Trophozoites showing considerable amœboidicity.

" 12 to 20. Large pigmented trophozoites: some are probably developing gametocytes.

" 21 to 25. Macrogametocytes.

" 26 to 30. Microgametocytes.

maintained in captivity for many months remained in apparently perfect health. Additional evidence of the low pathogenicity of the infection was obtained when splenectomy failed to provoke an increase in parasitæmia in one of the captive squirrels (*cf.* Mulligan, Sommerville and Swaminath, 1940).

Insect transmission.—Mosquitoes are extremely prevalent in the dense jungles which the Malabar squirrel inhabits and as human malaria is hyperendemic in this locality, the climatic conditions may be regarded as favourable for mosquito transmission of plasmodia. Despite extensive trials no suitable insect vector was discovered. Gametocytes were very prevalent in one of the captive squirrels but all feeding experiments proved negative. Exact records of the numbers and species of mosquitoes used in these experiments have been lost but the mosquitoes used included the following genera and species in considerable numbers :—

A. fluviatilis, C. seldidus, C. theileri and *C. whitmorei, Armigeres* (*Armegeris*) *obturans* and *Aëdes* (*Stegomyia*) *albopictus.*

Infectivity for other animals.—As the primary object of this investigation was to establish an experimental malarial infection in a small laboratory animal, attempts to transmit the squirrel malaria received special attention. Blood obtained from all of the infected squirrels was inoculated chiefly into guinea-pigs, rabbits and white rats. On a few occasions attempts were also made to transmit the infection by blood inoculation to monkeys (*S. sinicus*). In the case of white rats and monkeys both intact and splenectomized animals were used. The details regarding the quantity of blood given and the numbers of each species of recipient animal used are not now available.

The blood used for inoculation was obtained both from the squirrels shot in the jungle and from the two infected squirrels which were maintained in captivity. In the former case the thorax was opened immediately the animals fell and 10 c.c. to 20 c.c. of blood were withdrawn into sterile syringes containing citrate-saline solution as an anticoagulant. In every case bleeding was effected before the heart stopped beating. The citrated blood was transported to the laboratory in a portable ice box and was used for the subinoculation experiments within 4 to 8 hours of removal from the donor. Cardiac puncture of the infected captive squirrels was carried out on several occasions without difficulty or mishap.

All of the animals which were subinoculated with infected squirrel blood proved refractory to the infection. These failures may have been due to the relatively small numbers of asexual forms of the parasite present in the donor squirrels when the experiments were performed.

IDENTIFICATION OF THE PLASMODIUM.

There can be no doubt that the plasmodium described above is identical with that first observed in Malabar squirrels from the same locality by Donovan (*loc. cit.*). We cannot, however, agree with Donovan's statement that this parasite is 'very like *P. vivax* of man'. The squirrel plasmodium is readily distinguished from *P. vivax* of man and from *P. cynomolgi* of the monkey by the absence of a comparable degree of palor and enlargement of the infected erythrocytes and by the absence of stippling resembling Schüffner's dots. There are several other

distinguishing characters of a less obvious nature which it is not proposed to discuss in detail.

Although Donovan (*loc. cit.*) gives no description of the parasite which he observed in the Malabar squirrel he proposed the name '*P. ratufa* sps. nov.' for it while at the same time admitting that 'Vassal found a similar, if not identical parasite in a squirrel (*Sciurus griseimanus*) in Annam'.

We have studied with great care the descriptions and figures of the squirrel parasite given by Vassal (1905*a*, 1905*b*) for which Laveran (1905) proposed the name *P. vassali*, and we have been unable to detect any definite criteria by which the plasmodium described in this paper can be differentiated from *P. vassali*. In a later paper, Vassal (1907) reported the occurrence of *P. vassali* in other species of squirrels in Annam including *Sciurus rillatus*, *Sciurus vulgaris* and another unidentified species.

In view of the close similarity in the morphology (so far as this is known) of the plasmodium of the Malabar squirrel to that of *P. vassali* it does not seem to be justifiable to give a new specific name to the former as has been suggested by Donovan. The case would be amply met by provisionally classifying the plasmodium of the Malabar squirrel as *P. vassali* var. *ratufa*. Should further work prove this parasite to be a distinct species it could readily be given specific rank as *P. ratufa* (the name already proposed by Donovan) or conversely, should this parasite prove to be identical with *P. vassali* the varietal name could be omitted. The adoption of a similar procedure by Sinton and Mulligan (1933) in classifying the monkey plasmodia has ultimately proved simple and convenient.

It would not be justifiable to assume that *P. vassali* and *P. vassali* var. *ratufa* are distinct species solely because they have been recorded from different countries and different species of squirrel. In this connection it may be mentioned that a plasmodial infection occurring naturally in a specimen of the monkey *Silenus silenus* captured in the same locality in South India (Nilgiris foothills) proved to be in all respects identical with *P. inui* described by Mathis and Leger (1911) in *S. rhesus* and *S. lasiotis tchelensis* from Indo-China (*vide* Mulligan and Swaminath, 1940).

There is no likelihood of *P. vassali* var. *ratufa* being confused with any other known species of mammalian malaria.

SUMMARY.

A description has been given of a plasmodium found in the blood of seven out of nine specimens of *Sciurus indicus malabaricus* (the Malabar squirrel) shot or captured in the Nilgiri-Wynaad district of South India. This parasite is undoubtedly identical with that reported, but not described by Donovan (*loc. cit.*) in Malabar squirrels shot in the same locality. The identity of the parasite found in the Malabar squirrel has been discussed and the opinion is expressed that it is probably identical with *P. vassali* Laveran 1905, first described by Vassal (1905*a*) from *Sciurus griseimanus* from Annam, Indo-China. Pending further investigation to establish the true identity of the plasmodium described the name *P. vassali* var. *ratufæ* has been proposed for it thereby retaining the name (*P. ratufæ* sps. nov.) proposed by Donovan (*loc. cit.*).

ACKNOWLEDGMENTS.

We are indebted to the Indian Research Fund Association for financing the Protozoal Parasites Inquiry under which this investigation was undertaken. We should like to record our thanks to the Nilgiris Game Association for permission to procure specimens of the Malabar squirrel; to Mr. C. R. Farmer Williams, Indian Forest Service, for the facilities provided in connection with our field excursions; to Mr. James John, our Field Assistant, for the capture of the squirrels; and to Dr. Paul F. Russell, Malaria Investigations, Coonoor, for his valuable assistance in connection with the mosquito transmission experiments.

REFERENCES.

BLANFORD, W. T. (1888) ... *Fauna of British India, Mammalia*, p. 571.
DONOVAN, N. C. (1929) ... *Ind. Jour. Med. Res.*, **7**, p. 717.
LAVERAN, A. (1905) ... *Bull. Inst. Past.*, **3**, p. 809.
MATHIS, C., and LEGER, N. (1911) ... *Ann. Inst. Past.*, **25**, p. 593.
MULLIGAN, H. W., SOMMERVILLE, T., and SWAMINATH, C. S. (1940). ... *Jour. Mal. Inst. Ind.*, **3**, p. 591.
MULLIGAN, H. W., and SWAMINATH, C. S. (1940). ... *Ibid.*, **3**, p. 603.
SINTON, J. A., and MULLIGAN, H. W. (1933). ... *Rec. Mal. Surv. Ind.*, **3**, p. 381.
VASSAL, J. J. (1905*a*) ... *Ann. Inst. Past.*, **19**, p. 221.
Idem (1905*b*) ... *C. R. Soc. Biol.*, **18**, p. 350.
Idem (1907) ... *Ann. Inst. Past.*, **21**, p. 851.

Indian Journal of Malariology, 1, 2, June 1947.

SUPPRESSIVE MEPACRINE TREATMENT TO THE STAFF OF B. A. RAILWAY IN 1945.

BY

A. K. ADHIKARI,

Malariologist, B. A. Railway, Calcutta.

INTRODUCTION.

In 1944, the Army in the malarious zones in India and the Far East was placed under suppressive mepacrine treatment with excellent results. The suggestion, put forward by the Railway Board to treat the staff of the B. A. Railway on similar lines, was welcomed and a detailed scheme was prepared and put into operation in the malaria season of 1945. The antimosquito staff of this railway was temporarily strengthened accordingly.

The malaria season in the greater part of Assam and submontane areas of Bengal, where *A. minimus* is the carrier, starts from mid-April and ends in mid-October, June and July being the worst months. In the plains of Bengal, where *A. philippinensis* is the carrier, the season commences in June and ends in December; the peak month in this case is usually October or November.

In both these areas the railway employees were given one tablet of mepacrine daily during the malaria season and for a further period of 4 weeks as a curative measure so that the individuals harbouring malaria parasites at the end of the season may be completely or partially cured. The drug was therefore administered for seven months in each case.

The employees of this railway in almost all the malarious stations classified as follows were given suppressive mepacrine treatment :—

(*a*) Malarious stations in *minimus* areas where antimosquito measures were in force—40.

(*b*) Malarious stations in *minimus* areas where antimosquito measures were not in force—57.

(*c*) Malarious stations in *philippinensis* areas where antimosquito measures were in force—23.

(*d*) Malarious stations in *philippinensis* areas where antimosquito measures were not in force—15.

The stations in (*b*) and (*d*) are mostly small and way-side stations.

Arrangements were so made that mepacrine was administered daily at the work sites, at the residence of personnel not on duty, at roll calls and at change of shift duties. The open line assistant surgeons and sub-assistant surgeons were made responsible for submission of monthly returns of malaria sickness in the staff under treatment.

To encourage the employees to take this drug regularly, all possible means were adopted and instructions by the general manager and propaganda notices by the chief medical officer in the railway gazette proved most helpful. The heads of the various departments in their turn issued circulars to their district and assistant officers and so on, with the result that full co-operation afforded to the antimalaria medical staff encouraged the latter to perform their most arduous duties admirably.

Distribution of suppressive mepacrine to the staff at the stations in the *minimus* areas was commenced from April 15, 1945, and for the first two months the number of persons treated per month on an average was 22,632. When the stations in the *philippinensis* areas were also brought under suppressive mepacrine treatment with effect from June 15, the number receiving this treatment from middle of June to middle of November increased to an average of 44,986. From November 15 to January 15, 1946, the suppressive treatment in the *minimus* areas was discontinued, and the population receiving the treatment dropped to an average of 20,225 (Table I).

TABLE I.

Strength of staff under suppressive mepacrine treatment (1945).

	April.	May.	June.	July.	August.	September.	October.	November.	December.	January 1946.
Minimus areas ..	22,719	23,615	21,562	21,142	23,098	26,065	25,692	24,133	..	..
Philippinensis areas	..	..	19,193	21,375	21,800	22,018	22,041	21,798	20,996	19,454
TOTAL ..	22,719	23,615	40,755	42,517	44,898	48,083	47,733	45,931	20,996	19,454

Employees receiving this treatment were classified under the following categories [Tables II (*a*) and (*b*)]:—

(1) *Regular.*—Those employees who received suppressive mepacrine daily throughout the season.

(2) *Moderately irregular.*—Those who received this treatment for 15 days or over in each month.

(3) *Highly irregular.*—Those who received this treatment for less than 15 days in each month.

TABLE II.

(a) *In* minimus *areas* (1945).

Month.	Employees treated.	Regular.	Percentage.	Moderately irregular.	Percentage.	Highly irregular.	Percentage.
April* ...	22,719	17,753	78·2	4,966	21·8	*Nil*	*Nil*
May ...	23,615	19,470	82·5	3,942	16·6	203	0·9
June ...	21,562	17,740	82·4	3,060	14·1	762	3·5
July ...	21,142	16,734	79·3	3,184	15·1	1,224	5·7
August ...	23,098	19,129	82·8	3,260	14·1	709	3·1
September ...	26,065	22,561	86·7	2,866	10·9	638	2·4
October	25,692	21,900	85·3	3,084	12·0	708	2·7
November* ...	24,133	22,678	93·9	1,455	6·0	*Nil*	*Nil*

* For 15 days only.

(b) *In* philippinensis *areas* (1945).

Month.	Employees treated.	Regular.	Percentage.	Moderately irregular.	Percentage.	Highly irregular.	Percentage.
June* ...	19,193	13,893	72·4	5,300	27·6	*Nil*	*Nil*
July	21,375	15,414	72·2	4,388	20·5	1,573	7·3
August ...	21,800	16,557	76·0	4,110	18·8	1,133	5·2
September ...	22,018	17,862	81·2	3,578	16·2	578	2·6
October ...	22,041	18,691	84·9	2,763	12·5	587	2·6
November ...	21,798	16,669	76·5	4,449	20·4	680	3·1
December ...	20,996	16,617	79·2	3,615	17·2	764	3·6
January 1946*	19,454	15,777	81·1	3,677	18·9	*Nil*	*Nil*

* For 15 days only.

DIFFICULTIES EXPERIENCED IN DAILY ADMINISTRATION OF MEPACRINE.

Irregular administration was due to the one or more of the following reasons :—

(*a*) Staff on leave.

(*b*) Staff residing in the neighbouring villages or towns and absenting from duty without notice.

(*c*) Staff on relief duties and held up in outstations for indefinite periods.

(*d*) Staff not traceable either in their offices or their quarters on Sundays and holidays.

(*e*) During illness when mepacrine had to be withheld under instructions of the attending physicians.

(*f*) In moderately endemic areas where malaria was less rampant, the clerical staff was not favourably inclined to co-operate.

(*g*) Refractory and uncompromising attitude of certain groups of employees to avoid the treatment on account of adverse opinions expressed by private practitioners through lay press, etc.

(*h*) Popular belief that mepacrine disturbs mental equilibrium.

(*i*) Yellow pigmentation of the skin erroneously believed to be jaundice.

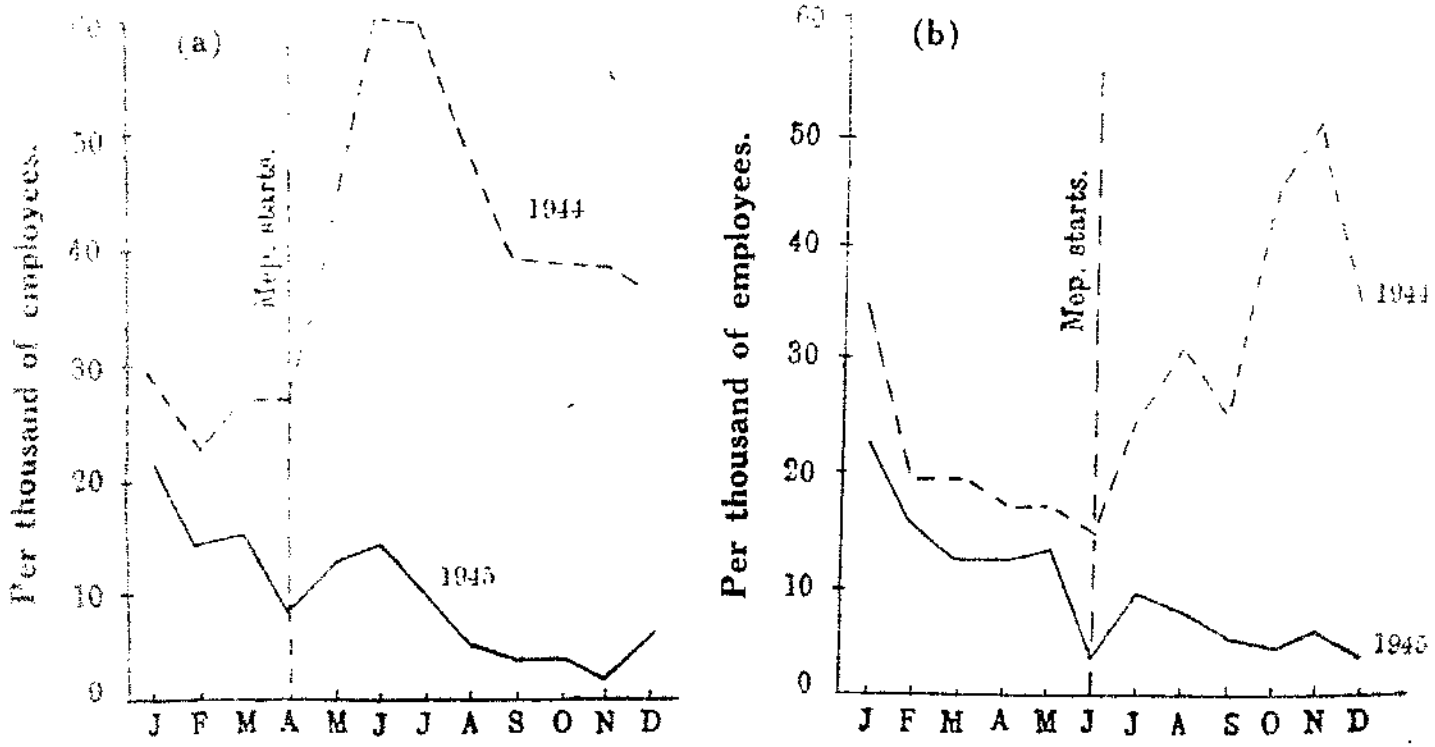
(*j*) Supervision of actual intake of tablets not possible with the running staff who were away from their headquarter stations with trains and those on relieving duties.

(*k*) Mohammedan staff observing fast during the 'Ramzan' were entrusted to swallow tablets at their convenience.

In spite of intensive propaganda, posters and railway gazette, the percentage of irregulars was sometimes one-fourth of the total strength under treatment. On an average one-tenth of the total strength could not be treated regularly.

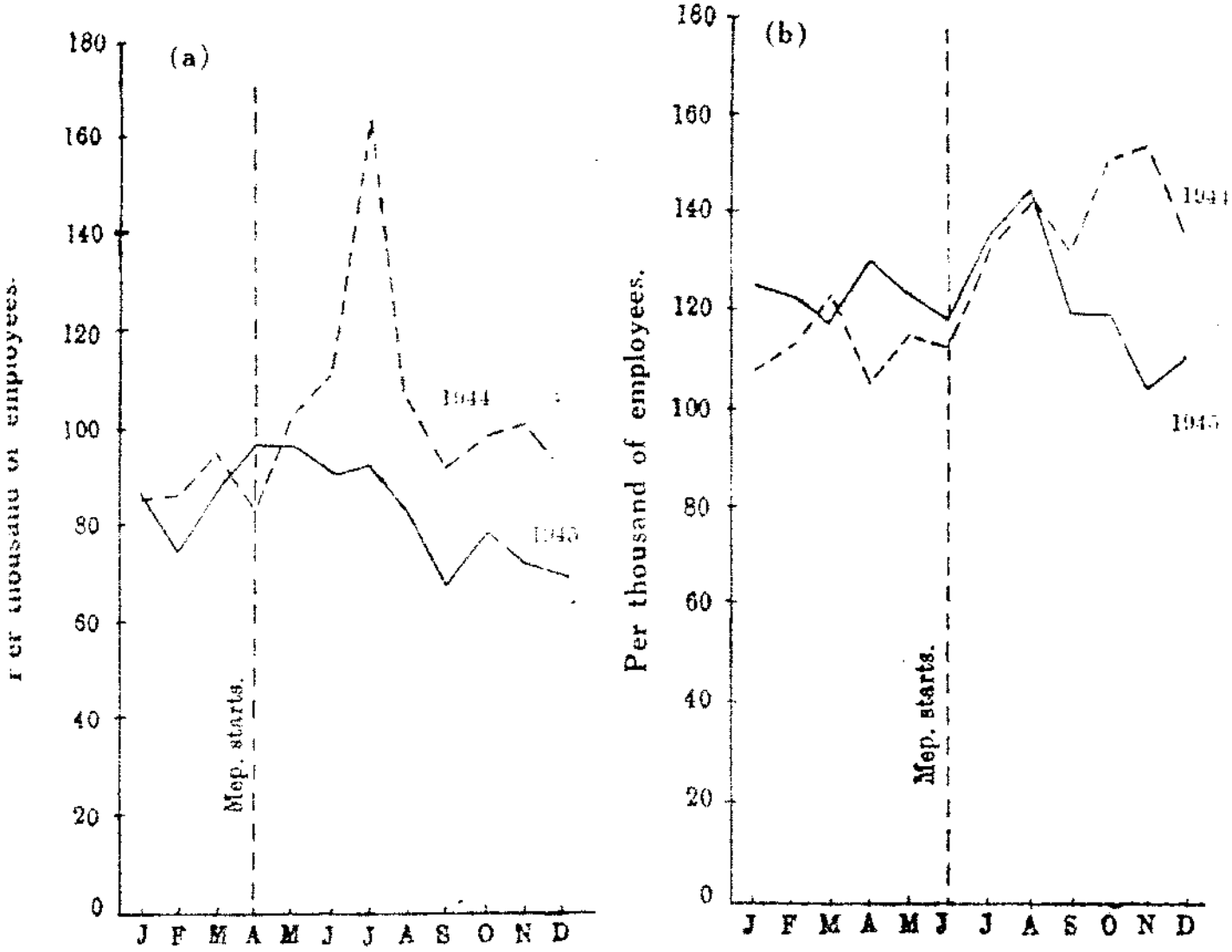
GRAPH 1.

Comparative graphs of certified malaria cases for 1944 *and* 1945 *in* minimus *country* (*a*) *and* philippinensis *country* (*b*).



GRAPH 2.

Comparative graphs of all causes (including malaria) for 1944 and 1945 for subtilinus *variety (a) and* philippinensis *variety (b).*



In the Assam Hill Section (Badarpur-Lumding) where malaria is hyper-endemic, the suppressive mepacrine treatment of engineering gang labourers residing between two stations was entrusted with the executive engineer who took the responsibility of proper distribution of mepacrine through the agency of the subordinate staff of the permanent way. The gangmates were instructed to supervise the daily ingestion of the tablets. As those labourers do not get any benefit of the antimalaria protection and as they suffer from malaria badly, they showed a tendency of genuine mepacrine-mindedness from the very commencement of the treatment. The sub-assistant surgeons of this section made surprise visits of the gang-huts to check the administration of mepacrine and to see how far the tablets were properly utilized. On a monthly average of 356·8 strength only 8·4 per cent of the labourers failed to take the tablets regularly.

RESULTS OBTAINED.

Incidence of malaria before suppressive mepacrine treatment was decreasing yearly as a result of anti-larval and anti-adult measures, but the drop in the incidence in 1945 was sharp and was due presumably to the introduction of this suppressive treatment.

It was observed that a greater number of fresh infections were found among the highly irregular group of staff than amongst the moderately irregular staff while in the staff which took mepacrine tablets regularly, primary infections were rare though a few chronic cases were encountered.

The considerable reduction in the malaria incidence resulted in a corresponding decrease in the general sickness rates. In areas where malaria was the major problem, reduction in the general sickness was more noticeable (Graphs 1 and 2).

A more interesting feature is elucidated in Tables III (*a*) and (*b*) and IV (*a*) and (*b*) where, besides the decrease in general sickness, reduction in the number of sick days, particularly those due to malaria during 1945 as against 1944, is indicated. Not a single case of blackwater fever was encountered whereas in the previous years several cases occurred and furthermore no deaths attributable to cerebral malaria were recorded in 1945. A few cases complained of slight disorder of bowels or insomnia, but these disappeared after a short time. Yellow pigmentation was observed after two weeks' treatment in a number of cases but this became less noticeable after second month.

TABLE III.

SICKNESS FROM ALL CAUSES AND MALARIA IN 1944 AND 1945.

(*a*) *In* minimus *areas.*

Month.	Rate per thousand—all causes.		Rate per thousand—malaria.	
	1944.	1945.	1944.	1945.
January ...	85·9	86·9	28·9	22·1
February ...	87·5	75·3	23·3	14·4
March ...	95·3	87·3	27·7	15·7
April ...	83·8	97·1	27·9	9·1*
May ...	102·2	97·1	40·4	13·1
June ...	111·4	91·3	60·9	14·7
July ...	164·3	93·2	60·9	10·1
August ...	106·7	84·6	49·2	5·7
September ...	92·5	67·1	39·5	4·4
October ...	98·7	78·9	39·8	4·1
November ...	101·1	73·1	39·1	2·7*
December ...	92·4	70·2	36·5	7·7

* For 15 days only.

TABLE III—*concld.*

(*b*) *In* philippinensis *areas.*

Month.	Rate per thousand—all causes.		Rate per thousand—malaria.	
	1944.	1945.	1944.	1945.
January ...	111·8	125·5	34·4	23·0
February ...	113·0	122·8	19·1	15·2
March ...	123·3	118·0	19·6	12·0
April ...	104·8	130·4	17·1	12·1
May ...	114·7	123·9	17·0	13·0
June ...	113·0	117·9	14·9	3·9*
July ...	132·3	134·2	24·7	9·3
August ...	142·5	143·9	30·8	8·0
September ...	131·8	119·5	25·3	5·4
October ...	150·5	118·8	44·1	5·1
November ...	152·8	104·4	51·1	5·9
December ...	136·5	110·0	34·3	4·0
January 1946 ...	125·5 (1945)	96·9 (1946)	23·0 (1945)	1·1 (1946)

* For 15 days only.

TABLE IV.

NUMBER OF DAYS LOST DUE TO ALL CAUSES AND MALARIA.

(*a*) *In* minimus *areas.*

Month.	Days lost due to all causes including malaria.		Days lost due to malaria only.	
	1944.	1945.	1944.	1945.
January ...	16,545	15,925	5,313	4,080
February ...	16,272	13,792	4,738	2,622
March ...	19,036	17,396	5,194	3,023
April* ...	17,135	18,447	5,322	3,730
May ...	19,876	19,423	6,713	3,489
June ...	22,492	19,661	10,693	2,775
July ...	23,466	17,036	11,407	2,010
August ...	21,187	16,807	9,289	1,528
September ...	18,848	15,735	6,216	1,123
October ...	18,849	16,058	7,636	911
November ...	19,870	13,197	6,908	967
December ...	18,180	12,633	6,683	1,301

* Suppressive mepacrine treatment commenced from April 15 and ended on November 15, 1945.

TABLE IV—*concld.*

(*b*) *In* philippinensis *areas.*

Month.	Days lost due to all causes including malaria.		Days lost due to malaria only.	
	1944.	1945.	1944.	1945.
January ...	24,575	28,266	7,165	5,428
February ...	21,892	25,570	4,036	3,593
March ...	26,351	25,389	4,332	2,747
April ...	26,335	26,817	3,873	3,349
May ...	25,965	29,151	3,611	2,544
June* ...	23,551	27,644	3,579	3,099
July ...	28,061	29,051	4,872	3,546
August ...	31,134	30,603	6,856	2,826
September ...	30,660	25,049	6,827	2,047
October ...	35,680	28,874	10,718	1,818
November ...	34,750	25,267	11,740	1,827
December ...	32,368	25,554	9,107	1,366
January 1946*	28,266 (1945)	21,324 (1946)	5,428 (1945)	863 (1946)

* Suppressive mepacrine treatment commenced from June 15, 1945, and ended on January 15, 1946.

COST OF SUPPRESSIVE MEPACRINE TREATMENT.

25 sub-assistant surgeons and 160 sub-assistant malaria inspectors were recruited temporarily to assist the existing medical and malaria staff for daily administration of mepacrine tablets. The total cost involved amounted to Rs. 2,92,344/- of which Rs. 1,01,076/- was incurred on the temporary establishment for 7 months including that on Defence of India zone and dearness allowance, etc. and the remainder Rs. 1,91,268/- as cost of 8,316,000 mepacrine tablets at Rs. 23/- per thousand. The cost *per capita* per month in both *minimus* and *philippinensis* areas came to Re. 0/15/2 or Rs. 6/10/4 per malaria season of seven months' duration.

It is hoped that with the introduction of drugs such as paludrine and chloroquine the cost *per capita* will be reduced considerably as the tablets of these drugs, besides possessing certain advantages over mepacrine, will need to be administered once or twice a week only. The objection to the yellow pigmentation by mepacrine will also be avoided by the use of the new antimalarial drugs.

SUMMARY.

Arrangements for daily distribution of mepacrine tablets to the employees of the B. A. Railway during the malaria season of 1945 and the difficulties encountered therewith have been described.

The remarkable reduction in the incidence of malaria due to suppressive mepacrine treatment and the fall in number of sick days have been elucidated.

The cost *per capita* has been worked out at Re. 0/15/2 per month or Rs. 6/10/4 per malaria season of seven months.

ACKNOWLEDGMENTS.

The author wishes to thank Dr. P. C. Datta, Chief Medical Officer, B. A. Railway, for his valuable guidance and permission to publish this paper and Dr. N. C. Ganguly, Assistant Malariologist, Calcutta, for his assistance in the preparation of this report.

Indian Journal of Malariology, 1, 3, September 1947.

A CRITICAL REVIEW OF THERAPEUTIC TRIALS ON PALUDRINE CARRIED OUT IN INDIA DURING 1946.

BY

LIEUT.-COLONEL M. K. AFRIDI, M.D., CH.B., D.T.M. & H., I.M.S.
(*Malaria Institute of India, Delhi.*)

[July 10, 1947.]

TRIALS on paludrine carried out up to the beginning of 1946 showed that this drug possessed the following distinctive characteristics in the treatment of malaria [Curd, Davey and Rose (1945); Fairley (1946); Adams *et al.* (1945); Maegraith *et al.* (1945)]:—

(*a*) Unlike quinine and mepacrine it was remarkably free from side-effects and toxic symptoms even in relatively large doses. Thus prolonged courses of 0·5 and 0·6 gramme of paludrine twice daily for 14 to 28 days were readily tolerated, producing only in the first few days of the course some abdominal discomfort and vomiting. In the Australian series, transient but marked toxic symptoms of diarrhœa and hæmaturia occurred in two of the cases who received one gramme of paludrine as a single dose.

(*b*) Being colourless it had no staining effect on skin and did not appear to affect the central nervous system. In these respects the drug was definitely superior to mepacrine.

(*c*) It effectively controlled *clinical attacks* of malaria in a wide range of dosages from 0·05 to 0·4 gramme given as a single dose.

(*d*) In doses of 0·3 gramme daily for 10 days, it was said to effect a *complete cure* of malignant tertian infections. In benign tertian, however, the above regime was found insufficient and a follow-up treatment of a weekly dose of 0·1 gramme or at most 0·2 gramme for periods up to six months was necessary to prevent recurrences.

(*e*) As a suppressive, paludrine proved effective against both the exo-erythrocytic and the blood forms of avian malaria parasites.

In man, it was fully effective against the pre-erythrocytic forms of *P. vivax* and *P. falciparum* which, in previous experiments, were shown to be resistant to the action of quinine and mepacrine.

(*f*) In daily doses of 0·1 gramme, paludrine completely prevented the development of *falciparum* malaria but not of *vivax* malaria, overt attacks of which always supervened from 29 to 31 days after the cessation of the drug. Further experiments showed that a single dose of 0·05 to 0·1 gramme of paludrine given on the 2nd to 5th day after infection by mosquitoes afforded complete protection against *falciparum* malaria, the parasites never appearing in the blood.

Under conditions prevailing in India, the potential advantages of using paludrine in the treatment of malaria were its low toxicity and absence of side-effects and the possibility of bringing about a clinical cure of a malarial attack with a single dose of the drug. Field trials on an extensive scale were, however, still necessary partly to confirm its effectiveness against the Indian strains of malaria parasite and partly to determine the optimum dosage schemes for :—

(*a*) the cure of an acute attack of malaria,

(*b*) the complete cure of malarial infections, and

(*c*) the chemotherapeutic prevention or suppression of malaria in persons exposed to natural infections.

In July 1946, therapeutic trials were accordingly initiated in different parts of India under the direction of the Malaria Institute, the results of which covering the period up to the end of that year are collated and reviewed critically in this paper. The findings of many of these investigators are either in press or have already been published, but for convenience all the reports reviewed are listed in the Appendix.

A number of trials on the suppressive action of paludrine were also carried out, but a review of these has been deferred till after the completion of an intensive investigation now in progress in a tea estate in Bengal.

METHODS AND MATERIAL.

Apart from an enquiry in Baluchistan conducted by the members of the staff of the Institute, the drug was tested by independent workers, many of whom followed a specified routine of dosages proposed by the Malaria Institute of India. Particular stress was laid on the fact that, in conducting these trials, tests be confined only to the microscopically diagnosed cases of malaria and that no effort be spared to ensure that the drug in prescribed doses was actually swallowed.

The trials were carried out under a variety of conditions such as in rural dispensaries, in general hospitals, in tea-garden practice and in jails. Each of these

situations offered distinctive advantages and disadvantages which had a definite bearing on the value of the results obtained. It is considered advisable therefore to describe the trials separately under each of these heads before taking up the final analysis of the combined results.

Trials in rural dispensaries.

Trials carried out in rural dispensaries had the disadvantage that owing to the irregular attendance of patients continuous observations on the daily progress of each case were not always possible. On the other hand, since these patients belonged to a restricted community, it was comparatively easier to check their history after treatment.

In most dispensaries the aim was to assess the value of a single dose therapy but in Baluchistan and U.P. a number of other dosage regimes were tested simultaneously. The results obtained from a regimen of 0·3 gramme of paludrine in a single dose in 693 microscopically diagnosed cases of material of all types treated in different dispensaries are grouped in Table I.

Table I.

	Effect on temperature.			Effect on asexual parasites.			Re-admission rate.
	Total cases.	Number, normal in 3 days.	Per cent.	Total cases.	Number, normal in 3 days.	Per cent.	Per cent.
Baluchistan ...	74	58	78	74	58	78	6
U.P. ...	59	53	90	...	...	...	...
Bengal ...	219	190	87	219	153	70	17
Madras ...	341	341	100	...	...	...	9
	693	642	93	293	211	72	...

... Information not available.

The effect of other regimes of paludrine and mepacrine tested simultaneously with the above regime are shown in Table II.

TABLE II.

	Effect on temperature.			Effect on asexual parasites.			Re-admission rate.
	Total cases.	Number, normal in 3 days.	Per cent.	Total cases.	Number, normal in 3 days.	Per cent.	Per cent.
Paludrine—							
Single dose 0·1 gm. (Baluchistan series).	67	53	79	67	47	70	14
0·2 gm. twice daily for periods up to 3 days (Baluchistan series).	66	57	80	66	53	80	8
Mepacrine—							
0·3 gm. daily for periods up to 3 days (Baluchistan series).	34	25	74	34	26	76	2
0·4 gm. daily for 4 days (U.P. series).	50	45	90	...	...	...	...

In addition, 60 microscopically diagnosed cases of malaria were treated with six different regimes of paludrine at Ghatkopar and Bhuleshwar dispensaries, Bombay. The results were uniformly good in all of the cases but the number placed under each regimen was too small to permit differential analysis. These have therefore been excluded from Tables I and II.

TRIALS IN HOSPITALS.

In the hospital trials, the effect of treatment on patients could be observed continuously from day to day but, owing to the inherent difficulties in follow-up, information regarding recrudescences was not as complete as in the dispensary cases.

A total of 181 cases were placed on paludrine treatment in different hospitals at Madras, Bombay and Calcutta. The regimes tried were mostly long courses of paludrine lasting from 2 to 10 days, the daily dosages varying from 0·2 to 0·6 gramme. In only two hospitals were single dose therapy of 0·1 and 0·3 gm. tried and that also on a limited number of cases. The dosage variations employed by the various investigators were, however, so diverse that a regime-wise tabulation of the results is impracticable. The following general conclusions, however, represent a fair summary of the findings as a whole :—

(*a*) With practically all of the regimes, the temperature reached normal within 3 days in 80 to 90 per cent of the cases, no particular regime displaying a definite superiority over the others.

(*b*) In severely toxic cases (seven in one hospital) paludrine in dosage of 0·2 gramme thrice daily for 2 days followed by 0·1 gramme thrice daily for 5 to 6 days was uniformly effective in resolving the symptoms rapidly. Two cases in this series were unconscious at the time of admission to whom the drug had to be administered through a nasal tube.

(*c*) In nine chronic cases of malaria who had frequently relapsed after treatment with quinine and mepacrine with or without pamaquin a weekly dose of 0·1 gramme of paludrine effectively stopped recurrences for the period of observation varying from 14 days to 7 months.

(*d*) The drug was free from unpleasant effects. Indeed, one of the patients volunteered the statement that paludrine was not associated with a feeling of 'hang over' he usually experienced after quinine. In only one hospital were minor untoward symptoms recorded such as urticaria, weakness, sleeplessness, loss of appetite, vomiting alone or associated with diarrhoea and that too in five of the cases under trial.

Trials in jails.

These trials were made on prisoners in jails located in three distinct geographical sectors of the Bombay Province, namely, Ahmedabad, Visapur and Belgaum. Also included in this series were 30 cases of malaria treated in a hyperendemic village in North Kanara District.

Three different regimes were tried in rotation on a total of 124 cases of microscopically diagnosed malaria. In this series patients were continuously under observation for fever and parasites both during and after treatment.

The courses of treatment tested were :—

Course I.—0·3 gramme of paludrine in single dose.

Course II.—0·2 gramme of paludrine twice daily for 2 days.

Course III.—0·1 gramme of paludrine thrice daily for 7 days.

The relative efficacy of the above three courses is brought out in Table III.

Table III.

	Effect on temperature.			Effect on asexual parasites.		
	Total cases.	Normal in 3 days.	Per cent.	Total cases.	Disappeared in 3 days.	Per cent.
Course I	28	24	86	28	28	100
Course II	26	23	88	26	25	96
Course III	54	41	76	54	50	93

Eight cases of quartan and 8 cases of mixed infection have been excluded from the above table as the number under each course was small. Re-admission rate worked out jointly on all the three courses was 10 per cent amongst 60 patients observed over a period of 2 months after the completion of treatment.

Trials in tea estates and collieries.

In these trials, conditions were similar to those in jails in that continuous observation on patients could be made both during and after treatment.

The trials were carried out in two localities: first, in the tea estates in Sylhet (Assam) under Juri Valley Medical Association and, second, in the collieries at Tipong and Namding (Assam) under the Assam Railway and Trading Co., Ltd.

In the tea estates series the bulk of cases were placed on three regimes :—

(A) 0·1 gramme of paludrine in single dose.

(B) 0·3 gramme of paludrine in single dose.

(C) 0·2 gramme of paludrine twice daily for 3 days.

From the second week of September onward, however, four new regimes were introduced :—

(B.1) B course followed by 0·1 gm. once a week.

(C.1) C course followed by 0·1 gm. once a week.

(C.2) C course followed by 0·1 gm. twice a week.

(C.3) 0·2 gramme of paludrine twice daily for 4 days.

The results obtained from treatment with the above regimes are given in Table IV.

Table IV.

	Total cases treated.	Effect on temperature.			Re-admission* rate, per cent.
		Number of cases with records of temperature.	Number, normal in 3 days.	Per cent.	
Course A	56†	43	38	88	18
Course B	150†	132	102	77	16
Course C	193†	193	163	84	8
Course B (1) ...	35	35	25	71	9
Course C (1) ...	43	43	41	95	5
Course C (2) ...	22	22	22	100	9
Course C (3) ...	15	15	12	80	7

* Based on subsequent attacks with homologous infections only.

† Exclusive of quartan cases.

In so far as effect on temperature is concerned, courses B and B (1) should actually have been combined as also courses C, C (1) and C (2) but these are shown separately so as not to complicate the presentation of re-admission rates.

In the collieries, a total of 235 cases were placed under three regimes of treatment as follows :—

Regime 'A'. A single dose of 0·1 gm. of paludrine.
Regime 'B'. A single dose of 0·3 gm. of paludrine.
Regime 'C'. 0·2 gm. of paludrine twice daily for 2 days.

No tabulated figures for the effect of these regimes on fever are recorded but it is observed that course 'A' did not control the pyrexia and that regime 'B' terminated a clinical attack as satisfactorily as regime 'C'. The first named regime was in fact suspended two months after the start of the trial. As regards the effect on parasites, in only two out of 195 cases examined were asexual forms detected on the third day after admission both of whom had been on regime 'C'.

The re-admission rate in the three regimes is given in Table V.

TABLE V.

Regime.	Total treated.	Total re-admitted.	Per cent.
A	15	2	...*
B	92	23	25
C	128	37	29

* Number of cases too small for calculating percentage.

THE EFFICACY OF PALUDRINE IN MALARIAL ATTACK CAUSED BY DIFFERENT SPECIES OF PARASITES.

Out of a total of 1,891 cases analysed in this paper :—
1,283 were *falciparum* (malignant tertian) malaria,
481 cases were *vivax* (benign tertian) malaria,
68 cases were *malariæ* (quartan) malaria, and
59 cases were caused by mixed infections.

From the available records, however, information regarding clinical cure, i.e. subsidence of fever within 3 days, is available in only 1,456 cases which are analysed in Table VI.

TABLE VI.

		0·1 gm. single dose.			0·3 gm. single dose.			All other regimes.		
		Total cases.	Number cured.	Per cent.	Total cases.	Number cured.	Per cent.	Total cases.	Number cured.	Per cent.
Malignant tertian ...	D	51	42	82	464	441	·95	47	42	89
	J.H.T.	30	29	97	155	122	79	293	251	86
	TOTAL	81	71	88	619	563	91	340	293	86
Benign tertian ...	D	15	11	*	127	109	86	16	12	*
	J.H.T.	16	12	*	34	24	71	138	111	80
	TOTAL	31	23	74	161	133	83	154	123	80
Quartan ...	D	0	0	0	38	34	89	1	1	*
	J.H.T.	0	0	0	3	3	*	5	2	*
	TOTAL	0	0	0	41	37	90	6	3	*
Mixed infections ...	D	1	0	*	5	5	*	2	2	*
	J.H.T.	3	3	*	6	5	*	14	6	*
	TOTAL	4	3	*	11	10	*	16	8	*
All infections ...	...	116	97	84	829	740	89	511	425	83

D = Dispensary series.
J.H.T. = Jail, hospital and tea estate series.
* = Number too small for calculating percentages.

A study of Table VI shows that in dispensaries as well as in hospitals, etc., the three types of malaria infections responded equally satisfactorily to the different regimes of paludrine tested. On the whole malignant tertian cases

appeared to react more rapidly than benign tertian but differences in this respect were not very marked.

As regards quartan, the satisfactory reaction of the cases recorded in Table VI has to be viewed in the light of experiences with a number of other cases which have for some reason or other been excluded from this table. Thus in tea estate series 8 cases of quartan had to be omitted as they, owing to poor response to paludrine, were transferred to 'other antimalaria treatment'. In Baluchistan (dispensary series) one case of quartan continued to have fever for 7 days after which the patient did not attend. The final result being uncertain this case had similarly to be excluded from the table.

Since the bulk of the cases in Table VI showing favourable reactions occurred in Bengal and Madras it is tempting to ascribe this difference in reaction to possible differences in the geographical strains of *P. malariæ*. It is more probable, however, that the resistant cases in Assam and Baluchistan were examples of 'slow' response, which has been observed to occur even in a proportion of malignant and benign tertian cases. Whatever the explanation, it is clear that the available results do not confirm the prevailing impression of paludrine being ineffective against quartan malaria.

Another impression needing detailed examination is that despite the high percentage of cures with 0·1 gm. single dose in Table VI, this regime was deemed ineffective particularly in the tea estates and in Baluchistan. On the basis of the re-admission rates which were higher with this than with the other regimes, there was some justification for this view in the Baluchistan series (Tables I and II) but no such difference was evident in the tea estates figures under Courses A and B in Table IV. In an effort to find an adequate explanation for this impression the re-admission rates were re-analysed in time groups as shown in Table VII.

TABLE VII.

	Baluchistan series.					Tea estate series.				
	Total cases.	Re-admission rates per cent within days.				Total cases.	Re-admission rates per cent within days.			
		10	20	30	Over 30		10	20	30	Over 30
0·1 gm. therapy	161	2·5	7·5	9·3	13·7	56	7·1	16·1	17·9	17·0
0·3 „ „	161	1·2	4·4	5·0	6·2	150	1·3	4·0	8·0	16·0
0·2 gm. twice daily for 3 days.	150	0·7	1·3	4·0	4·7	193	1·1	3·6	5·7	7·8

From Table VII it will be observed that in Baluchistan roughly twice as many re-admissions occurred amongst those treated with 0·1 gm. single dose as those placed on 0·3 gm., this ratio remaining almost constant in different time groups.

The proportion of re-admissions after divided dose therapy was much lower in the first twenty days but thereafter it approximated that observed in cases treated with 0·3 gm. single dose.

In the tea estate series this trend is even more marked. Thus, comparing 0·1 gm. and 0·3 regime, the ratio between the re-admission rates in the two groups did not remain equal as in Baluchistan series, but gradually decreased with time being 6 times higher in 0·1 gm. regime after 10 days, 4 times higher after 20 days, twice as high after 30 days and almost equal after more than 30 days. It would therefore appear that in 0·1 gm. therapy the disease tends to recur frequently in the first 10 to 20 days after the completion of treatment, which in turn is probably responsible for the clinical impression that the regime is ineffective. This view is further borne out by comparing the results of 0·3 gm. single dose with those obtained from treatment with divided doses in the tea estate series. Here the proportion of re-admissions remained equal in the two groups up to 20 days but thereafter the superiority of the latter course in this respect became clearly established. In other words, the effect of increase in the dosage of paludrine was that re-admissions were fewer in number as in Baluchistan or were simply delayed or both lessened and delayed as in the tea estates.

Since re-admissions could have been caused by relapses or/and reinfections, the varying trends with different regimes observed in Baluchistan and tea estates might have been due either to a higher reinfection rate or to a larger inoculation dose of sporozoites in the latter locality or to a combination of the two. Whatever the cause, it is obvious that in hyperendemic areas where patients are exposed to repeated infections it would be inadvisable to recommend 0·1 gm. single dose regime despite the high percentage of immediate cures recorded in Table VI.

DISCUSSION.

While it is realized that in the summation of grouped results the error introduced by differences in standards of observation cannot altogether be ignored it is felt that the number of cases analysed in this paper is large enough to dilute this error considerably. Moreover, a reference to the various tables in the text will show that the results obtained were extraordinarily consistent.

From the evidence presented by these trials as a whole the following conclusions may be drawn :—

First.—Paludrine proved as effective against the strains of malaria parasites in India as those tested elsewhere.

Second.—A single dose of 0·1 gramme and 0·3 gramme paludrine effectively terminated an acute attack of malaria in as large a proportion of cases as with longer course of paludrine or mepacrine. For reasons stated in the foregoing section, however, 0·3 gramme single dose therapy is preferable particularly in hyperendemic areas.

Third.—None of the regimes tested appeared to effect a *complete* cure either of the malignant or of the benign tertian infections. While it is possible that such a regime may ultimately be discovered in the present state of our knowledge it would be as

well to recognize this limitation of the drug thereby avoiding the analogous mistake in the past when progressively longer courses and increasing dosages of quinine were tried for similar purpose over many years without success.

This attitude is particularly desirable for two reasons. First the follow-up treatment with a weekly dose of 0·1 gm. or 0·2 gm. paludrine is convenient, safe and invariably successful in suppressing the disease even in the most persistently relapsing cases of malaria. It is still necessary, however, to define the minimum duration of the follow-up treatment as the existing recommendations vary from six months (Australian Army) to one year (Indian Army). In one of the relapsing cases under the author's care, the disease recurred at a time when there was no question of reinfection, three weeks after the cessation of a follow-up treatment of 0·1 gm. a week lasting three months. This is admittedly an individual case but is recorded as the patient took the drug conscientiously until he ran out of supplies.

Second, the maximum re-admission rate with 0·3 gm. single dose therapy in these trials was 25 per cent (Table V) and the maximum reduction in this percentage by prolonging the course did not exceed 11 per cent (Table IV). The question therefore arises whether it is justifiable to administer long courses to all patients knowing that it would protect only a small percentage from relapsing. In India, where the number of malaria cases requiring treatment runs into millions, a long course apart from other considerations would entail such an enormous increase in cost that much stronger evidence must be produced before it can be recommended for general adoption.

From the results of these trials, it would appear that the most logical scheme for the treatment of malaria would be as follows :—

In rural and hospital practice in India, the standard course for all cases of malaria should be 0·3 gm. of paludrine in single dose. For those who can be relied upon to take the drug regularly anti-relapse treatment may be prescribed by giving 0·1 gm. of paludrine once or twice a week for a minimum period of six months. In the remainder, relapses should be treated as and when they arise.

Fourth.—In patients with pernicious symptoms, paludrine was successful in resolving the attack rapidly in a small number of cases tested (7 in hospital series and one in tea estate series).

Fifth.—In the dosages given (maximum 0·6 gm. per day) paludrine did not show any ill effects except in 5 cases in whom minor symptoms were recorded. In the tea estate series unpleasant effects

from paludrine were said to disappear when the drug was administered on full stomach and with a glass of water. Here it was also observed that infants and pregnant women tolerated the drug extremely well, paludrine proving more satisfactory than quinine or mepacrine in the latter class of patients.

In the author's own series of cases, many of the intelligent patients remarked on the extraordinary feeling of well-being which the drug induced within an hour or two of taking it.

SUMMARY.

1. Field trials on paludrine for the treatment of malaria were initiated in July 1946 in different parts of India under the direction of the Malaria Institute of India. The tests were carried out under varying conditions such as rural dispensaries, hospitals, jails, tea estates and collieries. The results obtained up to December 1946 are analysed and reviewed critically.

2. The value of different dosage regimes was assessed on 1,891 microscopically diagnosed cases of malaria of which 1,283 were *falciparum* (malignant tertian) malaria, 481 were *vivax* (benign tertian) malaria, 68 were *malariæ* (quartan) malaria while the remaining 59 cases showed mixed infections.

3. Paludrine was found to be as effective against the strains of malaria parasites in India as those tested elsewhere.

4. A single dose of 0·1 gm. and 0·3 gm. of paludrine effected a clinical cure within three days in 84 to 89 per cent of cases. The drug was equally effective against the three species of malaria parasites although the response was more rapid in malignant tertian than in benign tertian or quartan. In trials where paludrine and mepacrine were tested side by side the curative action of paludrine in the above doses was equal to that of mepacrine in daily dose of 0·3 and 0·4 gm. for 3 and 4 days respectively.

5. Neither the prolongation of treatment up to 10 days nor an increase in the dosage of paludrine to 0·6 gm. per day caused any appreciable improvement in the percentage of clinical cure. The re-admission rates caused by relapses and/or reinfections were relatively lower in cases treated with high dosages but none of the regimes tested appeared to effect a complete cure. A follow-up treatment of 0·1 gm. once or twice weekly prevented the recurrence of disease in chronic relapsing cases.

6. It is suggested that in the present state of our knowledge the most desirable course of treatment for malaria in India both in the dispensaries and the hospitals would be a single dose of 0·3 gm. of paludrine. In majority of cases relapses should be treated as and when they arise, but for those who can be relied upon to take the drug regularly, a follow-up treatment of 0·1 gm. once or twice a week should be prescribed for a minimum period of six months.

7. Paludrine proved to be a safe drug, free from unpleasant effects and non-toxic even in high doses of 0·6 gm. per day. Patients placed on this drug experienced a feeling of well-being within an hour or two of taking it. It was well tolerated by infants and pregnant women.

8. In the small number of cases with toxic or pernicious symptoms tested in these trials paludrine was uniformly successful in effecting a rapid cure.

REFERENCES.

ADAMS, A. R. D., MACGRAITH, B. G., KING, J. D., TOWNSEND, R. H., DAVEY, T. H., and HARVARD, R. E. (1945). *Ann. Trop. Med. Parasit.*, **39**, pp. 225–231.

CURD, F. H. S., DAVEY, D. G., and ROSE, F. L. (1945). *Ibid.*, **39**, pp. 157–164.

FAIRLEY, N. H. (1946) ... *Trans. Roy. Soc. Trop. Med. & Hyg.*, **40**, 2, pp. 105–162.

MACGRAITH, B. G., ADAMS, A. R. D., KING, J. D., TOWNSEND, R. H., DAVEY, T. H., and HARVARD, R. E. (1945). *Ann. Trop. Med. Parasit.*, **39**, pp. 232–236.

APPENDIX.

List of reports on therapeutic trials on paludrine reviewed critically in the text of the paper.

Dispensary series.

An enquiry on certain aspects of paludrine.

By Lieut.-Colonel M. K. Afridi, Drs. S. P. Ramakrishnan, A. Goswami, and M. K. Menon, Malaria Institute of India, Enquiry in Baluchistan (*Ind. Jour. Mal.*, **1**, 1, pp. 221–229).

Preliminary report on the use of paludrine in the field.

By Major M. Jafar, Director of Public Health, Bengal (*Ind. Jour. Mal.*, **1**, 3, pp. 365–368).

Final report on the field trials of paludrine in selected hyperendemic malarious areas of Naini Tal Tarai in the U.P.

By Dr. R. S. Srivastava, Assistant Director of Public Health (Malariology), U.P. (*Ind. Jour. Mal.*, **1**, 3, pp. 361–363).

A brief summary of the field experiments conducted with paludrine by the Malaria Organization of the Madras Public Health Department up to 31st October, 1946.*

By Dr. K. S. Viswanathan, Assistant Director of Public Health (Malaria and Mosquito-borne Diseases), Madras.

Paludrine treatment in malaria.*

By Drs. B. C. Das Gupta, G. T. Balankhe, G. N. Kowshik and M. V. Hegde, Public Health Department, Bombay Municipality.

Hospital series.

Final report on the study of 58 cases of malaria treated with paludrine.

By Prof. M. N. De and Dr. Pramatha Nath Datta, Medical College Hospital, Calcutta (*Ind. Jour. Mal.*, **1**, 3, pp. 373–381).

Preliminary report on the result of treatment of malaria with paludrine.

By Prof. B. N. Ghosh, Carmichael Medical College, Calcutta (*Ind. Jour. Mal.*, **1**, 3, pp. 369–371).

Report on the treatment of malaria with paludrine.*

By P. Kutumbiah and M. D. Ananthachari, Medical Unit, Stanley Hospital, Madras.

Report on the treatment of malaria with paludrine hydrochloride.*

By Dr. Pisharoty, Physician, Govt. General Hospital, Madras.

Report on the use of paludrine tablets.

By J. G. Parekh and B. P. Boghani, Sir J. J. Hospital, Bombay (*Ind. Jour. Mal.*, **1**, 3, pp. 383–387).

Jail series.

Experiments with paludrine in the chemotherapy of malaria.

By Dr. D. K. Viswanathan and Rao Saheb J. D. Baily, Malaria Organization, Bombay Presidency (*Ind. Jour. Mal.*, **1**, 2, pp. 307–328).

Tea Estate series.

Paludrine prophylactic and treatment investigation.*

By Dr. K. S. P. Hamilton, Medical Officer, Juri Valley Medical Association, Sylhet (Assam).

Collieries series.

Paludrine treatment enquiry in Assam.

By Dr. P. H. Lomax, Principal Medical Officer, Assam Railway and Trading Co., Ltd. (*Ind. Jour. Mal.*, **1**, 3, pp. 389–393).

---

* A copy of the original report has been placed in the Library of the Malaria Institute of India. This is available on loan to workers who wish to consult it.—*Editor.*

Indian Journal of Malariology, 1, 3, September 1947.

FINAL REPORT ON THE FIELD TRIALS OF 'PALUDRINE' IN SELECTED HYPERENDEMIC MALARIOUS AREAS OF NAINI TAL TARAI IN THE UNITED PROVINCES (11TH SEPTEMBER TO 31ST DECEMBER, 1946).

BY

R. S. SRIVASTAVA

[*Assistant Director of Public Health (Malariology), U.P.*].

[January 24, 1947.]

INTRODUCTION.

THE present inquiry was instituted in this province under the direction of the Director, Malaria Institute of India, who supplied the requisite amount of paludrine tablets (100 mg. each) for the trial.

Two areas, viz. Tanakpur and Chakarpur, both in the tarai tract of Naini Tal District, formed the venue of these experiments. Tanakpur is a small market-place situated in the foot-hills of Himalayas at about 850 feet above sea level. It is the terminus of the Pilibhit-Tanakpur section of the O. T. Railway. The permanent population is about 500 persons which swells up to about 3,000 during the winters (market season), when there is an influx of people from the neighbouring districts of Almora, Garhwal, Nepal and some other plain districts of the United Provinces. The place is notorious for being highly malarious.

The second area, viz. Chakarpur, is a fairly big labourcamp established by the P. W. D. Irrigation Branch, U.P., for the construction of the Sarda Hydroelectric Power Station, at a distance of about 7 miles south of Banbassa and about 2 miles from Chakarpur Railway Station on the Pilibhit-Tanakpur section of the O. T. Railway. This area is also known to be notoriously malarious.

NATURE OF THE SCHEME.

The experiments were carried out under the direct supervision of two whole-time specially trained medical officers equipped with a laboratory.

(*a*) A single dose of 3 tablets of 100 mg. each was administered by the medical officer himself.

(*b*) A thick blood film was taken just before the administration of the drug, and in cases when found negative, a second smear was taken on the succeeding day and the results recorded in a register.

(*c*) Morning and evening temperatures were recorded every day for so long as fever persisted.

(*d*) Each patient was followed up for as long as it was possible to observe the recurrence of fever, if any. Relapsing cases were treated again as before with a single dose of 300 mg. of paludrine.

(*e*) Alternate cases were treated with mepacrine hydrochloride and 3 tablets of 100 mg. each a day for 3 days and records kept as in the case of paludrine-treated patients.

RESULTS.

During the period 11th September to 31st December, 1946, during which the trials were carried out, 138 cases in all were treated. Out of these, 76 were treated with paludrine and 62 with mepacrine. Of the 76 paludrine-treated cases, 37 were malignant tertian, 22 benign tertian and 17 negative for malaria parasite, while in the mepacrine-treated cases, 29 were malignant tertian, 20 benign tertian, 1 quartan and 12 negative.

The following table shows the results of the experiments :—

	Number of cases treated.	Number of days in which temperature came down to normal.					
		1	2	3	4	5	Untraceable.
1. Paludrine-treated malaria positive cases.	59	24	13	16	5	1	...
2. Mepacrine-treated malaria positive cases.	50	5	20	20	1	1	3
3. Paludrine-treated malaria negative cases.	17	8	4	2	2	1	...
4. Mepacrine-treated malaria negative cases.	12	5	3	4	...	...	...
TOTAL ...	138	42	40	42	8	3	3

Recurrence of fever in paludrine-treated cases was recorded in 30 per cent (23 out of 76) as compared to 8·0 per cent (5 out of 62) in mepacrine-treated cases. Out of the total cases where there was a recurrence of fever among paludrine-treated patients 11 were of benign tertian and 5 of malignant infection. Corresponding figures for mepacrine-treated cases were 1 and 2.

CONCLUSION AND SUMMARY.

The number of cases treated is too small to admit of final conclusions but the following inferences can be drawn from the data obtained from a total of 138 cases :—

(*i*) Paludrine in the dosage in which it was administered (300 mg. single dose) controlled malarial attacks quicker than mepacrine. The fever touched normal in 24 hours in 42 per cent of paludrine-treated cases against 16 per cent of mepacrine-treated cases.

(*ii*) In an hyperendemic area like that of the Naini Tal Tarai, it is very difficult to evaluate the relapse-preventing properties of paludrine, because of the difficulty to ascertain whether a person had actually relapsed or had been reinfected. If the cases which had a recurrence of fever in these areas were cases of relapses, paludrine did not show any advantage over mepacrine in its relapse-preventing properties.

(*iii*) No toxic effects were noticed.

Indian Journal of Malariology, 1, 3, September 1947.

PRELIMINARY REPORT ON THE USE OF PALUDRINE IN THE FIELD.

BY

MAJOR M. JAFAR, M.B.B.S., D.P.H. (Lond.), D.T.M. & H. (Lond.)
(*Director of Public Health, Bengal*).

[March 1, 1947.]

AN investigation into the efficacy of paludrine in the treatment of malaria under rural conditions was undertaken by the Health Directorate, Government of Bengal, in the beginning of October 1946.

The area selected for the experiment is situated in the Haringhata Police Station zone in the Nadia district, about 35 miles from Calcutta. It is hyperendemic from the malaria point of view, the spleen rate being over 85 per cent and the parasite rate 37 per cent. An attempt was made at the beginning to see the patients at fixed centres, but the attendance being poor and irregular, this procedure was discontinued. This was substituted later by the medical officers visiting the patients at their houses, where the drug was administered to the patient personally by them. History of fever of every patient was noted down and blood films taken on the first and subsequent visits to watch the progress of the case.

A single dose of 300 mg. of paludrine was administered to all adult patients. To those between 6 and 12 years and under 6 years, half and one-third of the adult dose was administered respectively.

Number of cases.—Up to the 31st of January, 1947, a total of 492 cases were treated with paludrine. Of this number, 481 were actually suffering from fever at the time of the first visit and the remaining 11 were afebrile cases but showed malaria parasites in the blood. The effect of the drug on the temperature is shown in Table I.

TABLE I.

Number of cases with temperature treated.	Number in which temperature reached normal within 3 days.	Percentage.	Number in which temperature reached normal after 3 days but within 6 days.	Total number of cases in which temperature reached normal within 6 days.	Percentage.
481	300	61·0	47	487	90·8

Of the 492 cases treated with paludrine, only 246 showed malaria parasites in their peripheral blood taken at the time of the first visit. The different varieties of parasite that were seen are shown in Table II.

TABLE II.

Parasites.	Asexual form.	Sexual form.	TOTAL.
P. falciparum	93	26	119
P. vivax	48	22	70
P. malariæ	21	9	30
Mixed *P. falciparum* and *vivax* ...	...	...	12
Mixed *P. falciparum* and *malariæ* ...	...	...	10
Mixed *P. vivax* and *malariæ* ...	...	...	5
		TOTAL ...	246

The effect of the drug on different types of clinical conditions caused by the three varieties of parasite is indicated in Table III. Cases with mixed infections have been excluded.

TABLE III.

Infections.	Number of cases.	Cases in which temperature reached normal in 3 days.	Percentage.	Cases in which temperature reached normal after 3 days but within 6 days.	Total number of cases in which temperature reached normal within 6 days.	Percentage.
Falciparum malaria ...	119	108	90·7	11	119	100·0
Vivax malaria	70	56	80·0	10	66	94·3
Malariæ malaria ...	30	26	86·7	4	30	100·0
TOTAL ...	219	190	86·7	25	215	98·1

The effect of paludrine on parasites in the different types of infection is given in Table IV.

TABLE IV.

Infections.	Number of cases.	Cases in which parasites disappeared within 3 days.	Percentage.	Cases in which parasites disappeared after 3 days but within 6 days.	Total number of cases in which parasites disappeared within 6 days.	Percentage.
Falciparum malaria ...	119	90	75·6	12	102	85·6
Vivax malaria	70	49	70·0	5	54	77·1
Malariæ malaria	30	14	46·6	4	18	60·0
TOTAL ...	219	153	69·9	21	174	79·4

The effect of the drug on asexual and sexual forms of parasite separately is shown in Table V.

TABLE V.

Infections.	ASEXUAL.							SEXUAL.				
	Total number of cases.	Number with asexual parasites.	Cases where parasites disappeared within 3 days.	Percentage.	Cases in which parasites disappeared after 3 days but within 6 days.	Total number of cases in which parasites disappeared within 6 days.	Percentage.	Number with sexual parasites.	Cases in which parasites disappeared within 3 days.	Percentage.	Cases in which parasites disappeared after 3 days but within 6 days.	Total number of cases in which parasites disappeared within 6 days.
Falciparum malaria	119	93	89	85·6	4	93	100·0	26	1	3·8	9	10
Vivax malaria ...	70	48	42	87·5	5	47	97·9	22	7	31·8	4	11
Malariæ malaria ...	30	21	11	52·3	5	16	76·1	9	3	33·3	1	4
TOTAL ...	219	162	142	87·6	14	156	96·2	57	11	19·5	14	25

The occurrence of a second malaria attack after 14 days of administration of the drug is set forth in Table VI.

TABLE VI.

Infections.	Total number of cases treated.	Number of relapses with homologous parasites.			Number of relapses with heterologous parasites.		
		Within 14 days.	Within 21 days.	Within 28 days.	Within 14 days.	Within 21 days.	Within 28 days.
Falciparum malaria	119	2	10 (3)*	11 (5)*	...	3	...
Vivax malaria ...	70	1	4 (1)*	5 (2)*	1	2	1
Malariæ malaria ...	30	...	2 (1)*	2	...	...	1
TOTAL ...	219	3	16 (5)*	18 (7)*	1	5	2

* ( ) Parasites could not be detected in peripheral blood of these cases.

During the period under report, no antimosquito measures were carried out in these villages.

SUMMARY.

The effect of paludrine on 492 cases of malaria is described. A dosage of 300 mg. given as a single dose was successful in resolving the clinical attack in 3 days in 81 to 87 per cent of cases in all types of infection both as regards fever and parasites.

Indian Journal of Malariology, 1, 3, September 1947.

PRELIMINARY REPORT ON THE RESULT OF TREATMENT OF MALARIA WITH PALUDRINE.

BY

B. N. GHOSH.

(*Carmichael Medical College, Calcutta.*)

[March 1, 1947.]

THIS trial was commenced from the middle of December 1946, therefore the number of cases treated is small.

METHOD OF SELECTION OF CASES.

(1) The use of paludrine was restricted only to indoor patients.

(2) It was tried only on those cases who were suffering from actual clinical attacks and whose blood showed presence of parasite.

(3) As far as possible cases of first attack only were selected.

(4) The drug was exhibited only to those cases who had not taken any other antimalarial remedy for at least six weeks.

Total number of cases was 20:

Malignant tertian	10
Benign tertian	6
Mixed infection	4

METHOD ADOPTED.

All cases were selected after these had been found positive on blood examination.

Paludrine was administered daily for two or three days and the blood was examined daily to ascertain when it became parasite free and the amount of paludrine taken was noted. The administration of the drug was stopped when the patient became fever free and parasite free. Object was to watch the patient for relapse but so far in the present series of cases no relapse has been recorded so that there was no necessity to administer the drug again.

Six cases received only a single dose of 100 mg., 4 showing *P. falciparum* rings and 2 *P. vivax.*

Other cases received multiple doses (100 to 200) daily for two to five days.

RESULTS.

Patients became fever free by the first to sixth day and parasite free by second to sixth day. It was noted that in some cases fever disappeared though the parasites were still present in the blood. Generally the patient became fever free after six doses had been taken in three days of 100 mg. each twice a day. Details are given in Table I.

TABLE I.

Number of cases.	Total amount of paludrine.	Type of infection.	Day of treatment patient became fever free.	Day patient became parasite free.	Gametocytes.	Period of observation, days.	Relapse.
2	100 mg. single dose.	M.T.	1st	4th	None found	11	*Nil.*
2	100 mg. single dose.	M.T.	3rd	2nd	*Nil*	10	*Nil.*
2	300 mg. (1st dose 200 mg.).	M.T.	2nd	2nd	Present	18	*Nil.*
2	700 mg.	M.T.	6th	4th	Crescents present till discharged.	16	*Nil.*
2	500 mg. (1st dose 200 mg.).	M.T.	6th	3rd	Present	18	*Nil.*
2	200 mg. ...	B.T.	4th	6th	Present	14	*Nil.*
2	100 mg. ...	B.T.	2nd	3rd	*Nil*	15	*Nil.*
4	400 mg. ...	B.T.+ M.T.	5th	4th	*Nil*	12	*Nil.*
2	100 mg. (in two doses of 50 mg. each).	B.T.	2nd	3rd	*Nil*	15	*Nil.*

Sexual forms :—

In all cases the sexual forms were present except only in five.

Relapse :—

So far there was no relapse up to the period of observation (18 days).

Untoward effects :—

The patients did not complain of any effects in the form of nausea, vomiting, nor were other untoward symptoms noticed.

SUMMARY AND CONCLUSIONS.

From the above it will be apparent that despite the small number of cases treated it can be asserted with confidence that paludrine is a safe drug to use and will stop clinical attacks of malaria in doses which produce no untoward symptoms. In the above series a minimum single dose of 100 mg. and a maximum of 700 mg. in five days were required to make the patient fever free and parasite free. It had little effect on the sexual forms of the parasite. Since no case of pregnant women was treated in this series, it cannot be stated whether paludrine has any effect on pregnant uterus. The drug was used under restricted conditions and on clear cases of malaria. When used indiscriminately and in less restricted doses perhaps some untoward symptoms not observed in this series may supervene.

Indian Journal of Malariology, 1, 3, September 1947.

FINAL REPORT ON THE STUDY OF 58 CASES OF MALARIA TREATED WITH PALUDRINE.

BY

M. N. DE, M.B., M.R.C.P. (Lond.), F.N.I.,

AND

PRAMATHA NATH DATTA, M.B.
(*Medical College Hospital, Calcutta.*)

[January 31, 1947.]

In this study only cases which showed malarial parasites in the peripheral blood were selected. After the parasites were detected in the blood, paludrine tablets, 100 mg. each, were started and the effects of the drug observed from day to day. Films of peripheral blood were examined every day at intervals of 24 hours for parasites and also to ascertain as far as possible the time when parasites disappeared from the blood. Along with this, the general condition of the patient was noted.

Altogether 58 cases were treated. Out of these, 20 were suffering from malignant tertian and the rest from benign tertian infection. We were unable to get any patient infected with *P. malariæ*. None of the cases in the series had taken any antimalarial remedy before admission into the hospital.

The cases were divided into 5 groups.

Group I (*Table I*).—This consisted of 12 cases. Paludrine was administered in doses of 1 tablet three times daily for 7 days and then 1 tablet twice daily for another 7 days. Before they were discharged special instructions were given to them to return immediately if they had any fever.

It will be seen from the table that out of the 12 cases 4 were malignant tertian and the rest benign tertian cases. The parasites disappeared from the peripheral

blood after 48 hours in 7 cases, after 72 hours in 4 cases and after 96 hours in one case. The temperature dropped to normal and remained normal after 12 to 80 hours of treatment. All the patients felt so well within 3 to 4 days that some of them insisted on leaving the hospital as they had no complaints, but they were detained till the full course of treatment had been completed. No sign or symptom suggesting any toxic effect was noticed. The details of this group of cases may be studied from Table I.

Group 2 (*Table II*).—In this series paludrine was given in doses of 1 tablet three times a day for 7 days continuously and then stopped. Patients were observed for a fortnight and then discharged. This group consisted of 20 cases of which 6 were due to malignant tertian and 14 due to benign tertian infection. Two of the cases (Nos. 4 and 6 in Table II) were admitted with severe toxic symptoms and one of them (No. 4) was in a semi-conscious state. In 2 cases, parasites could not be detected in blood films after 24 hours, in 12 cases after 48 hours and in 6 cases after 72 hours. Only in one case parasites disappeared after taking the tablets for 96 hours. The fever subsided within 12 to 96 hours. The details may be studied from Table II.

Group 3 (*Table III*).—This consisted of 14 cases. Paludrine was administered in doses of 1 tablet twice daily for 7 days continuously and then stopped.

It will be seen from Table III that there were 13 cases of benign tertian and one of malignant tertian infection. Parasites disappeared from the peripheral blood after 24 hours in 4 cases, after 48 hours in 9 cases and after 72 hours in one case. The fever stopped within 24 to 72 hours in 11 cases. In 2 cases, however, the fever persisted for 120 hours. There was no relapse.

Group 4 (*Table IV*).—This consisted of 7 cases. Paludrine was administered in doses of 2 tablets three times daily for the first 2 days and then 1 tablet thrice daily for the remaining 5 to 6 days. These were severe cases. The patients showed evidence of toxæmia and 2 of them were definitely unconscious. Blood films showed on examination very heavy infection. Four of the cases were malignant tertian and 3 benign tertian infection with high fever, drowsy state and signs of dehydration. In some of these cases the tablets had to be crushed, mixed with fluid and administered through a nasal tube. In 4 cases, parasites disappeared from peripheral blood after 48 hours and in 3 cases after 72 hours. Temperature subsided within 24 to 84 hours. None of them ended fatally and there was no relapse.

Group 5 (*Table V*).—These cases were treated by a colleague of the senior writer, Dr. D. R. Dhur, Honorary Additional Physician, who has very kindly allowed us to use his records. This group consisted of 5 cases and the course of treatment followed by him was 1 tablet twice daily for 3 days only. The results may be studied from Table V.

TABLE I.

Serial number.	Age in years.	Complaints.							Spleen.	Liver.	General condition.	Blood examination.					Maximum temperature during first 24 hours, °F.	Temperature dropped to normal in hours.	Toxic symptoms.	Relapse.
		Duration in days before admission.	Fever.	Continuous.	Intermittent.	Remittent.	Headache.	Vomiting.				Type of infection.	Parasites in blood.							
													After 24 hours of treatment.	After 48 hours of treatment.	After 72 hours of treatment.	After 96 hours of treatment.				
1	15	2	F	...	I	...	H	...	+	—	Fair	M.T.	+	+	—	—	103	72	—	—
2	14	2	F	...	I	...	H	...	+	—	Fair	M.T.	+	+	—	—	104	72	—	—
3	22	4	F	C	I	...	H	...	+	—	Fair	M.T.	+	—	—	—	103	72	—	—
4	26	7	F	...	I	...	H	...	+	—	Fair	M.T.	+	—	—	—	101	36	—	—
5	17	4	F	...	...	R	H	V	+	+	Fair	B.T.	+	+	+	—	104	72	—	—
6	35	3	F	...	I	...	H	V	+	—	Fair	B.T.	+	—	—	—	100	12	—	—
7	20	5	F	...	I	...	...	V	+	—	Fair	B.T.	+	—	—	—	103	72	—	—
8	27	5	F	...	I	...	...	V	+	—	Fair	B.T.	—	—	—	—	102	24	—	—
9	33	3	F	C	...	...	H	V	+	+	Fair	B.T.	+	—	—	—	104	60	—	—
10	22	3	F	...	I	...	H	V	+	+	Fair	B.T.	+	+	—	—	103·5	48	—	—
11	22	2	F	Loose motions.	I	...	...	V	+	—	Fair	B.T.	+	—	—	—	104·5	80	—	—
12	35	5	F	...	I	...	H	...	—	—	Fair	B.T.	+	+	—	—	103	48	—	—

TABLE II.

Serial number.	Age in years.	Complaints.							Spleen.	Liver.	General condition.	Blood examination.					Maximum temperature during first 24 hours, °F.	Temperature dropped to normal in hours.	Toxic symptoms.	Relapse.
		Duration in days before admission.	Fever.	Continuous.	Intermittent.	Remittent.	Headache.	Vomiting.				Type of infection.	Parasites in blood.							
													After 24 hours of treatment.	After 48 hours of treatment.	After 72 hours of treatment.	After 96 hours of treatment.				
1	18	8	F	...	I	...	H	V	+	+	Fair	M.T.	+	+	—	—	104	96	—	—
2	48	3	F	...	I	...	...	...	+	+	Fair	M.T.	+	—	—	—	101	12	—	—
3	29	10	F	C	I	...	...	...	+	+	Fair	M.T.	+	+	—	—	101	60	—	—
4	16	3	F	C	...	...	...	...	—	—	Semi-conscious.	M.T.	+	+	—	—	102	72	—	—
5	25	5	F	C	...	...	...	V	+	+	Fair	M.T.	+	—	—	—	102	24	—	—
6	12	4	F	...	I	...	H	...	+	+	Very toxic.	M.T.	+	—	—	—	101	48	—	—
7	50	4	F	...	I	...	H	V	+	—	Fair	B.T	+	—	—	—	103	36	—	—
8	30	3	F	...	I	...	H	V	—	—	Fair	B.T.	+	—	—	—	104·5	72	—	—
9	12	5	F	...	...	R	H	...	+	+	Fair	B.T.	+	+	+	—	99	80	—	—

10	27	1	F	...	I	...	H	...	+	—	Fair	B.T.	+	—	—	—	101	60	—	—
11	23	1	F	Loose motions.	I	...	H	...	+	—	Fair	B.T.	+	—	—	—	100	24	—	—
12	30	4	F	...	I	...	H	V	+	+	Fair	B.T.	+	+	—	—	101·5	80	—	—
13	42	3	F	...	I	...	H	V	+	+	Fair	B.T.	+	—	—	—	102	48	—	—
14	20	5	F	...	I	...	...	...	—	—	Fair	B.T.	—	—	—	—	98·6	6	—	—
15	21	3	F	...	I	...	H	V	+	—	Fair	B.T.	+	—	—	—	102	24	—	—
16	20	4	F	...	I	...	H	...	+	+	Fair	B.T.	+	—	—	—	103	36	—	—
17	60	30	F	...	I	...	...	...	+	—	Fair	B.T.	+	—	—	—	102	36	—	—
18	40	20	F	...	I	...	H	...	+	+	Fair	B.T.	+	—	—	—	101	48	—	—
19	75	2	F	...	I	...	...	...	—	—	Fair	B.T.	+	+	—	—	101	48	—	—
20	5	4	F	...	I	...	...	V	—	+	Fair	B.T.	+	+	—	—	104	72	—	—

TABLE III.

Serial number.	Age in years.	Duration in days before admission.	Fever.	Complaints.					Spleen.	Liver.	General condition.	Blood examination.					Maximum temperature during first 24 hours, °F.	Temperature dropped to normal in hours.	Toxic symptoms.	Relapse.
				Continuous.	Intermittent.	Remittent.	Headache.	Vomiting.				Type of infection.	Parasites in blood.							
													After 24 hours of treatment.	After 48 hours of treatment.	After 72 hours of treatment.	After 96 hours of treatment.				
1	24	9	F	...	I	...	...	...	+	—	Fair	B.T.	+	—	—	—	102	60	—	—
2	9	5	F	...	I	...	H	...	+	—	Fair	B.T.	—	—	—	—	103·5	48	—	—
3	65	3	F	...	I	...	...	...	—	—	Fair	B.T.	+	—	—	—	102	72	—	—
4	11	3	F	...	I	...	...	V	+	+	Fair	B.T.	+	—	—	+	103	36	—	—
5	50	5	F	...	I	...	...	...	+	+	Fair	B.T.	+	—	—	—	102	120	—	—
6	38	1	F	...	I	...	H	V	+	—	Fair	B.T.	—	—	—	—	...	24	—	—
7	18	2	F	Blood	I	Mucus	H	Stool V	+	—	Fair	B.T.	+	—	—	—	...	96	—	—
8	8	3	F	...	I	...	H	V	+	+	Fair	B.T.	—	—	—	—	...	24	—	—
9	12	90	F	...	I	...	H	...	+	+	Fair	B.T.	+	—	—	—	...	48	—	—
10	26	3	F	...	...	R	H	V	+	+	Fair	B.T.	+	+	—	—	...	48	—	—
11	16	5	F	...	I	...	H	...	+	—	Fair	B.T.	+	—	—	—	...	72	—	—
12	18	6	F	...	...	R	H	V	+	—	Fair	B.T.	+	—	—	—	...	24	—	—
13	30	17	F	...	I	...	H	...	+	+	Fair	B.T.	—	—	—	—	...	120	—	—
14	...	22	F	...	I	...	H	V	+	+	Fair	M.T.	—	—	—	—	...	24	—	—

TABLE IV.

Serial number.	Age in years.	Complaints.							General condition.	Spleen.	Liver.	Blood examination.					Maximum temperature during first 24 hours, °F.	Temperature dropped to normal in hours.	Toxic symptoms.	Relapse.
		Duration in days before admission.	Fever.	Continuous.	Intermittent.	Remittent.	Headache.	Vomiting.				Type of infection.	Parasites in blood. After 24 hours of treatment.	After 48 hours of treatment.	After 72 hours of treatment.	After 96 hours of treatment.				
1	25	7	F	C	...	...	...	V	Very poor	+	+	M.T.	+	+	—	—	103	72	—	—
2	20	4	F	...	...	R	H	...	Very toxic, unconscious.	+	—	M.T.	+	+	—	—	102	84	—	—
3	20	5	F	C	...	...	H	...	Very toxic	+	+	M.T.	+	—	—	—	105	48	—	—
4	35	3	F	C	...	...	...	V	Very toxic	+	+	M.T.	+	—	—	—	100	24	—	—
5	30	5	F	...	I	...	H	V	Very toxic	+	+	B.T.	+	+	—	—	106·5	80	—	—
6	20	3	F	...	...	...	H	V	Very toxic	+	+	B.T.	+	—	—	—	101	48	—	—
7	20	3	F	C	...	...	H	V	Very toxic	—	—	B.T.	+	—	—	—	105	20	—	—

TABLE V.

Serial number of cases.	Age in years.	Duration of fever before admission.	Day on which temperature dropped to normal.	Day on which malarial parasites disappeared.	REMARKS.
1	20	6 days	9th	7th	*P. vivax* and *P. falciparum* rings were found. Fever on the 7th and 8th day came without rigor.
2	10	8 „	11th	9th	
3	28	8 „	16th	11th	Had a rise of temperature of 100°F. on the 19th day but without chill or rigor.
4	30	4 „	6th	5th	No chill or rigor from the 5th day onwards.
5	35	5 „	8th	7th	

CONCLUSIONS AND SUMMARY.

It will be seen from the above that paludrine is undoubtedly an excellent and effective remedy to cure malarial infection. It is devoid of bad taste, has no toxic effects as far as it has been studied and so far it appears to hold out a fair prospect of being effective against relapse. The period of observation has not yet been long enough to confirm the last point.

It is obvious from the above records that although parasites disappear from the peripheral blood within 48 to 72 hours in the majority of cases, it takes a longer time before the patient becomes afebrile. It stands to reason that paludrine takes longer time to sterilize the blood completely and the parasites, though not detected in the peripheral blood, may be persisting in the internal organs. It is essential, therefore, to continue administration of the drug for a period much longer than that suggested by blood film examinations.

How far paludrine can be used prophylactically for prevention of malarial infection requires to be studied much more extensively and by many independent observers in different places. Although paludrine sterilizes the blood, the sterilizing effect seems to disappear once the drug is excreted from the system. After this, the system becomes liable to be infected by the parasite. This is very well illustrated in case No. 6, Table IV, who came in with benign tertian infection and was treated with paludrine in doses of 1 tablet three times daily for 7 days and completely cured. She was again admitted into hospital 2 months later and this time with severe malignant tertian infection. The patient was a girl student staying as a boarder in a school where malaria had been endemic for some time. The concentration of the drug in the blood, its rate of elimination, the routes

of elimination and the minimum amount of the drug which may bring on sufficient concentration in the blood to act in prophylaxis are worth investigation.

The administration of the drug in heroic doses in cases with pernicious symptoms is very interesting. It not only demonstrates that the drug is rapidly absorbed to produce a therapeutic effect but that even a considerable amount of the drug administered rapidly is without any untoward effects. In group IV, a large amount of the drug was given, even through nasal tubes, when patients could not swallow and the results were very satisfactory.

Indian Journal of Malariology, 1, 3, September 1947.

REPORT ON THE USE OF PALUDRINE TABLETS.

BY

J. G. PAREKH, M.R.C.P.,

AND

B. P. BOGHANI, M.B.B.S.

(*Sir J. J. Hospital, Bombay.*)

[January 31, 1947.]

The object of this study was to assess the value of paludrine as an antimalarial drug in the treatment of proved cases of malaria.

This is the first report on the use of this drug in Bombay but similar work is being carried out in other parts of India.

Fifty cases of malaria with parasites in the blood have been included. No other specific antimalarial drug other than paludrine was used. The paroxysm of fever was as far as possible allowed to recur at least once before any paludrine was given. This was considered important because benign tertian infection is known to resolve temporarily without any medical treatment. The blood films were examined repeatedly in each case.

The cases of malaria treated were either primary infections (23 cases) or relapse cases (27 cases).

DISTRIBUTION.

There were 26 cases of *P. vivax* infection,
20 cases of *P. falciparum* infection,
3 cases of *P. malariæ* infection, and
1 case of mixed infection.

DOSAGE.

As no definite standard dose has yet been worked out, different dosage schemes were tested. The drug was available in 100 mg. tablets for oral administration.

(1) 100 mg. once only, mostly in a single dose, but at times in two divided doses of 50 mg. at 12 hours' intervals. Seventeen cases were treated

in this way. Of these 7 were subsequently given 100 mg. at weekly intervals for varying periods of 2 weeks to 6 months.

(2) 100 mg. daily for 3 to 8 days in single or divided doses. Five cases were treated thus.

(3) 100 to 200 mg. three times a day for 2 to 10 days. Nineteen cases were treated by this dosage scheme.

(4) 300 mg. in a single dose once only—7 cases.

The nurse who administered the drug recorded each dose given stating whether it was retained or not.

CONTROL OF CLINICAL ATTACK.

The therapeutic effect was gauged clinically by the effect of the drug on (1) paroxysms, (2) temperature, and (3) disappearance of asexual forms of parasites from the blood.

EFFECT ON PAROXYSMS.

If the drug was given when the patient had pyrexia, the temperature was brought down to normal within a few hours and the patient felt better. This is known to happen so often even without any drug administration that it is not possible to say how far the improvement was due to the drug.

If the drug was administered early on the morning of the expected paroxysm, the paroxysm was completely absorbed or was milder in the majority of cases.

If there was no temperature at the time of drug administration the paroxysm and the fever did not recur in some, or more usually, a rise in temperature occurred without paroxysm and was milder than on the previous occasion in a large number of cases. Subsequently there was no rise, unless of course a relapse occurred.

Forty-eight cases out of 50 can be said to have had clinical cures, the other 2 cases both of malignant tertian infection with cerebral manifestations were administered 300 mg. of the drug on making the diagnosis.

They died within 4 to 6 hours of drug administration. With the use of other antimalarial drugs it is felt that these cases could not have been saved. If these 2 cases are excluded then the clinical cure could be said to be 100 per cent.

All the three varieties of infection responded satisfactorily. The fever was controlled and the clinical attack terminated. In benign tertian infection cases a single dose is often not enough and repeated doses need to be given.

The different dosage schemes did not seem to make much difference in the effects produced. The patients received from 100 mg. to 600 mg. per day and the length of treatment varied from a single administration to 10 days. The optimum dosage and the best standard course of treatment has yet to be worked out.

In India, in the out-patient department of hospitals, the single dose treatment would suit very well, for it would bring about a clinical cure and that is all that an ordinary patient cares for. He is not worried about radical cure nor is he often willing to take the drug once he is better. For radical cure a dose of 100 to 200 mg. 3 times a day for 10 days would seem to be the best.

EFFECT ON PARASITES.

Asexual and sexual forms behaved differently. Whereas there was rapid clearance of the asexual forms of the parasites from the blood stream mostly in a few hours, rarely up to 72 hours, the sexual forms persisted much longer up to a week to 20 days. In one case they were seen at the end of 3 months. An impression has been produced by the study of the blood films that in case of *P. falciparum* infection the number of crescents are actually more numerous than ordinarily seen without treatment or with other modes of treatment immediately after the drug. At times the crescents appear to be shorter and thicker than usual.

In one case, though no parasites were found in the blood, they were found in sternal marrow.

Different dosage schemes do not display any significant difference in clearing the parasites from the blood stream.

FOLLOW-UP, RADICAL CURE AND RETURN CASES.

It is difficult to decide, in a malarious country, to what extent a person suffering from malaria is radically cured. When a treated case of malarial infection after clinical cure gets temperature with malaria parasites in the blood, it is difficult to say whether the fever is due to a relapse or a reinfection, because usually no measures are taken to prevent a reinfection. In this series, such cases have therefore been designated as 'return cases'.

A great difficulty experienced in the present study was to follow up a case after discharge from the hospital. Even ordinarily this difficulty is great. Once a patient gets well he never bothers about coming again. If he is not well, and he does come again, he may not necessarily go to the same physician with the result that the case is lost.

To add to this difficulty, the unsettled political conditions in the city made it almost impossible to follow up a case.

In spite of these difficulties, 25 cases, i.e. half the number of cases, could be seen at least once at a later date. This is because many of the cases selected for this study belonged to J. J. Hospital where they could be traced. The follow-up period varied from a fortnight to over 7 months. Of the 25 cases followed up, 8 cases returned with fever. Five of these were clinically malaria and had parasites in the blood. The other 3 were neither clinically malaria nor were parasites found in the blood.

Of the 5 return cases of malaria, 4 were benign tertian malaria and one malignant tertian.

FOLLOW-UP TREATMENT.

In those cases, where the patients continued taking the drug at weekly intervals, no fever occurred.

One case of benign tertian infection referred to below was seen regularly once a week and blood films were also examined weekly for 7 months and the patient was quite well.

Another patient of benign tertian infection with a dose of 1 tablet thrice daily for 3 days was well for 6 months.

Nine patients followed up for a period varying between 3 to 6 months were still well. Of these, 5 were of benign tertian and one of quartan infection.

The other 9 patients—4 of benign tertian, 4 of malignant tertian and one of quartan—had been followed for less than 3 months and they needed to be observed further for final assessment.*

Of the different dosage, the weekly dosage scheme appears to give very promising results especially in benign tertian infections. For, on this regime it has been possible to keep one patient of a very chronic relapsing and resistant benign tertian malaria who had not satisfactorily responded to quinine, atebrine and arsenic, free from symptoms and from parasites in the blood for a period of over 7 months. It was over a month since the drug was stopped and the patient was quite well.

Other cases kept on similar treatment also did well as long as they took the weekly doses. Those that discontinued, got an attack after variable intervals of stopping the treatment.

TOXICITY.

According to Dr. D. G. Davey, toxic manifestations with a dose of less than 1 gm. are insignificant. None of our cases received more than 600 mg. per day.

No serious toxic effects were observed in any of the cases and the drug had not to be discontinued on account of toxic symptoms in any of the cases. But minor symptoms were observed in some cases. Thus, one patient developed back pain, itching, puffiness and erythema of the face, palms and soles, followed by desquamation. The dosage employed here was 100 mg. thrice daily for 2 days.

Another patient developed itching, erythema and urticaria.

Gastro-intestinal symptoms were not uncommon.

Nausea, vomiting and diarrhœa occurred in one case but they stopped with clinical improvement in spite of the drug.

Two patients complained of weakness, loss of appetite and sleepiness. Student patients frequently complained of drowsiness after taking the drug.

SUMMARY AND CONCLUSIONS.

Treatment of 50 cases of malaria with paludrine is described.

The number of cases treated is too small to draw any definite conclusions.

---

* Five additional cases returned with fever and parasitæmia subsequent to this report.

It is, however, certain that paludrine is equal, if not superior, to the existing antimalarials in bringing about a clinical cure.

Given once weekly it could indefinitely prevent malarial infection from recurring and this is a definite advance over the existing antimalarials which need to be taken more frequently for such purposes.

For in-patient cases, a dose of 100 to 200 mg. three times a day for 10 days would be a suitable regime for *P. falciparum* cases in bringing about a clinical and a radical cure. For benign tertian the radical cure is difficult to assess.

For out-patients, a single dose of 300 mg. followed by 100 mg. once a week would be the best.

The advantages possessed by paludrine are :—

(1) Smallness of the dose.

(2) Not required to be given frequently.

(3) Does not produce serious toxic manifestations in effective therapeutic doses. Does not stain the skin nor produce psychotic manifestations as in mepacrine.

(4) It should be easier and cheaper to produce.

Indian Journal of Malariology, 1, 3, September 1947.

PALUDRINE TREATMENT ENQUIRY IN ASSAM.

BY

P. H. LOMAX, M.R.C.S., L.R.C.P.

(*Principal Medical Officer, Assam Railway & Trading Co., Ltd.*)

[May 27, 1947.]

THIS enquiry was undertaken at the request of Major-General Sir Gordon Covell, Director of the Malaria Institute of India. The work of Fairley (1946) and Maegraith *et al.* (1946) had shown the superiority of paludrine over other antimalarial drugs with a very wide margin between an effective therapeutic dose and a toxic dose. The object of this enquiry was to try to determine the minimum therapeutic and suppressive doses in an hyperendemic area.

During the latter part of the war the American military authorities had employed extensive antimalaria measures which included all the recognized larval and adult control measures together with DDT spraying of the area from aircraft. The local population up to this time had enjoyed a degree of premunity, and it was thought possible that with the end of hostilities and the departure of the American military forces together with the malaria control, the incidence of malaria might rise to above the pre-war level by virtue of the loss of premunity.

The attitude of the population towards malaria has always been one of placid resignation, and they show little or no enthusiasm for suppressive drugs. Attempts to persuade them to take such drugs never show the reduction of malaria which would be expected and results are directly proportionate to the degree of administrative supervision which can be provided.

Two areas were selected for the trial. They were chosen because, first, they were isolated and consequently there was little population movement, and secondly, the population were, with few exceptions, employees over whom some measure of disciplinary control could be exercised.

All other antimalaria measures were suspended in May 1946 and the trial began on July 8, 1946, the procedure being as follows :—

1. Suppressive paludrine in the dose of one tablet (100 mg.) was given to all adults and half this dose to all children from 2 to 12 years of age.

2. It was the intention to have one hundred untreated 'controls' in each area, but at the end of the first week a certain number had not taken their first suppressive dose and were therefore added to the control group.

3. Any patient complaining of 'fever' had a thick and thin film taken and was then admitted to hospital and placed on one of the following therapeutic regimes if positive :—

   Regimen A, a single dose of one tablet (100 mg.).

   Regimen B, a single dose of three tablets (300 mg.).

   Regimen C, two tablets (200 mg.) twice daily for two days.

Relapses amongst cases on one regimen were readmitted to hospital and placed on the next higher regimen, relapses in patients on regimen C being given the same regimen.

Further thick and thin films were taken on the third and seventh day of illness and all slides were examined for at least 10 minutes before being pronounced finally as negative. This work was done by Dr. Goldsmith, malaria officer on the coalfields antimalaria staff.

A review of the trial after about two months indicated that :—

1. One tablet (100 mg.) per week was not a completely reliable suppressive dose (Table I, area A).

2. In areas of heavy infection regimen A (one single dose of 100 mg.) did not control the pyrexia.

3. Gametocytes were not destroyed with any of the therapeutic doses employed.

TABLE I.

INCIDENCE OF MALARIA.

Dose : 100 *mg. paludrine once a week from July* 8 *to September* 14, 1946.

	Population.	Cases of fever with parasites.	Percentage.
Area A.			
Paludrine ...	1,068	112	10·48
Controls ...	150	32	21·33
Area B.			
Paludrine ...	610	10	1·63
Controls ...	144	16	11·11

It was therefore decided to modify the experiment and from September 16, 1946, the following procedure was adopted :—

1. In area A, one tablet (100 mg.) twice a week was given.
2. In area B, two tablets (200 mg.) once a week were given.
3. Regimen A, one tablet (100 mg.) as a therapeutic measure was abandoned.

The result of this modification is shown in Table II.

TABLE II.

Results of suppressive treatment from September 16 to October 20, 1946.

	Population.	Cases of fever with parasites.	Percentage.
Area A.			
(100 mg. twice per week)			
Paludrine	1,075	24	2·23
Controls	118	13	11·01
Area B.			
(200 mg. once per week)			
Paludrine	800	10	1·25
Controls	128	23	17·9

Comparing the results in area A in Tables I and II it will be seen that the expected incidence of malaria fell nearly to one-half amongst the controls, whereas the incidence amongst those on paludrine fell nearly to one-fifth. Also in area B the expected incidence rose by 6 per cent in controls, whereas amongst those on paludrine the incidence fell by 0·38 per cent.

NUMBER AND TYPES OF INFECTION TREATED.

As will be seen from Table III, the majority of cases were *falciparum* (malignant tertian) infections and of the comparatively rare *malariæ* (quartan) infections in this area only seven were treated.

With regard to the persistence of parasites only those patients from whom slides were obtained on the first, third and seventh day are shown and the high persistence of parasites on the seventh day is from those suffering from *falciparum* (malignant tertian) infection.

TABLE III.

Types of infection and number treated.

Regimen treatment.	M.T.	B.T.	Mixed, M.T. B.T.	Quartan.
A	8	7	...	...
B	58	24	8	2
C	86	30	7	5
TOTAL ...	152	61	15	7

TABLE IV.

Persistence of parasites.

Number of patients.	POSITIVE 1ST DAY 100 PER CENT.				POSITIVE 3RD DAY 29·74 PER CENT.				POSITIVE 7TH DAY 40 PER CENT.			
	M.T.	B.T.	Mixed.	Quartan.	M.T.	B.T.	Mixed.	Quartan.	M.T.	B.T.	Mixed.	Quartan.
195	132	45	11	7	42	10	3	3	65	8	3	2

M.T. = *falciparum* (malignant tertian) infection.
B.T. = *vivax* (benign tertian) infection.
Quartan = *malariæ* infection.

With only two exceptions no asexual form of parasite was found in any slide taken on the third or the seventh day. The first exception had *P. falciparum* (malignant tertian) rings reported in a third day slide while on regimen C. The second exception had *P. falciparum* (malignant tertian) rings in his seventh day

slide while on regimen C. He had a further clinical attack with parasites twenty-one days later, and again had *P. falciparum* (malignant tertian) rings in his seventh day slide after regimen C. His third relapse with parasites occurred 14 days later.

RELAPSES.

While it is difficult to decide whether a patient has relapsed or has been reinfected for the purpose of this trial, a patient was considered to have relapsed if he had a parasite positive blood slide within 28 days of his last curative dose. Table V shows the relapse rate under the various regimens used.

TABLE V.

Regimens.	Total treated.	Total relapses.	Percentage.
A	15	2	13·33
B	92	23	25·00
C	128	37	28·90

Very few patients were treated with regimen A for the figures in this table to have any significance, and the overall relapse rate would appear to be about 27 per cent. This is keeping with the rapid excretion rate of the drug.

TOXICITY.

No toxic effects were noticed in any of the doses employed.

CONCLUSION AND SUMMARY.

1. As a suppressive, one tablet (100 mg.) of paludrine once a week would probably be adequate, but when dealing with mass administration to a disinterested population, a certain number are bound to miss the weekly dose for one reason or another. One tablet (100 mg.) twice a week reduces the chances of any one going a full fortnight without the tablet.

2. The success of suppressive measures is directly proportional to the efficiency of the administrative controls.

3. Three tablets (300 mg.) of paludrine will terminate a clinical attack and is as satisfactory from this point of view as two tablets (200 mg.) b.d. for two days.

REFERENCES.

FAIRLEY, N. H. (1946) ... Research on paludrine (M 4888) in malaria. *Trans. Roy. Soc. Trop. Med. Hyg.*, **40**, 2, pp. 105–151.

MACGRAITH, B. G., *et al.* (1946) ... Paludrine in the treatment of malaria. *Brit. Med. J.*, 1, p. 903.

Indian Journal of Malariology, **1**, 4, December 1947.

FLUSHING STREAMS AS AN ANTIMALARIA MEASURE UNDER FIELD SERVICE CONDITIONS.

BY

LIEUT.-COLONEL W. E. C. PETTMAN, R.E.

(*Lands Hirings & Disposals Service, Calcutta Area.*)

[February 12, 1947.]

1. (*a*) AN engineer unit of the Fourteenth Army in Assam was asked to flush streams in order to control the breeding of *A. minimus*, the local malaria vector. Economy of materials and transport precluded elaborate structures, and automatic flushing devices were rejected from fear of intricate adjustments. Simple earth dams were therefore made, only about 3 ft. high and pierced by salvaged petrol drums with the ends removed. The sluice gate was a board placed over the upstream end. The resulting waves were only a few inches high, but the malariologists approved, and the question arose 'How far apart must these dams be placed?' This article describes the experiments made, the theory evolved, and the approximate answer obtained to this question.

(*b*) The results obtained from the experiments were not numerous, nor consistent enough to allow of definite conclusions, but they appear to give some indication of what takes place. The theory contains several assumptions which are discussed in order that they may be fairly considered and improved upon. It is not claimed, therefore, that the general rule evolved is more than an approximation, and it is put forward in the hope that improvements to the theory based on future experiments may lead to a reliable rule.

2. The type of dam used is shown in Fig. 1. Fig. 2 shows the simplest form of sluice gate. Fig. 3 shows a more elaborate balanced gate devised to open easily in spite of the pressure of water, which was inconveniently heavy even with only 3 ft. head. It is difficult to make this gate water-proof, and a little more elaboration is advisable such as bending the flanges to fit the gate.

3. The chief practical points about this type of dam appear to be :—

(*a*) Its height is limited to about 3 ft. by the pressure of water, which not only makes the sluice gate difficult to open but also causes leaks, which weaken the structure.

(*b*) A by-pass round the dam is necessary to protect it from scour.

(*c*) It should slope at about 45°, otherwise it is unstable.

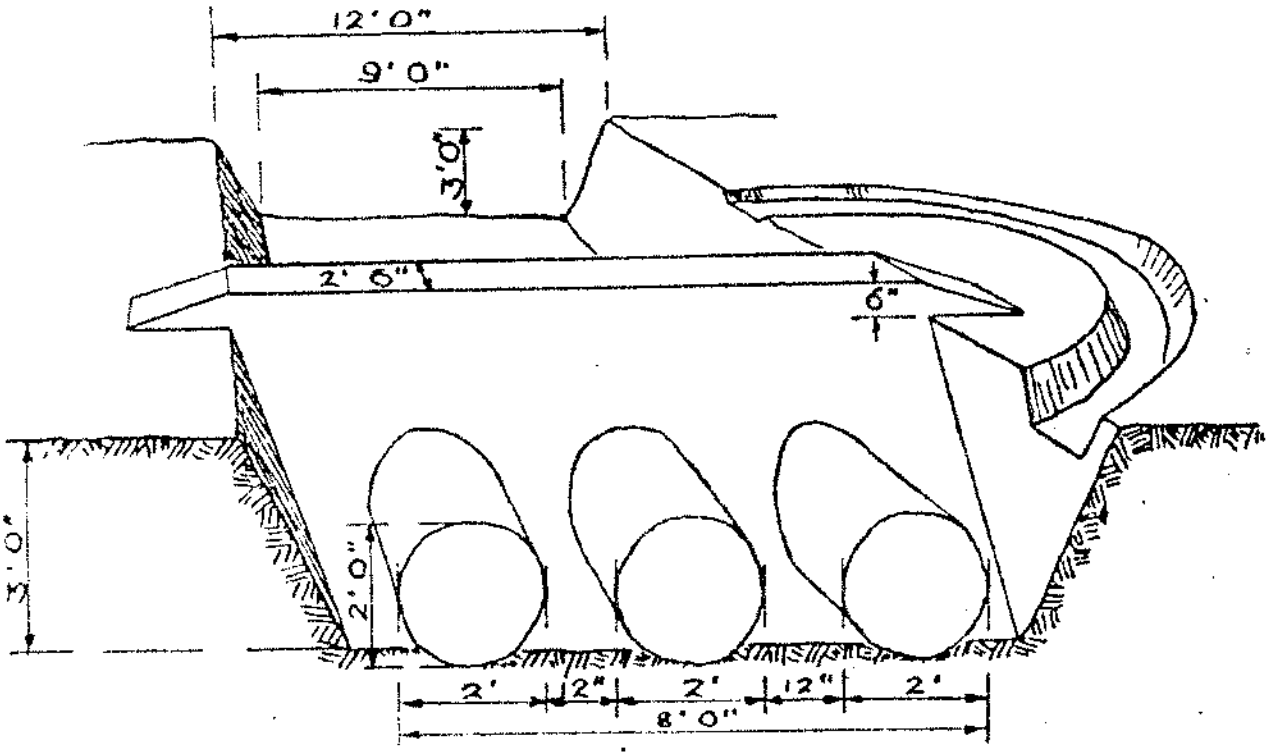
(*d*) The total area of the sluice openings should be about 30 per cent of the vertical face area of the dam. The reason for this is given in para 10 (*c*).

(*e*) The sluice drums should be at least 1 ft. clear apart, otherwise the space between them is difficult to pack, and will leak.

(*f*) Dams should be so sited as to impound as much water as possible. A narrow neck below a widening of the stream is ideal. The quantity of water impounded greatly influences the distance the wave will travel before subsiding to an ineffective ripple. This factor is of such importance that it is worth siting a dam at some distance away from the place indicated by other considerations if a larger enclosure is thereby obtained. It should be realized that the higher

FIG. 1.

Earth dam with sluices, looking upstream.



the dam the more will a small variation in its height affect the volume of water stored.

(*g*) Where there are several sluice gates, they should be opened as nearly simultaneously as possible and, at the most, within a minute of each other.

(*h*) Where there are several dams in one stream, the top one should be opened first. The greatest effect is obtained when each successive dam is opened as the wave reaches it. This necessitates strong construction.

(*i*) On active service it is desirable to make these dams so durable that their maintenance and operation can be entrusted to a local unit, but they are apt to leak so badly involving occasional rebuilding that it will seldom be practicable to do so.

FIG. 2.

Simple gate for head of water up to 3′ 6″.

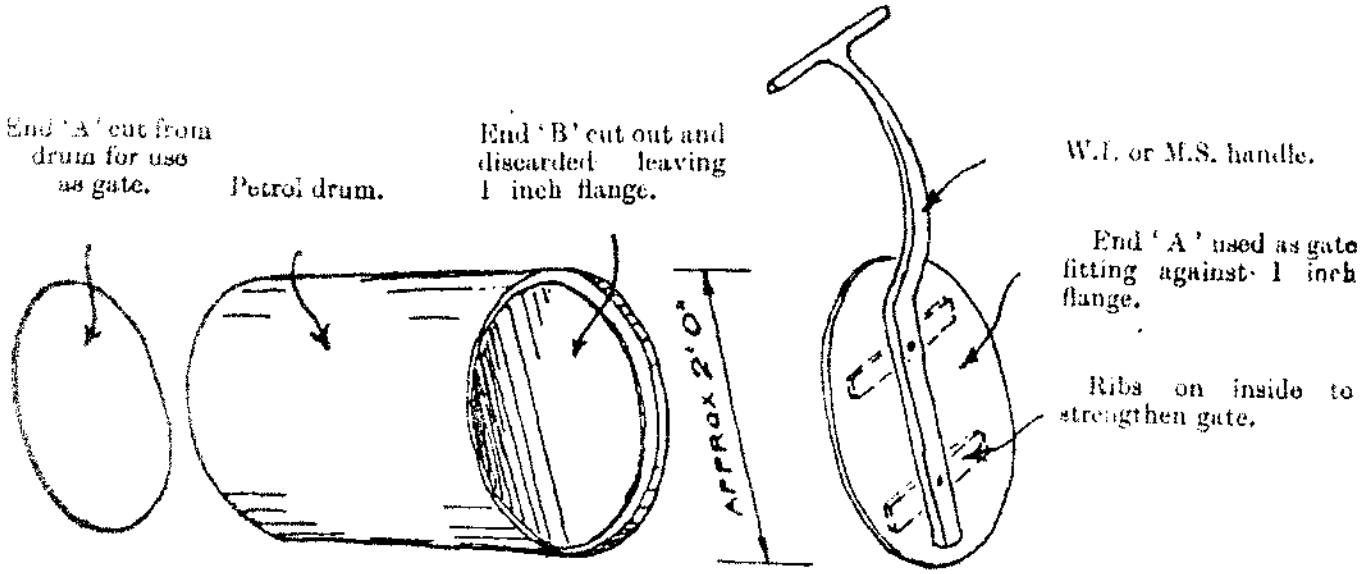
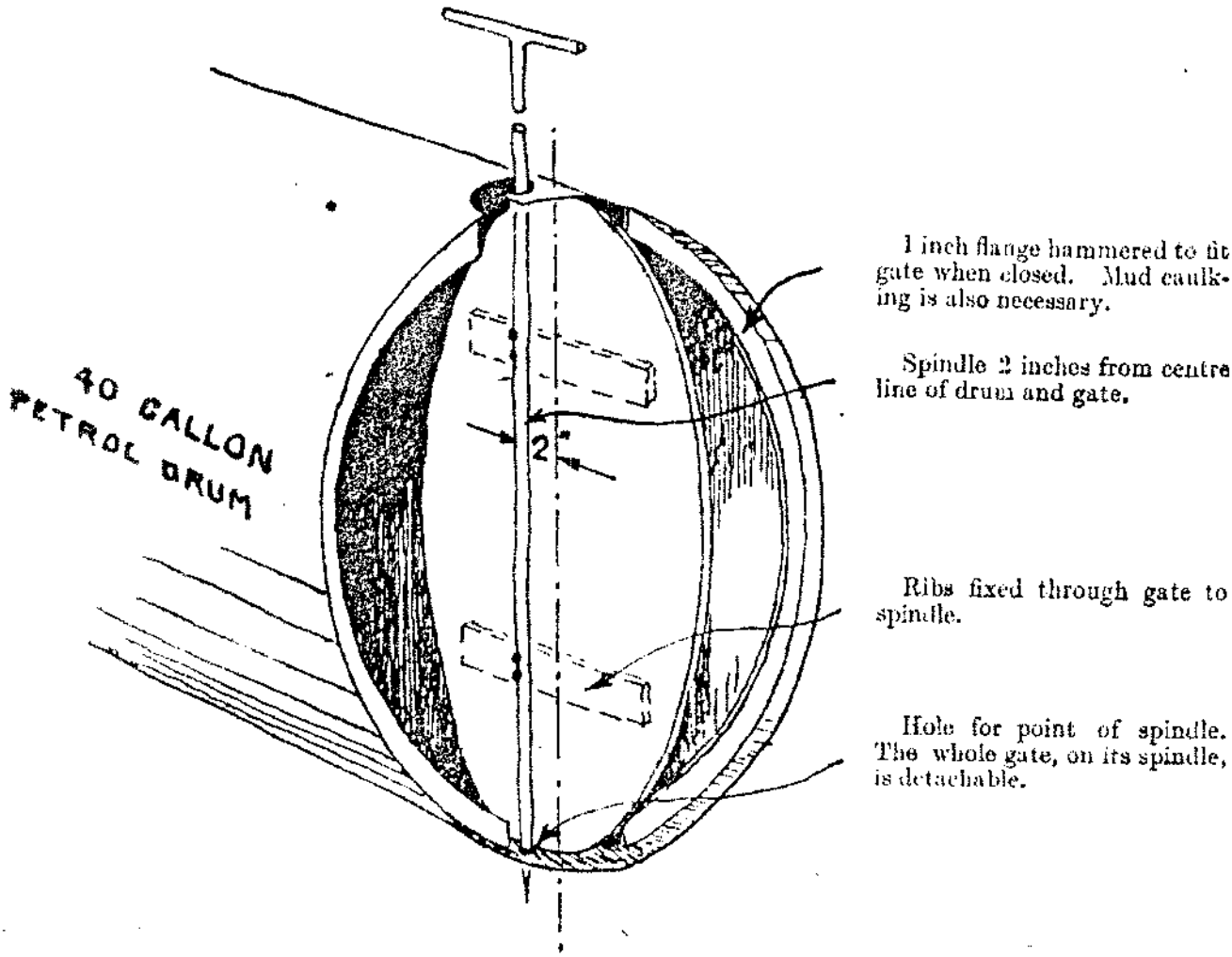


FIG. 3.

Balanced gate for head of water over 3′ 6″.



4. The question 'How far apart should these dams be located?' can be resolved into the following questions:—

(*a*) 'What proportion of potential vectors in their early stages, i.e. arvæ and eggs of the species concerned, must be killed in order to reduce sufficiently the incidence of malaria?' Only malariologists can assess this, since it depends on many factors, e.g. local density of vectors, species of local vectors, humidity, temperature and wind, distance of the stream from the population to be protected. In this case the minimum figure was fixed at 95 per cent as the target and the approximate rule obtained is worked out for this percentage. The working shown, however, can be applied to any target by drawing the appropriate line in Fig. 12 and working onwards from that.

(*b*) 'What is the larvicidal effect of a wave?' This was determined by actual observations here described.

(*c*) 'How does the larvicidal effect vary with the characteristics of the wave?' Speed and height are the essential characteristics, speed being somewhat the more important. Speed depends on the slope and the roughness of the stream bed. Height depends on the head of water at the dam. The object of these experiments was to measure the influence of speed and height on the larvicidal effect of the wave, and to determine the relation between these two characteristics and the factors on which they in turn depend.

(*d*) 'To what extent do the required wave characteristics depend on the design of the dam?' It was possible to control only the head of water at the dam and the size of the sluice openings. The latter was fixed at 30 per cent, and on that basis the relation between head of water and height of wave was determined by actual observations.

(*e*) 'What other factors effect the larvicidal value of a dam?'

The fall of the stream decides the speed of the wave, and the correlation between these two has been determined by experiments described here. The roughness of the stream bed, which effects its resistance to the passage of a wave, is another important factor. It is however assumed that this factor would be common to streams in malarious terrain whose fall is between 1 and 30 and 1 and 80, and that it need not therefore be considered as a variable factor. Furthermore, it would be difficult to include this factor in the calculations. Another factor is the depth of water. The leading edge of a wave in a shallow stream is steep, and its larvicidal effect is greater than when travelling over deep water, which causes it to be smooth but does not much alter its height or speed. Since the streams encountered were seldom more than a few inches deep, this factor was not taken into account; nor was the rate of flow of the stream which depends on the same factors as the speed of the wave.

5. (*a*) The method of observation was to drive pegs graduated to half inches into the stream bed at intervals below the dam. Observers with synchronized watches noted the rise and fall of the water after the sluice gates were opened. Their observations, plotted on squared paper, showed approximately the profile of the wave at each stage. They also showed its speed, which was found to be nearly uniform in each stream, though it was very slightly greater over the first two or three hundred yards, i.e. while the 'initial turbulence' lasted. This initial

turbulence is neglected in the calculations for the general effect of a wave, but is allowed for later on, since its larvicidal effect, although short-lived, is considerable.

(*b*) Before and after the passage of a wave men from an antimalaria unit trained in larval collection counted the density of larvæ in several pools along the stream. This was done by making scoops with uniform care, and noting the average numbers of larvæ per scoop. It was found necessary to resist the temptation to scoop more carefully in the pools with few larvæ than in those with many. Only anopheline larvæ were counted, and no attempt was made to distinguish their species. This was perhaps a mistake. Culicines must be almost equally vulnerable and would have swelled the numbers and given better averages.

6. (*a*) Before analysing the results of these experiments, some hitches must be mentioned which affect the reliability of the results. These hitches, besides warning any future investigators of this subject, introduce a new idea which might, perhaps, be turned to advantage (*vide* para 7).

(*b*) Some of the pegs were placed in midstream, and the wave swirled past them so roughly that it was difficult to see exactly when the water level passed each graduation. Pegs must therefore be protected by stones from the direct force of the wave.

(*c*) Each test occupied several hours. The dams, and especially the sluice gates, required much caulking with mud, and the dam from which our figures were obtained was one of our earlier efforts and was too thin at the base. Owing to pre-occupation with other duties, the larva collectors were unable to complete their pre-wave counting in time, with the result that the wave was not always released at the exact head intended, namely at 3, 2½, 2 ft., etc., head, with 1, 2, 3 and 4 sluice drums opened in each case. These regrettable variations in the head could however be easily allowed for when plotting the results by drawing a smooth curve between several points.

(*d*) While the water is accumulating at the dam, the stream below it is running dry, except for the leakage through the dam. Therefore the recorded rise and fall of the wave is not normal. This was not realized until the last test but one, when the results which had been excessively influenced by this factor were discarded. The calculations based on the results finally accepted must therefore be considered as somewhat inexact. Fortunately, there are enough observations, some of which are good, to allow us to believe that the rule obtained is a reasonable approximation to the real state of affairs assuming that this theory is correct.

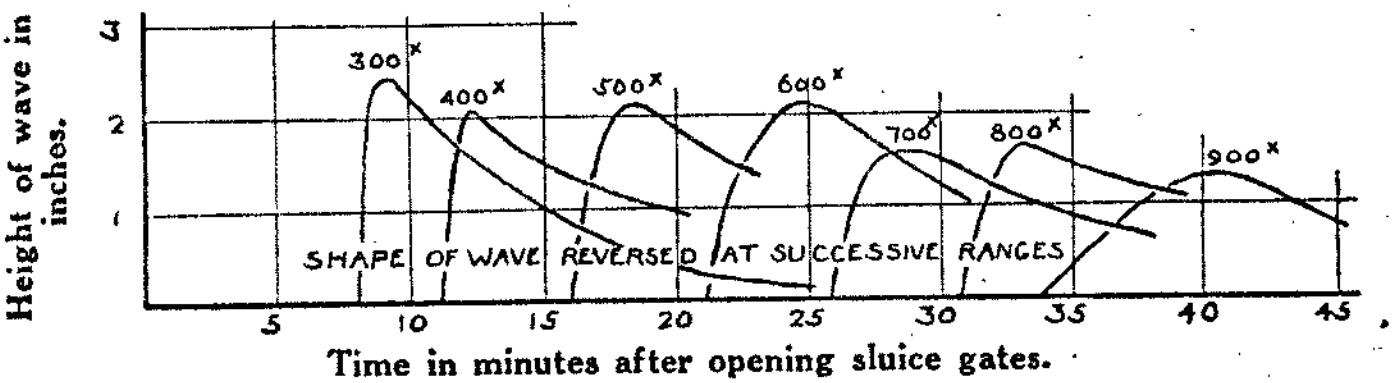
(*e*) Larva collectors were not always available, and larvæ were sometimes too scarce to yield useful results, although collecting tests were carried out at intervals of at least one week.

7. The new idea referred to in para 6 (*a*) was that the partial drying out of the stream might have enough larvicidal effect to increase the value of damming. This evidently is not the case as Major R. A. Senior White in a personal communication informed the author that he found partial drying out for an hour useless against all species of larvæ with which he had worked including *A. minimus* and *A. fluviatilis*. The idea is mentioned here in case a suitable occasion may arise where a dam constructed high enough may prolong the drying out sufficiently to be effective. Leakage from the dam would not interfere with these results since

eakage water would follow the deepest part of the bed and might even be a help as it would delay the overflow. On the other hand, the effect of drying would be most noticeable near the dam and this is not of much advantage as flushing is most effective in this part. Where it is possible to divert a stream the possibilities would be enormous but that is not relevant to the problem under discussion.

FIG. 4.

The progress of a wave. Rise and fall of water level at each observation point.

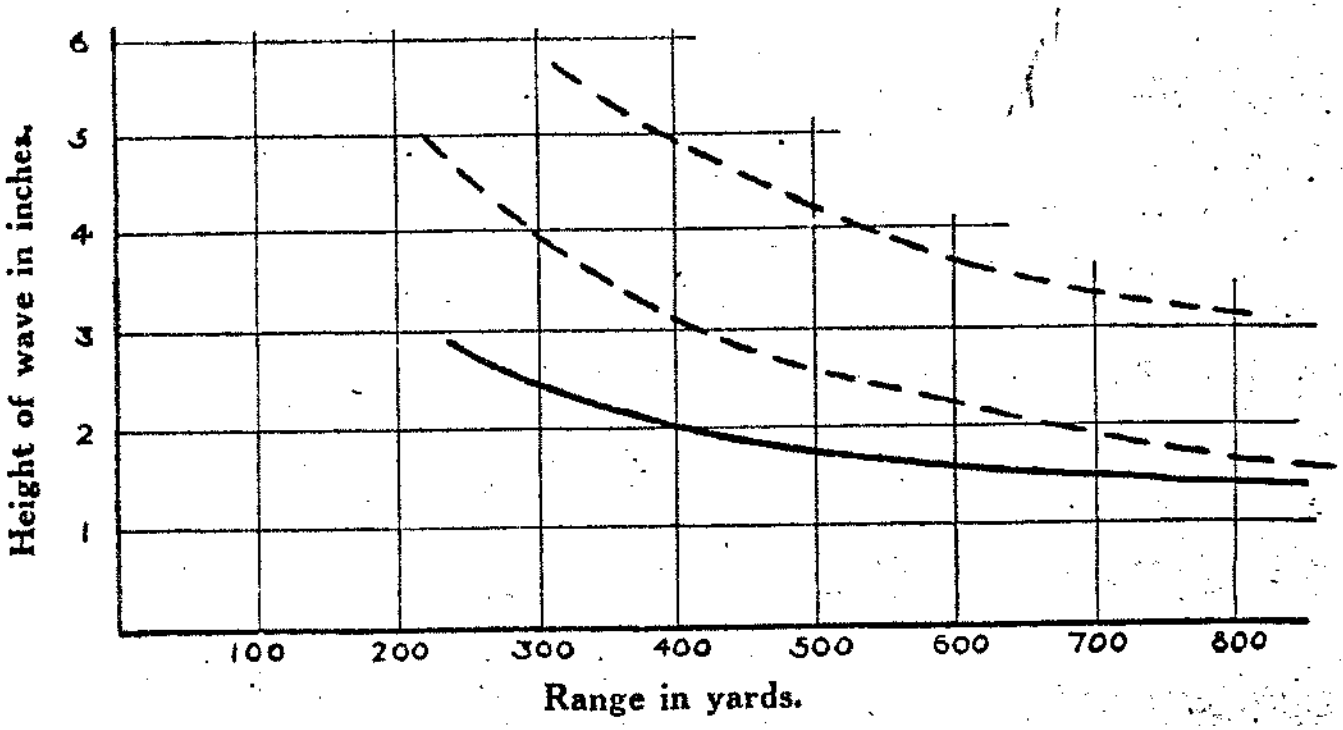


8. (*a*) The information obtained about waves is shown in Figs. 4 to 8. Fig. 4 shows the rise and fall of the water at each point, i.e. the successive shapes,

FIG. 5.

Average height of wave at various ranges.

Wave described in this article : Firm line.
Other waves : Dotted lines.



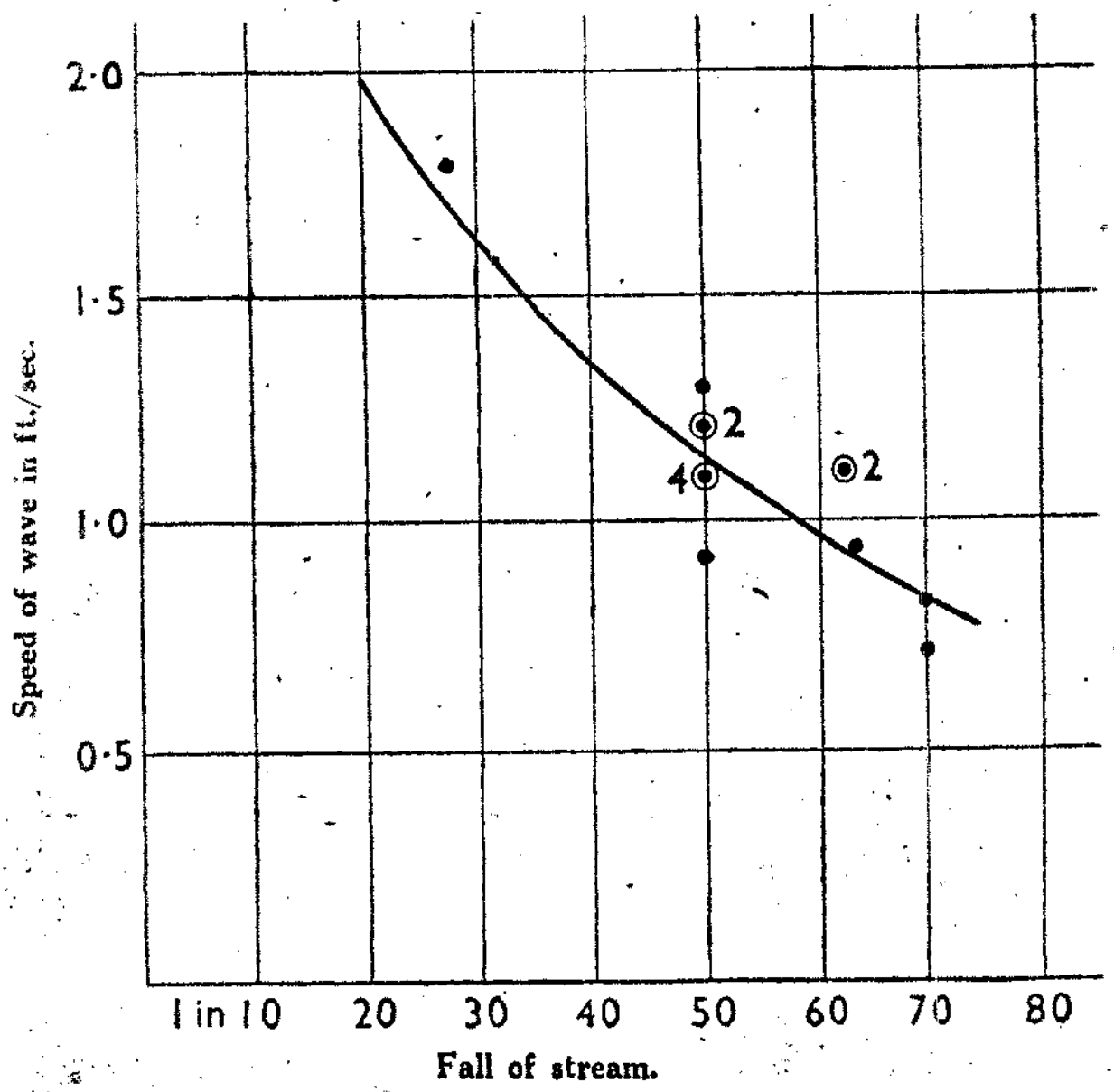
or profiles, of the waves reversed. After one or two hundred yards, the leading edge of the wave dies to a smooth slope, and there is merely a rise of the water level. Shallow water causes steepness in a wave while deep water makes it smooth. The streams in which these observations were made averaged about 15 ft. wide and 5 inches deep, with stony beds and many small quiet pools along the banks. Unfortunately, in the widest places, where breeding places are usually most abundant, the wave is shallow and slow, whereas it is steepest and swiftest where the stream is narrow and pools are fewer.

(*b*) The height of the wave at each point is plotted in Fig. 5 and a smooth curve drawn, giving its mean height at any distance. The initial turbulence lasted 300 or 400 yards, after which the wave diminished steadily and its graph is nearly

FIG. 6.

Fall of stream and speed of wave.

⊙2 denotes the same result in 2 tests.

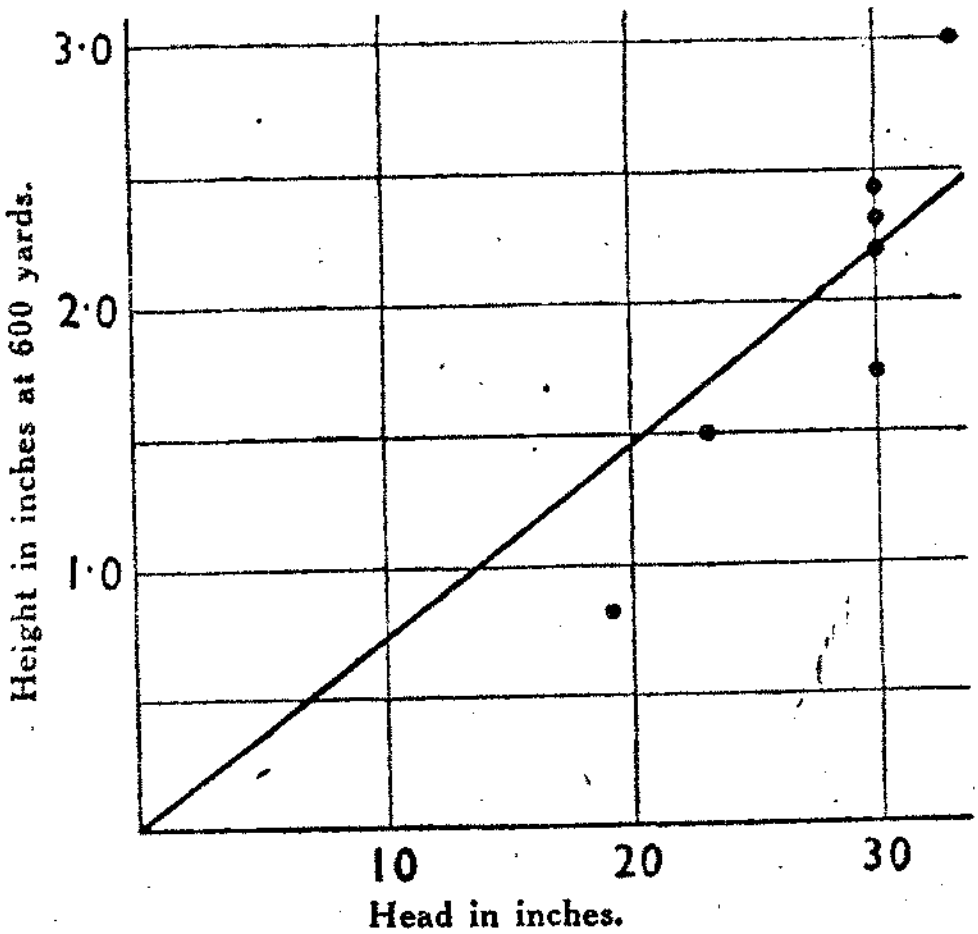


a straight line. In the calculations that follow, the straighter part of the graph is considered first and initial turbulence is allowed for later. The dotted lines in Fig. 5 are the 'characteristic curves' of two waves in other streams.

9. As already stated the larvicidal effect of the wave depends on two chief factors—speed and height—in order of importance. Speed is beyond our control, depending as it does chiefly on the slope or fall of the stream, and partly on the resistance which its bed offers to the passage of the wave. The latter factor has however been ignored for reasons previously given. Fig. 6 shows the speed of all the waves tested, plotted against their fall. This curve must resemble a hyperbola

FIG. 7.

Head of water and height of wave.



since a wave would fall from a vertical cliff at a speed approaching gravity, whereas in a stream that was almost flat it would travel slowly. These readings are the most consistent of our data and fix the curve quite accurately enough for our purpose. The graph is drawn to pass slightly below the 1 in 28 speed since the particular stream under test had unusually smooth straight banks which must have assisted the speed of the wave. There are not enough data to consider streams steeper than 1 in 30.

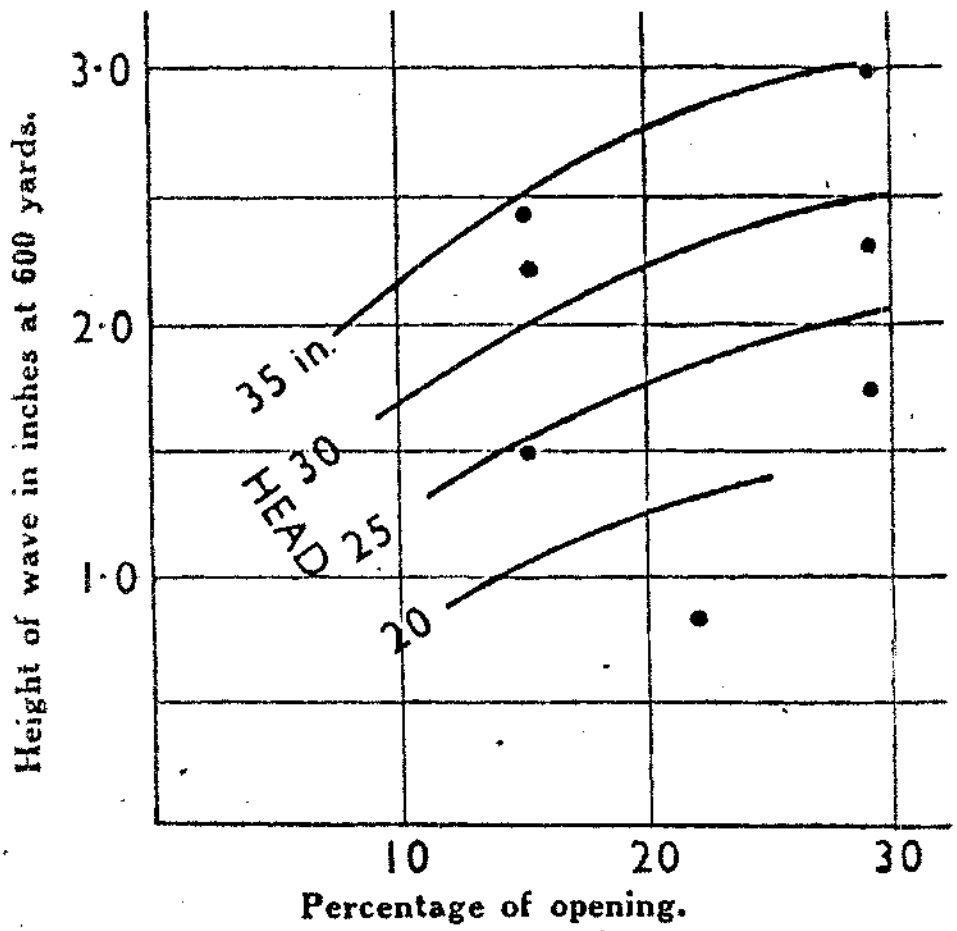
10. (*a*) The height of the wave depends on the dam, where it is possible to control two factors, viz. the head of water and the size of the opening. Since

the height of a wave varies throughout its course, the term 'height' in these calculations means its height at 600 yards below the dam, which is referred to as '600 yards range'.

(*b*) Fig. 7 shows how the height (i.e. at 600 yards range) depends on the head of water at the dam. The results are not very consistent, for reasons already explained, but if it is agreed that the graph should be a straight line, the result as drawn may be accepted as approximately correct for the type of stream under discussion.

FIG. 8.

Opening and height.



(*c*) The size of the opening at the dam is fixed less accurately in Fig. 8. It was assumed that if the sluice opening had been a ½-inch pipe, then a 1-inch or 2-inch pipe would have greatly improved the result. Whereas if the opening had been 75 per cent of the whole vertical face area of water at the dam, the results obtained would have been practically equal to those obtained by the instantaneous demolition of the whole dam, giving a 100 per cent opening. The graph in Fig. 8 and some interpolations not quoted here suggest that an opening of 30 per cent is the optimum, and that any greater area will not greatly improve the larvicidal effect of the wave. This conclusion is so convenient that we may perhaps be accused of wishful thinking, because our form of construction rendered any greater

sluice area difficult to produce. The dam shown in Fig. 1 has a sluice opening of 29 per cent.

11. So far the results quoted indicate the relationship between the fall of a stream and the speed of a wave, and between the head of water at the dam and the height of a wave. It has also been assumed that other characteristics of a wave are comparatively trivial from a larvicidal point of view, and that the factors which affect those other characteristics are too complicated to be accurately measured or controlled. Furthermore, the results appear to be approximately correct within reasonable limits for the purpose in view. The next step was to find out the larvicidal effect of one wave from which, by allowing for variation of head and fall, the 'effective range' of any dam of this type may be found.

TABLE I.

LETHAL INDEX AND EFFECTIVE RANGE.

Table of catches giving killing rate.

ACTUAL OBSERVATIONS.

Head 2′ 6″. Opening 29 per cent.
Fall of stream 1 in 50
Flow 1·1 ft./sec.
Mean speed of wave 0·8 M.P.H.

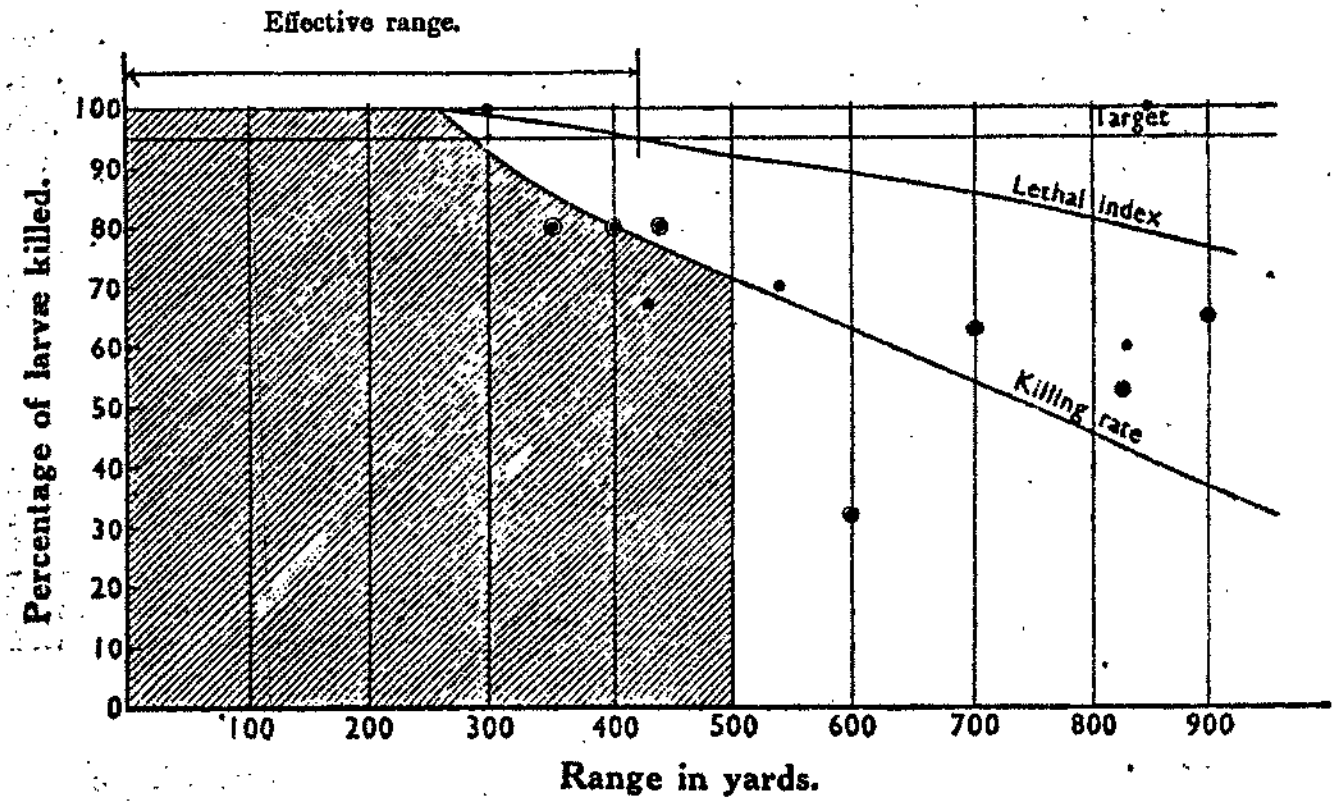
Pool number.	Range in yds.	DENSITY OF LARVÆ.				PERCENTAGE OF		REMARKS.
		BEFORE FLUSHING.		AFTER FLUSHING.				
		Catches.	Average per scoop.	Catches.	Average per scoop.	Survivors.	Killed.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	300	15 in 10	1·5	*Nil* in 10	0·0	0	100	
2	350	16 in 10	1·6	3 in 10✓	0·3	19	(80)	
3	400	20/10	2·0	4/10✓	0·4	20	(80)	
4	430	3/5	0·6	1/5	0·2	33	67	
5	440	10 in 10	1·0	2 in 10✓	0·2	20	(80)	
6	500	*Nil* in 5	0·0	*Nil* in 5	0·0	...	...	Inconclusive.
7	540	10/5	2·0	3 in 5	0·6	30	70	
8	560	*Nil*/5	0·0	*Nil* in 5	0·0	...	...	Inconclusive.
9	600	12/5	2·4	8/5✓	1·6	67	(33)	Sheltered pool.
10	700	40 in 5	8·0	15/5✓	3·0	37	(63)	

Note.—Promising results are 'ticked' in column 5 before averages are worked out so as to select them without bias.

12. (*a*) Table I shows a set of actual recordings by larva collectors, who completed columns 3 and 5 from the results of their scoops and showed them to the officer conducting the experiment before leaving the ground. The latter 'ticked' in column 5 are the results whose numbers, both of larvæ and of scoops, promised the most reliable percentage. For instance, the collector had not stayed long at pools 5 and 7, and if by chance one larva more or less had been caught, the results would have been noticeably different. Pools 2 and 10, however, seemed to yield much more reliable averages. The results which are ticked are 'ringed' in column 8 and are given more weight when drawing the graph of column 8. This is shown in Fig. 9, where the ticked results are emphasized by a ring drawn round them. This line we call the 'killing rate'.

FIG. 9.

Killing rate, lethal index and effective range.



(*b*) This emphasis on the most promising catches may be open to criticism. It would not have been necessary if the collectors had correctly carried out their instructions, which were to stay at each pool till they either found 10 larvæ or completed 10 scoops. This plan was therefore adopted because it would be unsound to attach as much importance to the results obtained from 5 scoops as those obtained from 10. It may however be doubted whether the selection was ideal. The author, who ticked these readings in Table I, now considers that pool 1 should have been included, in which case this series of results would have been more consistent. In any future experiments, collectors should make at least 10 scoops per pool, thus rendering weightage of results unnecessary.

(*c*) The examination of the figures before leaving the ground had the useful advantage of calling attention to obvious inconsistencies. Thus the results in Table I called for a re-examination of pool 9 which was found to be so sheltered from the wave that the low killing rate was only to be expected there. This experience emphasized the need to inspect each stream and to trim the banks or connect up the pools in unfavourable situations. Labour for this, however, is usually scarce, otherwise the whole stream might be trimmed and flushing would be unnecessary. Auxiliary measures of this sort, or the use of larvicides, will naturally increase the effective range of the dam beyond that determined by the rule propounded in this paper.

(*d*) The wave described in Table I was the only one whose killing rate was fixed with reasonable accuracy, the other tests being spoiled by scarcity of larvæ or by the partial draining of the stream. The results obtained with this wave have therefore been checked by statistical methods, which show that if all readings are given equal value the series is not consistent enough to be statistically significant. They are, however, significant if the 'italicized' figures are given 2½ times the weight of others. If pool 1 had been included, a weighting of about 2 would have been sufficient, which seems permissible since the majority of the selected figures were obtained from twice as many scoops as the others. This killing rate may, therefore, be accepted as a basis for further calculations.

13. (*a*) The killing rate is drawn in Fig. 9 as a straight line except near the dam where it curves upwards to correspond with the initial turbulence of the wave. This line indicates the percentage of potential vectors killed *at* any particular range or distance below the dam. But what is more important is the percentage of larvæ killed *over the whole of* any particular range. A wave in its earlier stages kills a higher percentage than the target figure, and thereby builds up a surplus, which balances the deficiency further down the stream where the killing rate becomes less than the target. The total percentage killed up to any point will, therefore, be the mean of the killing rates up to that point. This is easily found from Fig. 9 by finding the area below the killing rates and the 100 per cent lines up to the point in question, and expressing it as a percentage of the whole area of the figure from the dam to the point, e.g. at 500 yards it is the shaded area expressed as a percentage of the rectangle which encloses it, i.e. 92 per cent. This percentage is referred to henceforth as the 'lethal index'.

(*b*) The 'effective range' of the dam, which we want to find, is the range at which the lethal index equals the target. In this case it is 410 yards, which is therefore the maximum safe distance between dams 2½ ft. high in a normal stream whose fall is 1 in 50. If the target were 90 per cent, the effective range would be 540 yards, which shows how much depends on accurate fixing of these two lines whose angle of intersection is so acute. However, if the dams should be slightly too far apart, the lethal index at extreme range should be only slightly below the target, and this small error would not greatly endanger the neighbours.

14. (*a*) Having found the larvicidal effect, and hence the effective range of one wave, the next step is to allow for variations in height of dam and fall of stream, so that a rule may be obtained for any dam in any stream.

(*b*) Fig. 7 shows that the graph relating head to height is a straight line passing through the origin, and Fig. 8 shows that the height which caused the known killing

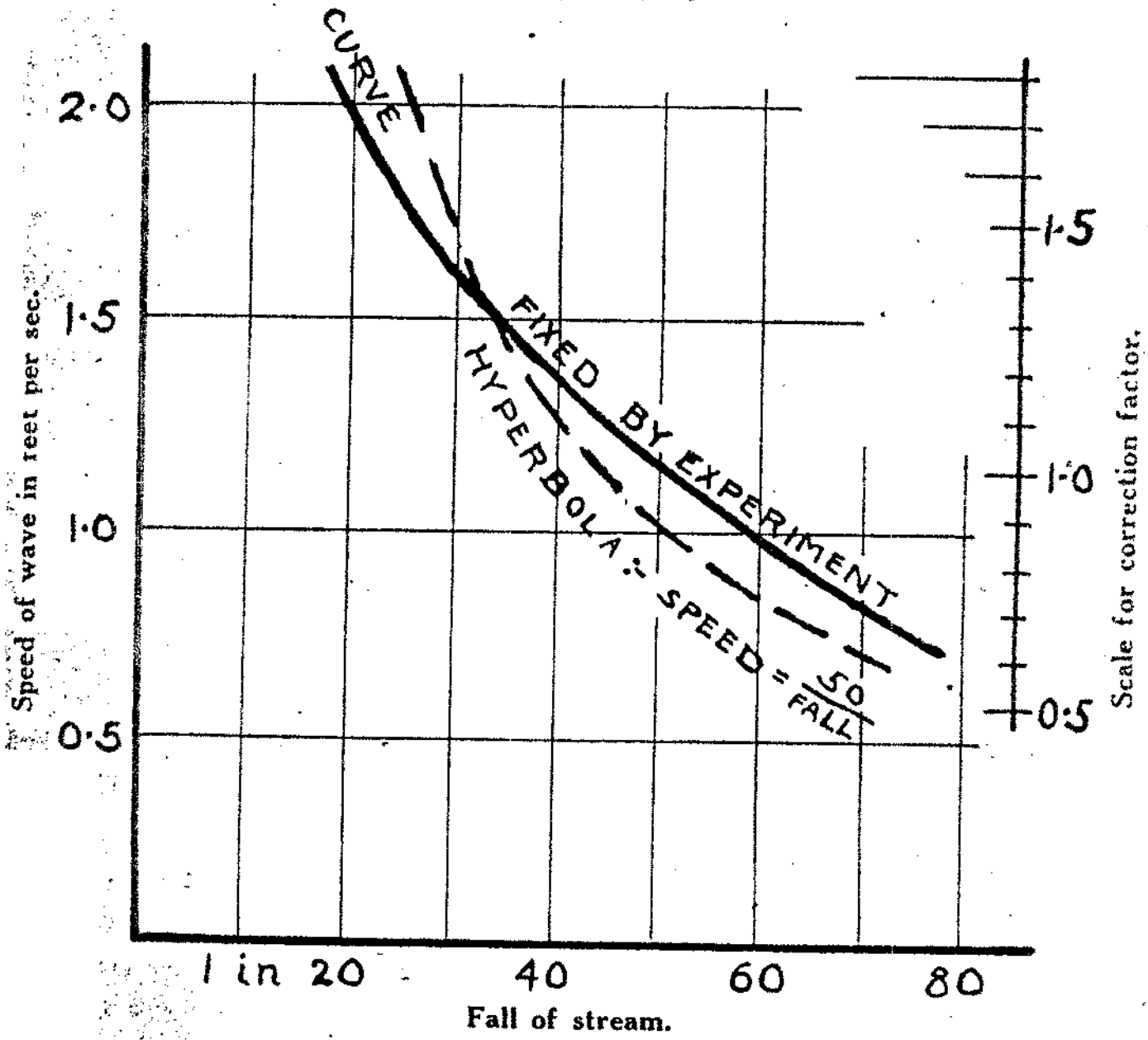
rate was produced by a head of $2\frac{1}{2}$ ft. Therefore the correction to be applied to the known or standard killing rate is :—

$$\text{Corrected K. R.} = \text{Standard K. R.} \times \frac{H}{2\cdot 6}$$

$$= \text{S. K. R.} \times 0{\cdot}4H \text{ where H is in ft.}$$

FIG. 10.

Correction factor for fall.



(*c*) The correction for fall is less simple. The fall speed curve in Fig. 6 approximates to a hyperbola, but not closely enough for accuracy. This is seen in Fig. 10, where the curve is compared with the nearest hyperbola whose formula is simple, viz. Speed $= \frac{50}{\text{Fall}}$. The correction for fall is, therefore, read from the curve by drawing a vertical scale according to which unity corresponds with

the fall of our standard results, i.e. 1 in 50. The correction for any other fall can then be read from this scale. Such a scale is added in Fig. 10. From it was compiled Table II.

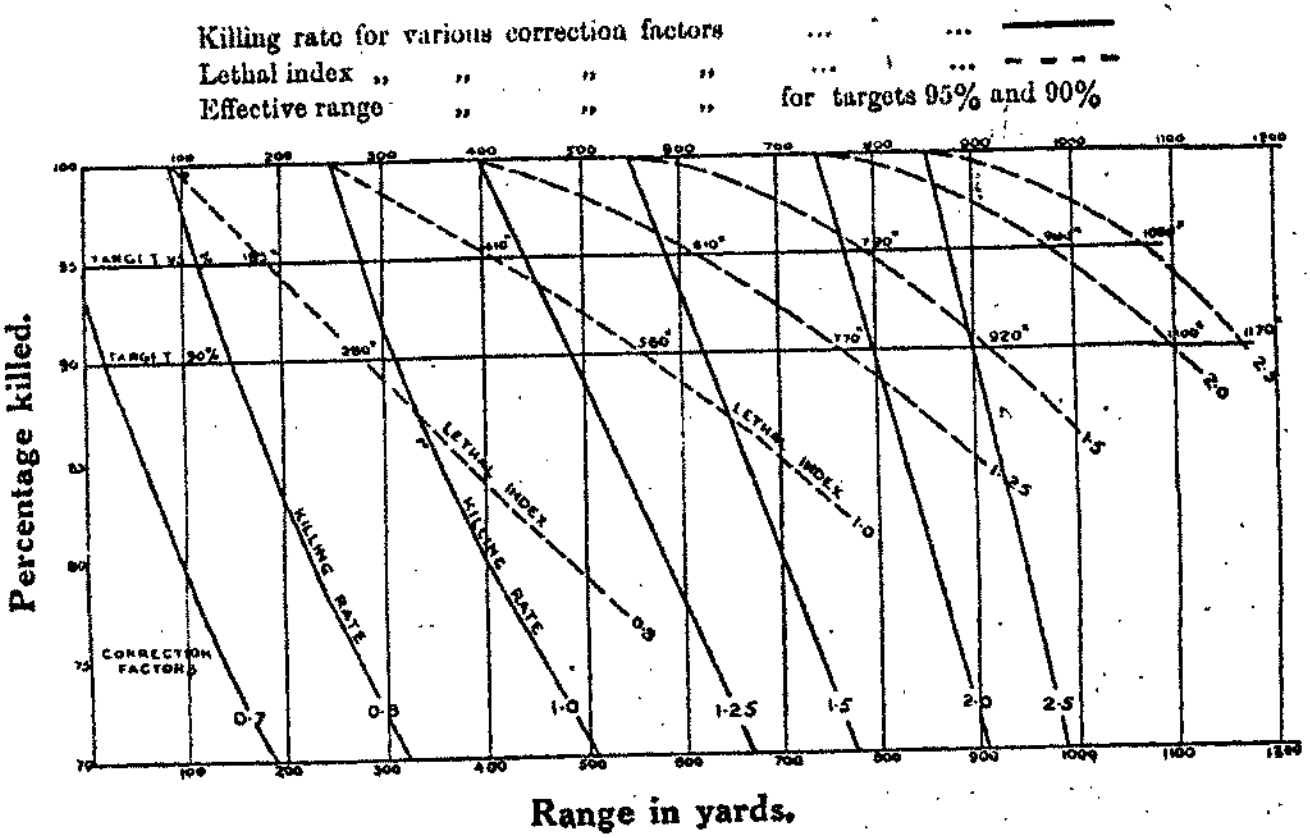
TABLE II.

Correction factor for head and fall combined.

FALL: 1 in		30	40	50	60	70	80
Head in feet.	Respective factors.	1·40	1·18	1·00	0·85	0·70	0·60
4	1·6	2·24	1·89	1·60	1·36	1·12	0·96
3½	1·4	1·96	1·65	1·40	1·19	0·98	0·84
3	1·2	1·68	1·42	1·20	1·00	0·84	
2½	1·0	1·40	1·18	1·00	0·85		
2	0·8	1·12	0·94	0·80	Flushing is useless		
1½	0·6	0·84	when the factor is below 0·7				

(*d*) At any place along any stream, the killing rate for the local head and fall is found by applying to our standard killing rate a 'combined correction factor' consisting of the appropriate correction factors for head and fall respectively, multiplied together. The results of this are shown in Table II.

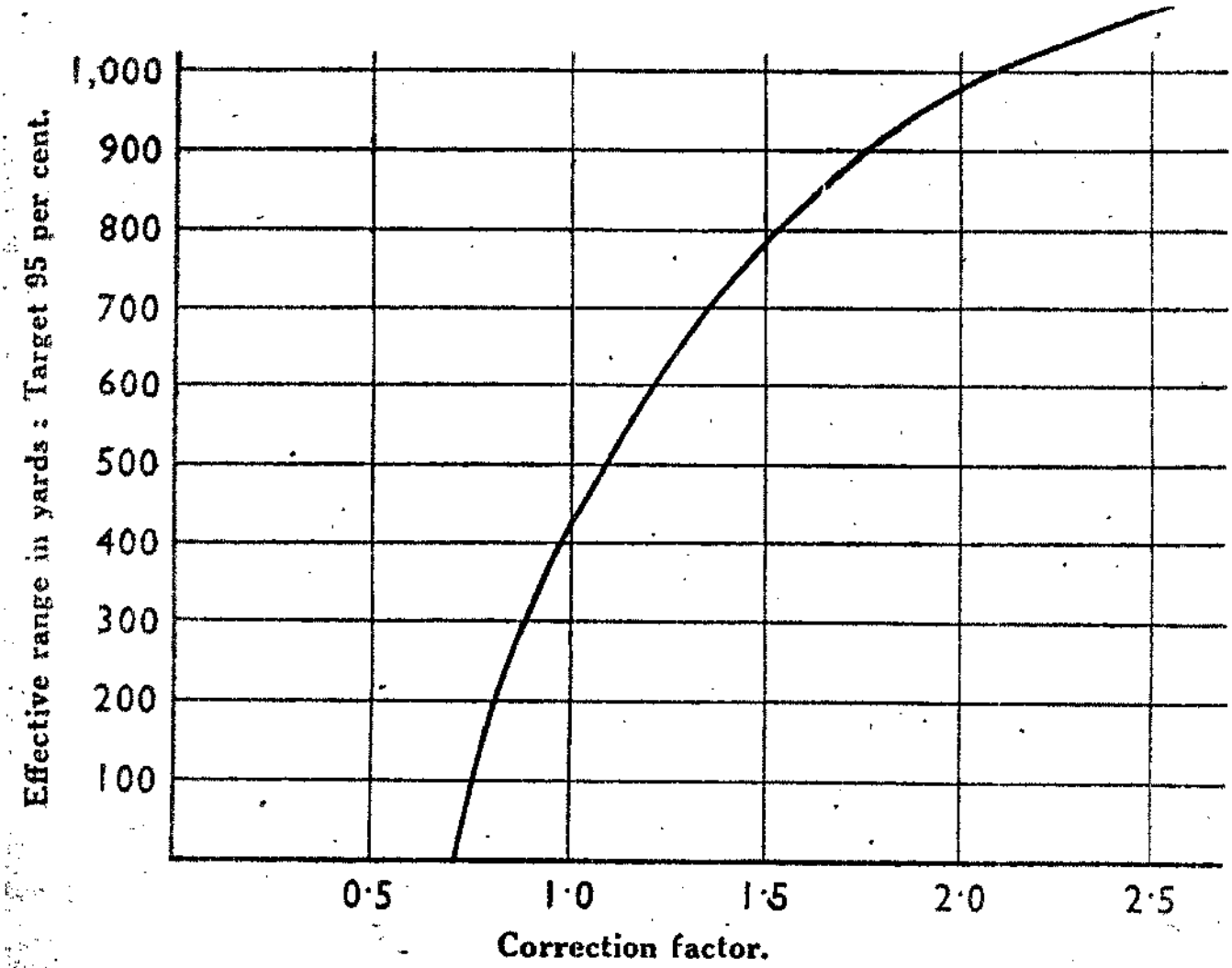
FIG. 11.



(*e*) The killing rates deduced from these allowances for head and fall are plotted in Fig. 11, which also shows the lethal index and effective range of each combined correction factor, i.e. for any combination of head and fall. From this, Fig. 12 is plotted, giving the effective range caused by any 'combined correction factor'. According to this curve, flushing is useless when the correction factor is less than 0·7, i.e. a low dam is useless in a flat stream.

FIG. 12.

Effective ranges for various correction factors. Target 95 per cent.



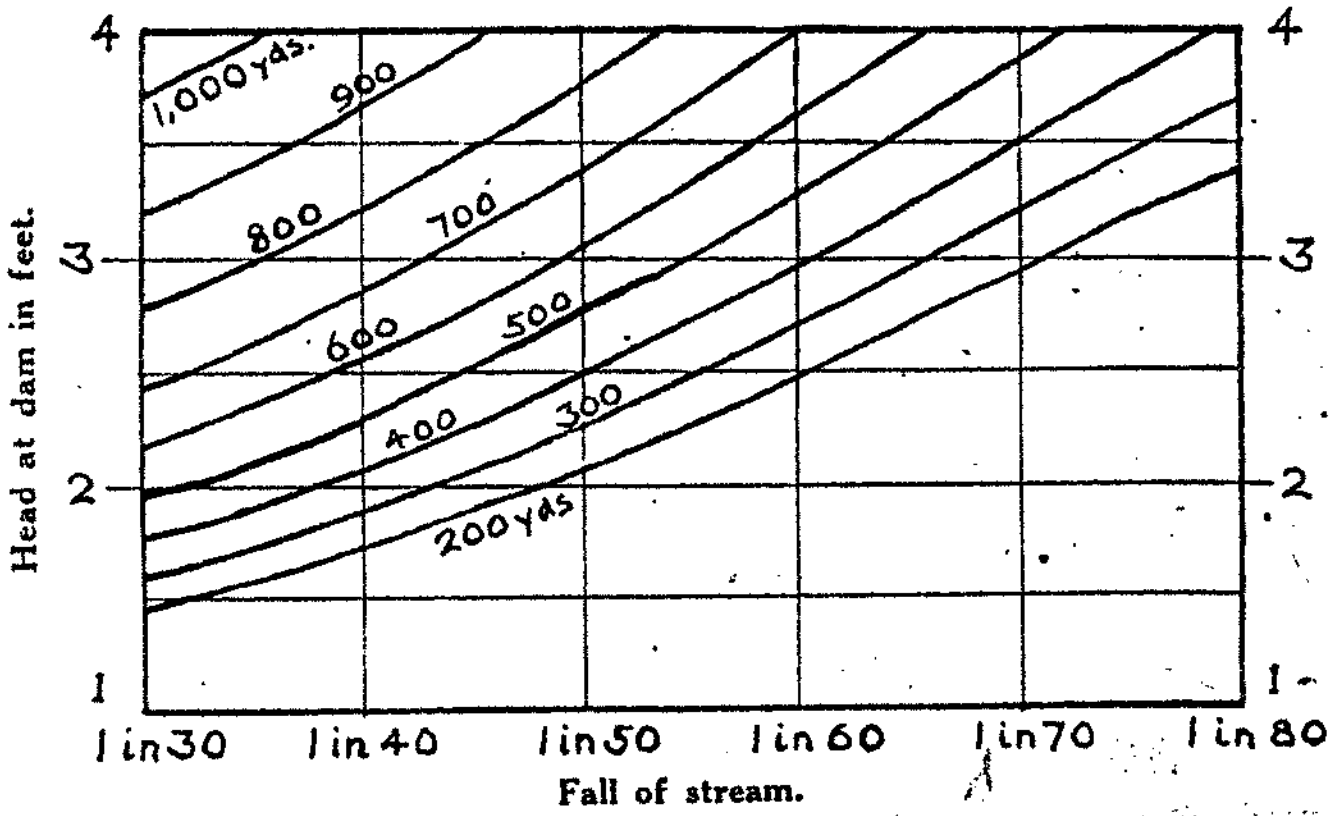
(*f*) This reasonable implication of the graph justifies attention to its upper end which implies that little is gained by increasing the combined correction factor beyond 2·5. From Table II it can be found that this figure corresponds to a 4½-ft. dam when the fall is 1 in 30 and about 7 ft. when the fall is 1 in 60. In flatter streams it is so much higher that there is little risk of building a dam higher than necessary. The inference is that the steeper the stream the more the speed of the

wave contributes to the larvicidal effect and the less the need for a high dam and a deep wave.

(*g*) Table II and Fig. 12, used together, show the effective range for any combination of head and fall. This is the rule we set out to find, and it is plotted in Fig. 13.

FIG. 13.

Effective range for any head or fall, within the limits shown, when the target is 95 per cent.



15. (*a*) This finding must not be accepted without reservation. The accuracy of the data is doubtful and the theory omits several factors of varying importance. For this reason the experiments and the line of argument have been described, it is hoped, in sufficient detail to enable both the data and the deductions to be improved.

(*b*) No theoretical rule can ever be independent of expert inspection of the pools on the bank, and obviously the value of trimming the worst places is beyond calculation. Expert judgment is needed in these matters, and the following quotation from Senior White in a personal communication has a direct bearing on the point at issue :—

'*Flushing among rocks.*—With a very elaborate engineer-built sluice gate holding over 6 ft. of head, I got very little success in a nullah about 20 ft. wide, zig-zagging among boulders, with sand stretches between the jutting-out rocks. Flush does not appear to get behind tree roots, partially in the stream, where so

much breeding occurs. A 3-in-wave is useless, in my experience, save in a channel in sand, already trained, and therefore almost sterile without the flush.'

(*c*) The effect of introducing some form of larvicide at the dam could be measured but only by prolonged experiments, perhaps in the 'back areas' of the next war.

(*d*) It is realized that towards the end of the effective range, where the killing rate falls below the target, there may be a slight risk of mosquito breeding, despite the excess mortality just near the dam. This dangerous length is found from Fig. 11 to be 200 yards long at the most, and that only when the correction factor exceeds 1·5. From this distance must be deducted the length of the pond at the next dam, which is of course 100 per cent controlled. A 3-ft. head in a 1 in 50 stream causes a pond 50 yards long, so, not much labour would be required to trim the remainder of the dangerous length. This point is, perhaps, a weakness in the theory, but it seems advisable to space the dams as far apart as we dare.

(*e*) The volume of water impounded is another important factor, and it is worth departing from the rough rule if a large enclosure can thereby be obtained, since this greatly prolongs the vigour of the wave and increases the effective range. The dam described in this article contained no very great enclosure. The greater the height of a dam, the more will its contained volume be increased by a small increase in height.

(*f*) Little or no advantage is gained by releasing waves more than once during the breeding cycle, since the pools unaffected by the first wave will also escape the second. One flush per week seems a convenient interval.

16. Flushing has at least one application outside malariology, viz. in general sanitation. Many a station in the plains of India has miles of open drainage so nearly level that water scarcely flows along it, but stagnates, sometimes in pools. An earth dam, even if only a few inches high, can remedy this. It is convenient that the flatter the drain, the greater the accumulation of impounded water.

17. In conclusion, this theory of wave action is put forward, because the author was told that this subject, admittedly a slight incursion into malariology, has not before been dealt with in this particular way. It is hoped that it may lead to a more reliable rule than that which is given here.

SUMMARY.

1. This is an attempt to find a rule for the distance between dams along a stream which is being flushed for anti-larval purpose. The rule obtained is shown as a graph, and applies only to dams up to 4 ft. high and in streams whose fall is between 1 in 30 and 1 in 80. Some practical points in the design of such dams are also given.

2. Experiments in Assam, under 'back area' war conditions, provided data which, though meagre, show roughly the larvicidal effect of one particular wave. From this is deduced the distance below the dam within which the required percentage of larvæ are killed. This distance is called the 'effective range' and is applied only to the stream and the dam under trial,

3. The answer for other dams and other streams is obtained by assuming that the larvicidal effect of a wave depends on its *height* and on its *speed*, and that these two characteristics depend respectively on the *head* of water at the dam and on the fall of the *stream*. The experiments in Assam also showed the relation between these two factors, and the respective wave characteristics which depend on each. Hence a succession of graphs leads to a general rule for any dam within the limits stated.

4. The roughness of the stream bed is an important factor but is omitted from the calculations partly because of the difficulty of allowing for it, and partly because it is assumed that it will not vary much among malariogenic streams whose fall is between 1 in 30 and 1 in 80. It is, however, observed that each stream must be inspected before siting dams, and in particularly unfavourable streams the dams must be closer together than the rule requires.

5. The effect could be improved and the dams spaced further apart by trimming the banks in the worst places and by applying larvicides to the water at the dam before releasing the wave.

6. The percentage of larvæ which must be killed is called the *target* and is laid down by malariologists. The vector in this case was *A. minimus* and the target was fixed at 95 per cent. The rule is given for this target but could be worked out for others.

7. Neither the data nor the assumptions are exactly accurate and the rule obtained is therefore only approximate. It is however recorded because it appears to be a new approach to the subject.

ACKNOWLEDGMENTS.

The author wishes to express his thanks for assistance and advice received from :—

(1) Officers and other personnel of 924 Indian Works Section, R. I. E.

(2) Major McCann, Officer Commanding, No. 1 Malaria Field Laboratory.

(3) Major G. S. Hick, Deputy Assistant Director of Hygiene, 256 Sub-area.

(4) Brigadier M. K. Afridi, Consultant Malariologist, Allied Land Forces, South East Asia.

(5) Major R. A. Senior White, Malariologist, Bengal-Nagpur Railway.

(6) Dr. R. B. Lal, All-India Institute of Hygiene and Public Health, Calcutta.

Indian Journal of Malariology, 1, 4, December 1947.

FURTHER NOTES ON MALARIA IN FORT SANDEMAN.

BY

LIEUT.-COLONEL B. DE BURCA, B.SC., M.B., B.CH.,

AND

MAJOR V. P. JACOB, I.A.M.C.

[May 5, 1947.]

THE following notes are supplementary to the article on 'Malaria in Fort Sandeman' (de Burca, 1946) and are intended to record the results of a survey carried out by a section of the Central Military Malaria Laboratory during the period from mid-August to mid-October 1946. The object of the survey was (*a*) to incriminate the malaria vectors in the area and (*b*) to carry out further observations on the importance of the Zhob River as a source of anopheline mosquitoes in Fort Sandeman.

The malaria vectors.—As in previous surveys it was again found that numerically there were only two mosquitoes of importance, *A. culicifacies* and *A. stephensi*. Of 1,331 adults and 1,817 larvæ collected, 1,065 and 834 respectively comprised these two species.

The dissections carried out during the period of the present survey were as follows :—

	Number dissected.		Total.	Number infected.		Sporozoite rate per cent.
	Gland.	Gut.		Gland.	Gut.	
A. culicifacies	364	7	364	1	...	0·27
A. dthali	15	1	15	...	...	...
A. fluviatilis	4	...	4	...	...	...
A. pulcherrimus ...	33	9	33	...	...	...
A. stephensi	152	29	152	1	...	0·65
A. superpictus ...	17	2	17	...	...	...
A. turkhudi	15	...	15	...	...	...
TOTAL ...	600	48	600	2	...	0·13

The infected *A. culicifacies* was collected on September 16 in a building in the centre of the controlled area, and *A. stephensi* on August 31, in the village of Chuhi Killi Shehar, three miles from the perimeter of the controlled area. In this small village the spleen rate was 75 per cent and the parasite rate 44 per cent. Both the positive mosquitoes showed very heavy infections.

The failure to dissect guts was due to the fact that the majority of mosquitoes died within 24 hours of capture. It was thought probable that this was caused by the D.D.T. spraying which was being carried out for control purposes.

The Zhob River.—From the present survey it was concluded that the Zhob River was of no importance as a source of anopheline mosquitoes in the station. It should, however, be pointed out that this investigation was carried out much later in the season than the previous survey so that the above inference does not cover the conditions which prevailed earlier in the season. The decision to ignore the river as a source of anopheline mosquitoes was reached for the following reasons :—

(*a*) There were more than enough breeding places in the controlled area to account for all the anopheline mosquitoes present. An absolute reliance appeared to be placed upon the efficiency of fortnightly D.D.T. spraying with consequent neglect of breeding places. *A. culicifacies* and *A. stephensi* breeding was found everywhere throughout the station in fire tanks, swimming pools, animal troughs, syphons, blocked water channels, rain pools and a variety of other breeding places.

(*b*) *A. maculatus* and *A. moghulensis* which were breeding freely in the Zhob River were not found in Fort Sandeman (*A. moghulensis* had not previously been reported from this area).

(*c*) While the shortest distance to the river is $2\frac{3}{8}$ miles from the controlled area, the main breeding places on the river were 4 to 5 miles distant and the anopheline mosquitoes from this area had a nearby summer camp of Pathans as a source of blood feed. In 15 minutes four insect collectors caught 130 specimens in a tent in this camp.

(*d*) There were two floods in the river during August which washed out the breeding places. This caused no apparent diminution in the number of adults caught in Fort Sandeman.

ADDITIONAL OBSERVATIONS.

Villages.—Apart from the villages of Apozai within ¼ mile of the station, and Chuhi Killi Shehar which lies 3 miles to the east, an opportunity to visit Sheik Khan Killi occurred during the present survey. This is a small village lying in the foothills 4 miles south-east of Fort Sandeman. A spleen rate of 83 per cent was found and a parasite rate of 44 per cent. *A. culicifacies* and *A. stephensi* were found breeding profusely in a stream and in springs. There is a flat uninterrupted stretch of country between Fort Sandeman and this village. There must

consequently be some remote risk of mosquitoes being blown into the station or flying in, particularly in the late autumn.

Larval drift.—This was noted along the main Apozai channel in 1940 and again during the present survey. It was previously thought to be of little importance, but during the present survey numbers of larvæ were noted in channels in the Political Agent's garden after a period when the main channel had been closed and again re-opened. This normally occurs twice a month. The manner in which the drift occurs is a simple one. Damage to the sides of the main channel leads to pool formation, and when the main channel empties, these pools if they are above the level of the main channel bed flow into it, carrying any larvæ they contain. When the water is again opened, the larvæ get distributed throughout channels in the station. It is not thought possible that larvæ would survive in the main channel when it is running full.

Feeding time of A. stephensi.—The feeding times noted for *A. stephensi* make early morning personal prophylaxis important. In the open it has been found feeding freely at 0900 hours. On one occasion the feeding time at another station (Sargodha, N. Punjab) upset all our previous ideas on this subject. In the early afternoon while sitting in rather a dark office it was seen biting in numbers.

Christophers and Shortt (1921) have described *A. pulcherrimus* in Mesopotamia as feeding actively during the day in houses. In the hot, moist climate of the Duars, during the rains, Anopheles (largely *A. minimus*) may actively feed during the day within the bungalow (Christophers and Missiroli, 1933).

This day-time feeding must, however, be a rare occurrence. In authors' experience apart from *A. stephensi*, only one other anopheline species has been noted feeding in the daytime; on one occasion *A. culicifacies* was noted feeding in the early afternoon while sitting on the edge of a stream in a jungle area.

Conclusion.—The present survey had to be carried out in a station where fortnightly D.D.T. spraying (5 per cent solution of D.D.T. in kerosene) was being carried out and in some lines at more frequent intervals.

It was found, however, that some menial and certain civilian quarters were neglected. It is interesting to note that the infected *A. culicifacies* was collected in the centre of the controlled area at a distance of one-half mile from its periphery on all sides. It is unfortunate that larval control work should have deteriorated with the advent of D.D.T. spraying. This neglect made it difficult to study anopheline infiltration from other possible sources.

The question of the importance of *A. superpictus* often crops up. In a study of reports from and during visits to all stations in Waziristan this species was not noted to occur in sufficient numbers to be of any practical importance as a malaria vector at elevations up to 5,000 feet.

SUMMARY.

In a survey carried out between mid-August and mid-October 1946 at Fort Sandeman, *A. stephensi* and *A. culicifacies* were found infected, gland infections

in each case. No other mosquitoes occur in sufficient numbers to be of any practical importance.

The Zhob River was not considered to have any bearing on the malaria problem in this station during the period of the survey.

REFERENCES.

CHRISTOPHERS, S. R., and MISSIROLI, A. (1933). Quarterly Bulletin of the Health Organization of the League of Nations. II. Ext. No. 6, p. 421.

CHRISTOPHERS, S. R., and SHORTT, H. E. (1921). Malaria in Mesopotamia. *Ind. Jour. Med. Res.*, **13**, pp. 343–405.

DE BURCA, B. (1946) ... ... Malaria in Fort Sandeman. *Jour. Mal. Inst. Ind.*, **6**, pp. 359–365.

Indian Journal of Malariology, 1, 4, December 1947.

WINTER VARIATIONS OF THE LARVA OF *A. FLUVIATILIS* FROM NORTHERN INDIA AND BOMBAY PRESIDENCY.

BY

LIEUT.-COLONEL B. DE BURCA, B.SC., M.B., B.Ch.,

AND

CAPTAIN H. W. FORSHAW, M.B., Ch.B., R.A.M.C.

[April 21, 1947.]

THIS note briefly describes some winter variations of *A. fluviatilis* larvæ as found in Clement Town and Poona during the cold season of 1945-46. Clement Town is situated five miles south-west of Dehra Dun in the United Provinces at an elevation of 2,000 ft. approximately, while Poona is in Bombay Presidency at roughly the same elevation.

Clement Town lying as it does just below the Himalayas has a rather long and moderately severe cold season during which the lowest temperature is recorded in January. The minimum temperature remained below 60°F. between October 4, 1945 and April 2, 1946. The average minimum temperature during January and February was 47°F. Poona on the other hand has a very mild and short cold season.. The minimum temperature in January varied between 43 and 56°F.

Early in December 1945, a larva of *A. fluviatilis* was found at Clement Town which had one external clypeal dividing into two equal branches at the junction of the inner third and outer two-thirds. During subsequent weeks it was noted that greater numbers showed divided clypeals and of 357 larvæ examined between January 19, 1945 and February 23, 1946, this variation was observed in 182. No constant variation was seen. Where the outer clypeals were divided, it occurred 87 times on one side only and 76 times on both sides. The division was sometimes basal, more often at the junction of the outer two-thirds and inner third and most commonly in the distal third. The branches were always approximately equal in size. The last type mentioned was similar to that which was seen in

A. moghulensis and already described and illustrated by Puri (1931, Plate XLI). In two specimens the outer clypeals had four branches on each side. In addition, in 17 specimens one of the inner clypeals was also divided, and in two specimens both were divided. In these last two specimens the division was basal and the branches equal, giving the appearance of four inner clypeals. Like the outer clypeals, the position at which the division occurred varied. The posterior clypeals were simple in all specimens.

In the third week of March 1946, of 67 *A. fluviatilis* larvæ examined in Clement Town, only 3 showed a division of the outer clypeals and in each case only one outer clypeal was branched and always in the outer third.

Another variation noted was in the number of branches on the inner sutural hairs—they varied between three and nine instead of the 6 to 8 described by Puri (*loc. cit.*, p. 153) though this is not thought to be a winter variation.

During the winter months, particularly at Clement Town, marked variations were noted in the wing markings of *A. fluviatilis* adults. Not many *A. fluviatilis* hatched out in the laboratory at Clement Town but correlating the findings here and at Poona, no relation was found between abnormal larvæ and adults. Marked hypermelanic adults hatched out from normal larvæ.

One of us visited Poona in the first week of January 1946 and exactly similar variations in both adults and larvæ were found though the numbers were much smaller. In January, five of 82 larvæ examined had branched outer clypeals—four branches in one case. During February, 4 out of 35 showed this variation, while in March, of 133 examined only one specimen showed any variation—fraying of one inner clypeal. This was the only specimen found with fraying. All adults examined during March were normal in appearance.

SUMMARY.

A brief description is given of some winter variations noted in the larva of *A. fluviatilis* during the cold season of 1945-46 in North India (U.P.) and Bombay Presidency (Poona). A large proportion of larvæ were found with branched outer or inner clypeals. A division of the outer clypeals with two equal branches was the commonest variation seen, and often this was unilateral.

REFERENCE.

PURI, I. M. (1931) ... ... *Ind. Med. Res. Mem. No.* 21.

Indian Journal of Malariology, 1, 4, December 1947.

CONTROL OF BREEDING OF *A. SUNDAICUS* BY *EICHHORNIA*-COVER.

BY

V. VENKAT RAO, F.R.S.T.M. & H., M.R.San.I.,

AND

V. RAMAKRISHNA, M.A., F.R.E.S.

(*Malaria Section, Medical Department, B. N. Railway.*)

[March 21, 1947.]

IYENGAR (1946) has stated that the breeding of *A. sundaicus* in ponds and marshes can be effectively controlled by means of a thick cover of *Eichhornia speciosa*. This effect is attributed to *Eichhornia* killing other vegetation like *Enteromorpha*, *Hydrilla* and *Najas* and by cutting off the illumination necessary for the growth of algæ and sub-aquatic vegetation and the consequent changes brought about in the phytoplankton content of the water. These observations are based on his work in the Calcutta area.

As the observations of the present authors are different from the above, they are presented here with a view to indicating that the findings of Iyengar (*loc. cit.*) are not necessarily applicable to other *sundaicus*-infested areas such as Orissa and North Vizagapatam Coast.

During the course of a malaria survey of Ichchapuram Town (North Vizagapatam Coast), the present authors came across a tank (Tank 6 of our malaria control plan) which contained considerable growth of the following vegetation in association with a thick cover of *Eichhornia speciosa* :—

Hydrilla verticillata	*Eliocharis* spp.
Najas spp.	*Spirogyra* spp.
Ceretophyllum demersum	*Cladophora* spp.
Scirpus grassus	

Larvæ of *A. hyrcanus*, *A. barbirostris*, *A. subpictus*, *A. vagus*, *A. culicifacies*, *A. annularis* and *A. pallidus* were found in the tank on survey in good numbers. *A. sundaicus* larvæ were not, however, found in it.

In Berhampur (Orissa), the authors saw a large tank, called the Dhoby Tank, in which the following vegetation was found interspersed with a thick *Eichhornia*-cover :—

Hydrilla verticillata
Lemna minor
Spirogyra spp.

Both the tanks were shown to Major R. Senior White (formerly Malariologist of the Bengal Nagpur Railway) and he agreed that *Eichhornia* was present in them in a fairly thick cover.

In these areas, therefore, *Eichhornia*-cover did not appear to exclude other vegetation.

Iyengar (*loc. cit.*) states that when all other vegetation is killed blue-green algæ may remain and be present in small quantities along with *Eichhornia*. Covell and Singh (1942) have observed larvæ of *A. sundaicus* on many occasions in association with blue-green algæ like *Lyngbya*, *Anabena* and *Oscillatoria* on the Chilka Coast. Presence of blue-green algæ, even in small quantities, is, in the present authors' experience, unsafe as larvæ of *A. sundaicus* have often been found under such conditions.

Iyengar (*loc. cit.*) also states that the salinity toleration limits of *Eichhornia* are well within the salinity range of *A. sundaicus* breeding places in Lower Bengal. On the Chilka Coast, Senior White and Adhikari (1939) and Covell and Singh (*loc. cit.*) found the optimum salinity of *A. sundaicus* breeding at 600 to 800 parts per 100,000. The present senior author planted *Eichhornia* in the manner advocated by Iyengar in a pond near Khallikota railway station. The salinity of the water at the time was 600 parts per 100,000, but the plant died completely within a month of planting, though it was thriving very well in a fresh water tank (salinity 50 parts per 100,000) in the same village. Tadulingam and Venkatanarayana (1932) state that salt water kills the plant and refer to a suggestion made to deal with it by collecting and shoving it into the sea. Waters within the salinity range of *A. sundaicus* are thus found to be unfavourable for the growth of *Eichhornia* in the Chilka area.

In order to see if *Eichhornia* prevented breeding of *A. sundaicus*, a thick cover of the plant was provided in a railway borrowpit near Langleshwar village (3 miles north of Khallikota station), using another unplanted borrowpit nearby as control. The salinity of both the pits was 75 parts per 100,000 at the time of planting. The plant grew very well in the pit and is still present as a thick cover. Fortnightly larval collections have been made from both the pits since August 1946. On several occasions in November and December 1946, larvæ of *A. sundaicus* were found in almost equal numbers in both the *Eichhornia*-covered pit and the control pit.

SUMMARY.

In Orissa Coast, the presence of *Eichhornia speciosa* does not inhibit the growth of other aquatic vegetation nor does it prevent the breeding of *A. sundaicus*. The experiences are at variance with the observations made in Bengal.

REFERENCES.

COVELL, G., and SINGH, P. (1942)	*J. Mal. Inst. Ind.*,	**4**, pp. 457–593.
IYENGAR, M. O. T. (1946) ...	*Ibid.*,	**6**, p. 309.
SENIOR WHITE, R., and ADHIKARI, A. K. (1939).	*Ibid.*,	**2**, p. 422.
TADULINGAM, C., and VENKATANARAYANA, G. (1932).	*A Hand Book of Some South Indian Weeds.* Superintendent, Government Press, Madras.	

Indian Journal of Malariology, 1, 4, December 1947.

A SCHEME FOR THE CONTROL OF MALARIA IN VILLAGES IN DELHI PROVINCE.

BY

LIEUT.-COLONEL M. K. AFRIDI, M.D., Ch.B., D.T.M. & H., I.M.S.,

AND

CAPTAIN DALIP SINGH, I.A.M.C. (Retd.).

(*Malaria Institute of India.*)

INTRODUCTION.

THE scheme for malaria control in Delhi Province, which forms the subject of this paper, was planned in May and enforced in the first week of July 1947. Normally, it should have been published at the end of the malaria season but as many of the problems discussed are of a wider application it is felt that its publication at this stage might be of help to those engaged on organizing antimalaria measures in similar terrain namely the Indo-Gangetic plain where *A. culicifacies* is the malaria carrier.

GENERAL DESCRIPTION.

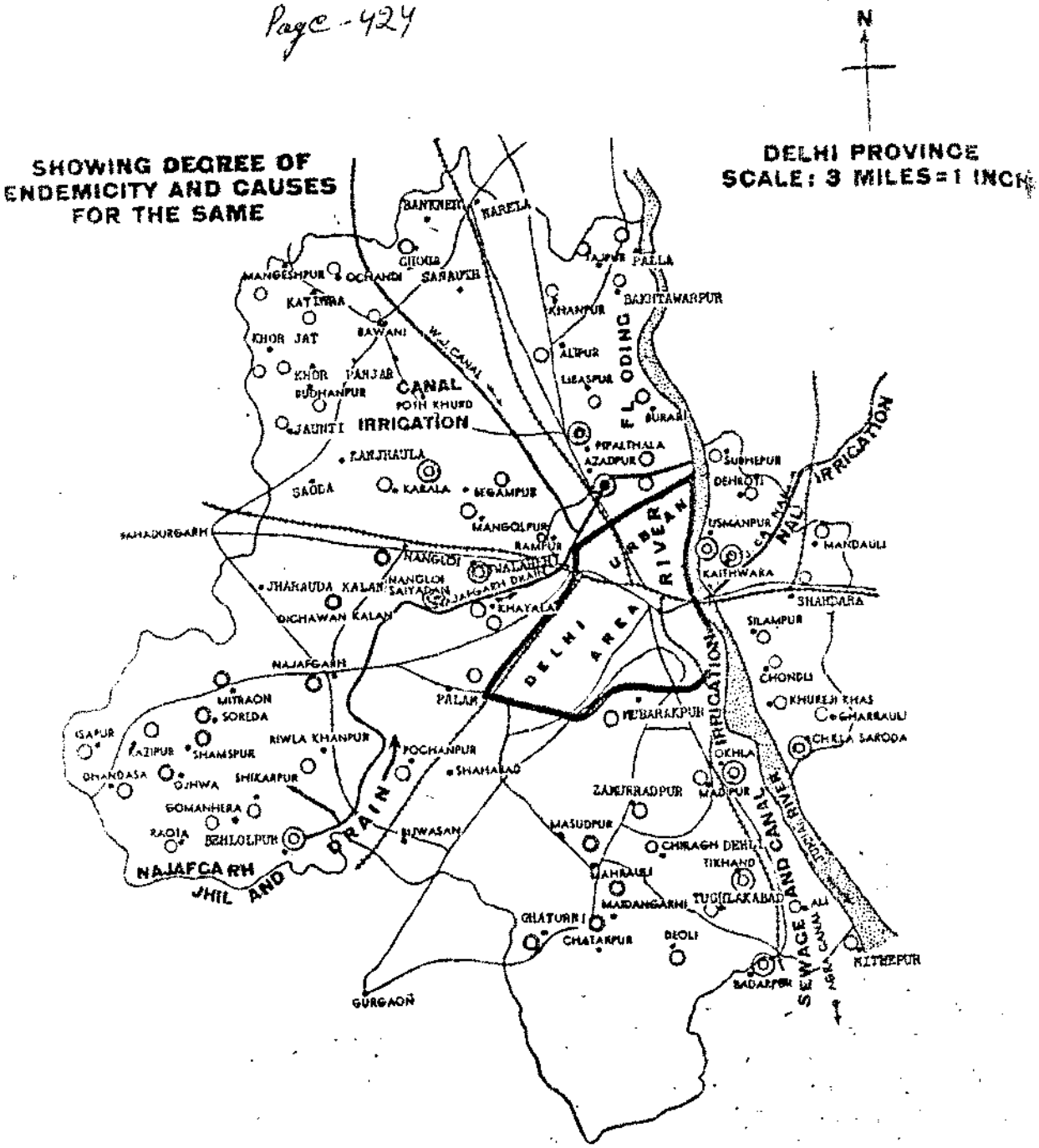
The rural section of Delhi Province comprising an area of 502 sq. miles contains about 266 villages with a population of 292,102. The size of the individual village varies from anything like 15 houses to 1,800 houses, an average village consisting of about 200 houses. There are eight dispensaries and eleven health centres spread over the province for medical relief and general sanitary uplift.

Malaria surveys of the northern, southern and Shahdara zones of this area were carried out in 1937 and 1938 by Major (now Lieut.-Colonel) W. H. Crichton and Lieut.-Colonel. (now Major-General Sir) G. Covell respectively. A fresh spleen census was undertaken during March and April 1947 which covered not only the zones dealt with by these two investigators but also the remaining sections of the rural area.

A study of this data shows that the amount of malaria varies considerably in different localities even from village to village depending entirely upon whether the favourite breeding places of *A. culicifacies* are prevalent in the vicinity or not.

MAP I.

Page - 424



Considered on a regional basis, a uniformly high degree of malaria prevails in villages exposed to the flooding of the River Jumna or of Najafgarh Lake and those situated in the canal irrigation sector (Sketch Map I and list of spleen rates in Appendix A).

SELECTION OF CONTROL MEASURES.

In selecting antimalaria measures suitable for rural areas, two basic principles had to be kept in view. In the first place, measures selected must be such that they can be adequately supervised as without such supervision no method of control will effectively reduce malaria. Secondly, the cost must be low so that the financial authorities can accept it as a permanent commitment even in years of economic stress.

On this basis, control by recurrent antilarval measures is, as a rule, not feasible, as, the population in rural areas being scattered, the treatment of breeding places around each village necessitates an enormous permanent supervisory staff at a prohibitive cost. It is emphasized that the above view pertains only to recurrent antilarval measures and not to permanent works having other collateral benefits, such as anti-flood protective measures or drainage schemes for the reduction of waterlogging in irrigated tracts.

In so far as recurrent measures are concerned, those directed against adult mosquitoes would therefore offer a more practicable approach to the problem. Here, the choice lies between spraying of houses with pyrethrum solution and with D.D.T. both of which have proved effective. The disadvantage of the former insecticide however is that it has to be sprayed twice or three times a week throughout the malaria season. In practice, it becomes necessary therefore to provide a separate supervisory staff for each group of villages in a relatively small area. The expenditure involved, though less than that on the antilarval measures, is usually high enough to render the method economically impracticable.

Per contra, one application of D.D.T. remains effective for a long period, so that spraying need not be repeated for weeks and in some localities for months. The residual effect of D.D.T. can thus be put to practical advantage by allowing a single spraying team to cover as wide a field as possible. It is this particular feature of D.D.T. which, if properly exploited, reduces the cost of malaria control thereby rendering it as the method of choice in rural areas.

ORGANIZATION.

General principles.

From the foregoing discussion it is obvious that the basic feature of any organization designed to carry out large-scale D.D.T. spraying would be a mobile spraying team capable of ranging over a wide circle of villages. The supervisory staff in such a team must be particularly strengthened at the level where it can ensure a correct dosage of D.D.T. This is essential as defective dosage, unless avoided at the time of actual treatment of wall surfaces, cannot be rectified later.

Another organizational feature deserving particular attention is that D.D.T. constitutes the most expensive item in the overall expenditure on a spraying campaign. From the economic viewpoint, therefore, reduction in costs can, apart from reducing the number of spraying rounds to the minimum, be effected only by curtailing the permanent staff in spraying teams to the lowest limit compatible with efficiency.

Existing organization.

The organization sanctioned for the Delhi Province was based on the recommendations of the Health Survey and Development Committee Report (1946) according to which each province was to instal a headquarter unit and to recruit a number of malaria control units. The former unit was however not considered necessary in the case of Delhi, as its functions being investigatory and instructional could be readily performed by the Malaria Institute of India. The provincial antimalaria organization for rural areas was thus reduced to three malaria control units and one clerk working under the administrative and technical control of the Director of the Institute. Each malaria control unit comprised one medical officer in charge of the unit, three malaria inspectors, two laboratory assistants and 25 field workers.

The units were located in three subordinate civil centres of Mahrauli, Najafgarh and Narela and the intention was to start control measures in the centres and the villages nearby, later extending them further afield till the entire province was covered.

Revised organization.

Viewed in the light of the general principles enunciated above, it will be observed that the establishment of the malaria control units was unsatisfactory in two respects. In the first place, the entire personnel being permanent, expenditure under this head was too heavy to leave sufficient economic margin to meet the cost of D.D.T. Secondly, the unit was strongest in the upper grade supervisory staff such as the malaria assistant and malaria inspectors whereas the number of field workers was too small to undertake spraying on the requisite scale.

It was recognized therefore that the structure of these units would have to be radically altered before they could undertake the control of malaria with D.D.T. Many modifications suggested themselves but every change had to be carefully tested out in the field before it was adopted. As the result of these small-scale trials, the organization outlined below was evolved which has so far been found to work admirably under the conditions prevailing in Delhi Province.

The revised organization now operating consists of (*a*) headquarters, (*b*) three malaria spraying units and (*c*) transport.

The headquarters is composed of one malaria assistant who controls the entire spraying campaign, one malaria inspector who supervises the preparation and distribution of D.D.T. suspension concentrate, six laboratory assistants who carry out entomological and parasitological investigations to assess the effects of spraying, and one clerk-storekeeper who attends to general administrative routine. The equipment provided is that required for entomological and parasitological surveys.

The 'malaria spraying unit' was purposely designated as such mainly to avoid confusion with the malaria control unit of the Health Survey and Development Committee (*loc. cit.*) with which it has little in common. Thus its permanent staff has been reduced to the minimum nucleus of two malaria inspectors and one mechanic while during the malaria season its expansion is provided for by additional temporary labour of eight superior field workers and 44 field workers to form two full-sized spraying teams. In Delhi Province the three units can thus put into the field six such spraying teams which are sufficient to cover the entire rural area. Villages earmarked for control have accordingly been grouped into three spraying zones which, in turn, have been subdivided into sub-zones 'A' and 'B', each of which will be treated by one spraying team (Sketch Map II).

The transport requirement of each spraying unit is assessed at one truck as it has been found possible to adjust the spraying programme so that it can transport men and material of the two spraying teams without undue loss of time. Additional reserve is however still necessary partly to meet the emergency demands in cases of breakdown and partly to treat villages which cannot be reached by ordinary trucks in the rainy season. For this purpose a quota of three vehicles with four-wheel drive has been provided making a total of six, all of which are located at headquarters. The unit vehicles are issued out only during the malaria season so as to reduce the misuse of transport to the minimum.

Details of spraying.

In an effort to curtail unnecessary expenditure of D.D.T., villages with spleen rates below 5 per cent have been excluded from spraying programme, those between 5 and 20 per cent are to receive one spraying while those above 20 per cent are to be sprayed twice in the season. This is a trial arrangement which, if successful, would entail considerable saving inasmuch as 47 of the villages will on this basis need no spraying while 73 will require one spraying out of a total of 266 villages in the province.

The schedule for spraying has been framed to fit in with the incidence of infective mosquitoes which in Delhi begins in mid-July and reaches its peak in mid-September. Villages earmarked to be sprayed twice are consequently to receive first round of spraying from July 1 to 31, and the second round from August 15 to September 15. In the intervening period from August 1 to 15, the spraying teams will treat the single spray villages, thus eliminating a break in the employment of temporary labour. Since the effect of each application of D.D.T. at the intended dosage, namely 50 mg. per square foot, has been found to last for at least six weeks in Delhi (Puri and Krishnaswami, 1947), it will be observed that even in the single spray villages spraying is so timed that its effectiveness should last through the peak period of infection in mosquitoes.

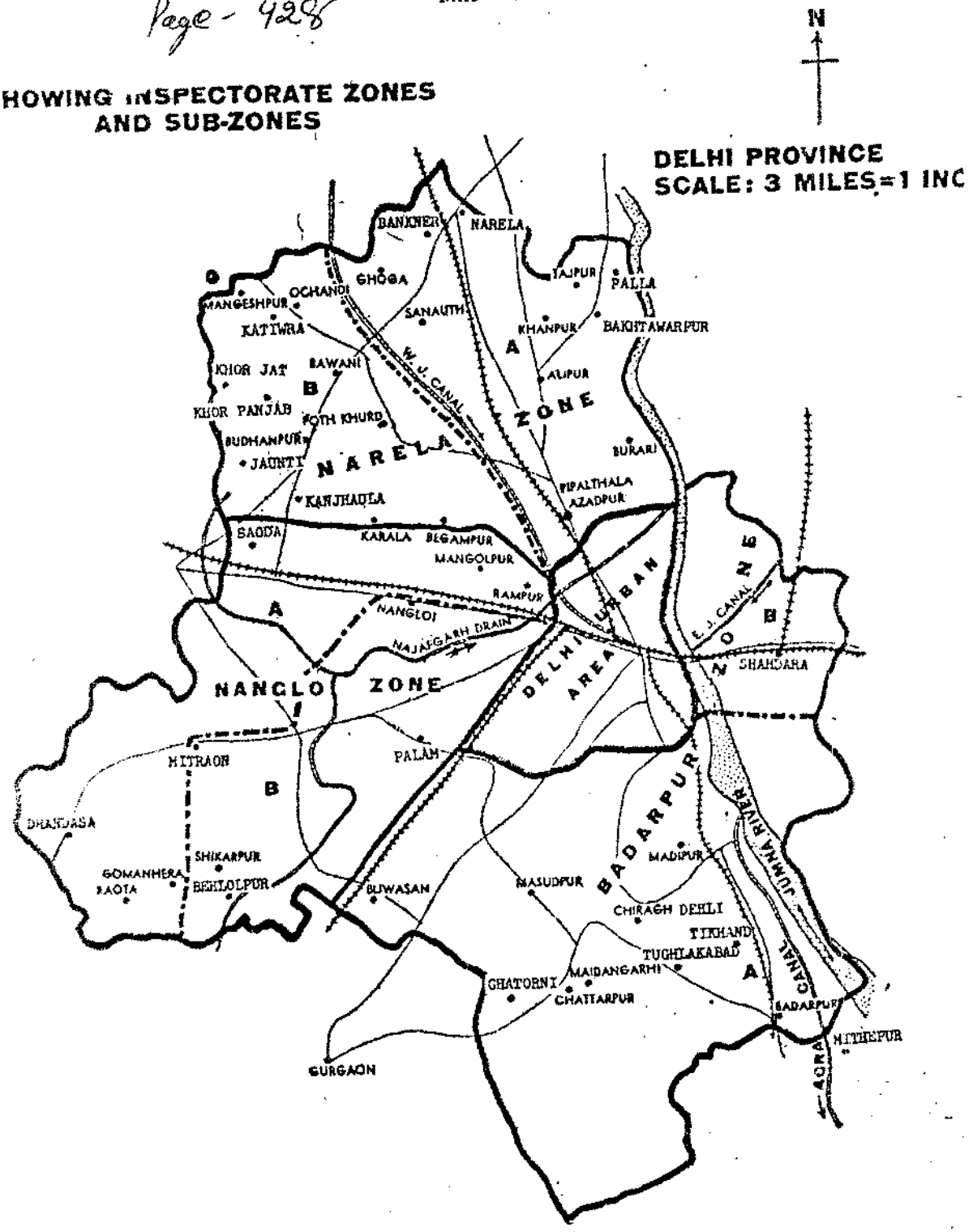
D.D.T. spraying fluid.

Each spraying zone is being treated with a different formulation of D.D.T. In one zone a watery suspension of D.D.T. locally prepared with gelatine and gum acacia in accordance with the formula evolved by Puri (1947) is being used at a dosage of 50 mg. per square foot. In the other two zones, commercial preparations

Page - 428

MAP II.

SHOWING INSPECTORATE ZONES AND SUB-ZONES



BOUNDARY LINE OF ZONES —
" " " SUB-ZONES - - -

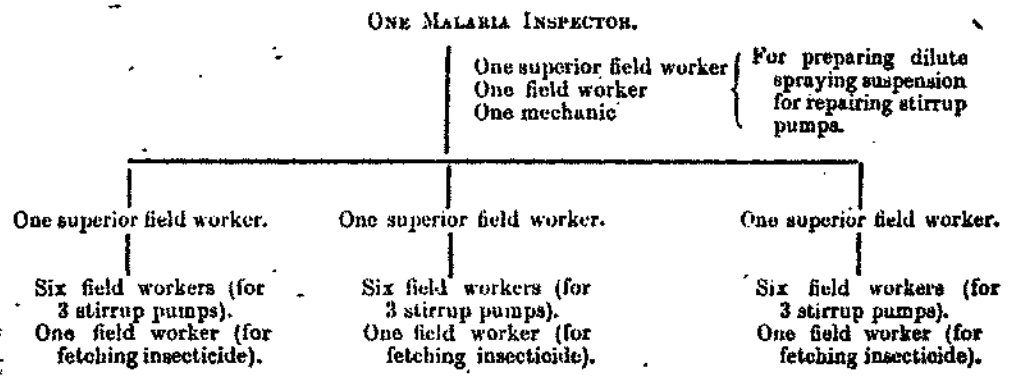
of D.D.T. are being tested at dosages recommended by the respective firms to be comparable to 50 mg. per square foot of the locally prepared D.D.T. suspension. In one zone a wettable powder is being tried at the rate of 30 mg. of D.D.T. per square foot while in the other an emulsion at 10 mg. of D.D.T. per square foot.

In villages earmarked for two sprayings, all the above dosages will be halved at the second application. This decision is based on the finding of Puri and Krishnaswami (*loc. cit.*) in whose experiments D.D.T. applied late in the malaria season remained effective for longer periods even at 25 mg. per square foot.

The three types of D.D.T. preparations are varyingly diluted so that in each case the requisite dosage is obtained by applying the final spray at the rate of two quarts per 1,000 square feet. This greatly facilitates the work in the field but it does not wholly solve the problem of evolving a readily intelligible procedure which would ensure a correct amount of spraying fluid being applied to the surfaces. In Baluchistan, the field workers had been instructed to aim a specified degree of wetness (Afridi and Bhatia, 1947) but this necessitated constant vigilance on the part of the supervisory staff which may not always be available. The method utilized in Delhi is to regulate the up-and-down movement of the stirrup pump lance by making the field workers count one-two at a specified rhythm which in previous experiments had been found to represent a spraying rate of two quarts per 1,000 to 1,200 square feet.

Work programme of a spraying team.

It should be pointed out that each spraying team working under a malaria inspector is virtually self-contained, only sharing accommodation and transport with the second team in the malaria spraying unit. The staff of a spraying team thus consists of one malaria inspector, four superior field workers and 22 field workers. At the time of spraying the personnel are disposed as shown in the diagram below :—



The usual routine followed is that on arrival at a village the malaria inspector establishes a centre near a well for preparing the dilute spraying fluid from the concentrate received from the headquarters. He then makes a quick survey of the village and allots specified sections for spraying to each of the three superior field workers. The three stirrup pumps working under each superior field worker

are employed in one house at a time and the next house is taken up only when the first has been dealt with. Spraying thus proceeds house by house till the superior field worker has covered the sector allotted to him. This arrangement ensures good supervision and eliminates the possibility of missing a house in spraying.

The provision of one extra field worker for fetching insecticides in each spraying gang has been found essential as it eliminates frequent interruption of the spraying operations which otherwise occurs. On an average, each spraying team thus organized is capable of spraying 200 houses each of 3 rooms in one day. To complete this schedule, however, adequate arrangements for effecting speedy repairs to the stirrup pumps are necessary. In Delhi, each spraying team carries a reserve of 9 pumps, distributed as follows :—

(*a*) One pump with each of the three superior field workers in charge spraying gangs.

(*b*) Six stirrup pumps with the mechanic.

When a stirrup pump goes out of order, it is immediately replaced by the one carried by the superior field worker. The defective pump is sent immediately to the mechanic for repairs through the field worker assigned for fetching insecticides. The latter, on return, brings back a good pump from the mechanic's reserve. Such a planned cycle of replacement is essential otherwise much time is unnecessarily wasted.

On a non-working day, the inspector and the mechanic review all the stirrup pumps once a week to carry out major repairs, oiling and general maintenance.

Financial effect.

The estimated expenditure on recurrent and non-recurrent items of the scheme is Rs. 1,00,000 and Rs. 42,000. On this basis the cost *per capita* works out at As. 5·5 and 2·3 respectively under recurrent and non-recurrent heads. After actual experience however it is probable that the figure for recurrent charge may turn out to be much lower than the one given above.

SUMMARY.

1. A scheme for the control of malaria by D.D.T. spraying in 266 villages in the Delhi Province is described. The basic formation in the revised organization is a mobile malaria spraying unit capable of ranging over a wide circle of villages. The routine working programme of such a unit is described in detail.

2. The spraying schedule has been arranged so as to effect the greatest possible economy in the expenditure of D.D.T. The estimated cost *per capita* for the whole scheme works out at As. 5·5 on the recurrent items and As. 2·3 on non-recurrent items.

REFERENCES.

Afridi, M. K., and Bhatia, M. L. (1947). *Ind. Jour. Mal.*, **1**, 2, pp. 279–288.

Health Survey and Development Committee Report (1946). Vol. II, pp. 149–150.

Puri, I. M. (1947) ... ... *Ind. Jour. Mal.*, **1**, 1, pp. 211–220.

Puri, I. M., and Krishnaswami, A. K. (1947). *Ibid.*, **1**, 1, pp. 193–209.

APPENDIX A.

Spleen rates determined in March-April 1947.

Serial number.	Name of village.	Spleen rate per cent.
	Villages with spleen rates below 5 per cent.	
1	Mundka	4·5
2	Baqarpur	0·0
3	Jafarpur-Hirankudna	3·3
4	Jharauda Kalan	2·5
5	Surakhpur	0·0
6	Mitraon	0·0
7	Kair	1·8
8	Mundela Kalan	4·0
9	Bakar Garh	2·5
10	Khera Dalar	0·0
11	Malikpur	3·5
12	Bhartal	0·0
13	Kharkhari Jatmal	3·1
14	Munirka	0·0
15	Khanpur	0·0
16	Tigri	0·0
17	Nib Sarai	3·7
18	Maidan Garhi	3·9
19	Sultanpur	0·0
20	Yahya Nagar	0·0
21	Bhati	0·0
22	Malikpur	0·0
23	Rajokri	0·0
24	Bijwasan	0·0
25	Kapashera	0·0
26	Samalkha	0·0

APPENDIX A—*contd.*

Serial number.	Name of village.	Spleen rate per cent.
27	Nangal Dewat	0·0
28	Sohalsarai	0·0
29	Manglapuri	0·0
30	Mehramnagar	0·0
31	Mehpalpur	0·0
32	Masudpur	4·0
33	Mahrauli	2·2
34	Adhchini	3·8
35	Palanji	0·0
36	Kalu Sarai	2·7
37	Begampur	2·5
38	Tut Sarai	0·0
39	Shahpurjat	0·0
40	Mujahidpur	4·1
41	Shekh Sarai	0·0
42	Chiragh Dehli	0·0
43	Madangir	2·4
44	Madipur	2·0
45	Kilokri Sewage Farm	2·2
46	Dichawan Kalan	4·5
47	Hauz Khas	0·0
	Villages with spleen rates between 5 and 20 per cent.	
1	Karari Suleman Nagar ...	18·1
2	Mubarakpur Dibas	20·0
3	Nizampur Rashidpur	15·0
4	Qamaruddin Nagar	7·4
5	Tikri Kalan	19·09

APPENDIX A—*contd.*

Serial number.	Name of village.	Spleen rate per cent.
6	Ranhaula	8·3
7	Nil Wal	8·0
8	Soreda	8·5
9	Jafarpur Kalan	5·4
10	Shamashpur Khalsa	5·3
11	Kazipur	13·9
12	Ojwah	10·0
13	Isapur	11·6
14	Dhandasa	11·6
15	Daryapur Khurd	7·1
16	Sarangpur	15·0
17	Pondwala Khurd	6·8
18	Kharkhari Raund	18·7
19	Nitri	19·0
20	Hamidpur	15·0
21	Tajpur Khurd	15·0
22	Goela Khurd	15·0
23	Singhu	15·0
24	Nangloi Jat	7·8
25	Budhela	18·1
26	Hasht Sal	11·1
27	Nawada Hashta	9·8
28	Palam	20·0
29	Matola	9·5
30	Bagraula	11·9
31	Ambar Hai	7·3
32	Pochanpur	11·8

APPENDIX A—*contd.*

Serial number.	Name of village.	Spleen rate per cent.
33	Bamnauli	10·8
34	Nangli Sakroti	8·3
35	Najafgarh	6·5
36	Dindarpur	8·3
37	Chawiah	19·3
38	Khaira	19·5
39	Paprawat	7·3
40	Kharkhari Nahar	10·0
41	Pindwala Kalan	6·8
42	Hasanpur	18·7
43	Daulatpur	20·0
44	Uldanpur	9·9
45	Sanoli	13·04
46	Jhil Khoranjan	14·8
47	Nagla Razapur	6·6
48	Saidulajib	16·66
49	Deoli	10·0
50	Chatarpur	5·8
51	Junapur	11·4
52	Dera Mandi	5·7
53	Sahibabad	7·9
54	Katwaria Sarai	5·3
55	Lado Sarai	6·9
56	Hauz Rani	10·9
57	Gatoo Mubarakpur	11·0
58	Zamurradpur	13·3
59	Kakaj Don	12·0

APPENDIX A—*contd.*

Serial number.	Name of village.	Spleen rate per cent.
60	Narela	7·4
61	Bakhtawarpur	11·8
62	Nangli Puna	11·5
63	Bankauli	9·1
64	Tikri Khurd	20·0
65	Singhola	12·5
66	Khanpur	15·0
67	Khera Kalan	18·9
68	Khera Khurd	19·6
69	Holambi Khurd	20·0
70	Lampur	15·0
71	Bankner	9·5
72	Mundela Khurd	5·0
73	Khanpur	15·0
	Villages with spleen rates above 20 per cent.	
1	Rampur	45·09
2	Shakurpur	36·3
3	Pitampura	29·8
4	Naharpur	35·4
5	Magholpur Kalan	36·06
6	Rathaula	27·7
7	Sultanpur	29·5
8	Puth Kalan	22·2
9	Rani Khera	22·2
10	Madanpur Dibas	39·1
11	Rasulpur	27·2
12	Gheora	27·9

APPENDIX A—*contd.*

Serial number.	Name of village.	Spleen rate per cent.
13	Saoda	42·7
14	Gomanhera	37·03
15	Jhilijhili	26·0
16	Raota	42·1
17	Diwrala	30·0
18	Madipur	25·0
19	Basai Darapur	33·3
20	Jwala Heri	53·6
21	Garhi Pira	21·0
22	Nangli Saidari	50·0
23	Khanyala	34·1
24	Tatarpur	36·6
25	Keshopur	30·5
26	Tehar	25·0
27	Nilothi	31·2
28	Poshangpur	29·0
29	Nangli	27·9
30	Asalatpur Khadar	26·0
31	Dabri	61·9
32	Mirzapur	24·2
33	Nasirpur	63·0
34	Kakraula	22·9
35	Riwla Khanpur	20·3
36	Kanganheri	21·2
37	Asalatpur Khadar	25·0
38	Shikarpur	44·8
39	Behlolpur	71·1

APPENDIX A—*contd.*

Serial number.	Name of village.	Spleen rate per cent.
40	Padora	25·0
41	Nanakheri	25·0
42	Galibpur	25·0
43	Nangal Raya	28·0
44	Subhepur	48·3
45	Beharipur	40·0
46	Saadatpur	33·3
47	Dehroti	46·1
48	Mustafabad	60·0
49	Mirpur	42·0
50	Khajuri	26·3
51	Garhi Mandu	61·2
52	Ghondi	62·5
53	Ghonda	22·8
54	Usmanpur	52·7
55	Kathiwara	75·0
56	Babarpur	31·03
57	Tahirpur	21·2
58	Gokalpur	40·0
59	Mandauli	37·3
60	Chilla Sarauda	59·2
61	Dalupura	47·0
62	Gharrauli	35·0
63	Patparganj	59·0
64	Shamapur	59·0
65	Khichripur	55·1
66	Ghazipur	25·0

APPENDIX A—*contd.*

Serial number.	Name of village.	Spleen rate per cent.
67	Shakarpur Khas	48·1
68	Mandauli	48·1
69	Kakari Duman	23·8
70	Khureji Khas	30·5
71	Ghondli	33·3
72	Silampur	43·3
73	Gandhi Nagar	30·0
74	Shahdara	15·3
75	Badarpur	64·5
76	Mithepur	80·0
77	Jaitpur	75·0
78	Molar Band	62·9
79	Ali	82·3
80	Tughlakabad	31·3
81	Tikhand	65·9
82	Madanpur Khadar	50·0
83	Jasaula	50·0
84	Okhla	59·3
85	Jogabai	40·0
86	Bhaula	45·5
87	Kilokri	27·5
88	Sat Bari	25·0
89	Gadaipur	21·9
90	Fatehpur Beri	25·6
91	Asaula	50·0
92	Mandi	24·3
93	Jharauda Majra	42·6

APPENDIX A—*contd.*

Serial number.	Name of village.	Spleen rate per cent.
94	Jagatpur	52·6
95	Burari	32·3
96	Ibrahimpur	61·1
97	Garhi Khusro	54·5
98	Hiranki	63·8
99	Muhamniadpur	60·0
100	Tagipur Jat	55·5
101	Akbarpur Majra	46·6
102	Palla	37·8
103	Tajpur Kalan	31·5
104	Bhalswa Jahangir	65·0
105	Libaspur	30·0
106	Gadipur	57·1
107	Nangli Puna	32·4
108	Azadpur	50·0
109	Bharaula	60·0
110	Pipal Thala	57·8
111	Haidarpur	50·0
112	Badli	38·8
113	Shamapur	33·3
114	Siraspur	28·9
115	Garhi	25·0
116	Naya Bans	33·3
117	Holumbi Kalan	22·2
118	Sanauth	30·0
119	Razapur Kalan	27·02
120	Kuraini	29·4

APPENDIX A—*concld.*

Serial number.	Name of village.	Spleen rate per cent.
121	Ghog	28·2
122	Begampur	61·5
123	Sahibabad Daulatpur	40·0
124	Pehladpur	21·0
125	Karala	29·0
126	Barwala	28·5
127	Puth Khurd	25·0
128	Sultanpur Dibas	26·8
129	Kanjhaula	30·6
130	Bawana	22·3
131	Chandpur	66·6
132	Ladpur	36·5
133	Jaunti	28·4
134	Chatesar	22·2
135	Silampur Majran Buphanpur ...	31·9
136	Khor Punjab	33·8
137	Khor Jat	53·6
138	Qutab Garh	24·0
139	Katiwara	33·3
140	Mungashpur	46·1
141	Bazidpur Takharan	25·0
142	Nangal Takran	33·3
143	Darya Pur Kalan	20·7
144	Ochandi	28·8
145	Hareoli	30·7
146	Chandan Hula	34·4

Indian Journal of Malariology, 1, 4, December 1947.

THE INCIDENCE OF MALARIA IN A DELTAIC AREA OF LOWER BENGAL BETWEEN THE DAMODAR AND THE HOOGHLY RIVERS.

BY

LIEUT.-COLONEL M. JAFAR, M.B., B.S., D.P.H., D.T.M. & H.,

AND

M. O. T. IYENGAR, D.SC.

(*Bengal Public Health Department.*)

[July 14, 1947.]

THIS paper records the results of a malaria survey of the tract situated between the two rivers, the Damodar and the Hooghly in Lower Bengal, constituting the area of the proposed Damodar-Hooghly Flood-flush Scheme. The area is flat and deltaic in character and includes portions of the three districts, Burdwan, Hooghly and Howrah. There is a slight fall in the general level of the ground from north-west to south-east, so that the northern and central parts are comparatively elevated while the southern part is low lying. The elevated parts have a noticeable degree of natural drainage and in spite of the fairly heavy rainfall (which is about 55 inches annually) do not contain any extensive collections of water. The area on the south and south-east is low lying, does not have any appreciable natural drainage and is characterized by the presence of many extensive low pockets that hold water for several months in the year.

The population is mainly rural; a large number of villages are scattered over the area, of which 372 villages were surveyed from November 1945 to February 1946. Altogether 25,632 children were examined of whom 8,729 showed enlarged spleen. The gross spleen rate for the entire area was 34·1 per cent.

Blood smears taken from fever cases were examined for malaria parasites. Out of 321 smears examined, 87 showed malaria parasites. Malignant tertian was found to be the predominant infection, the relative prevalence of the three species of malaria parasites being in the following proportions: *P. falciparum* 62, *P. vivax* 28 and *P. malariæ* 10.

In the course of the investigation, 4,863 adult mosquitoes were collected and identified as follows: *A. annularis* 1,356, *A. vagus* 1,200, *A. pallidus* 1,164,

A. aconitus 668, *A. hyrcanus* var. *nigerrimus* 141, *A. varuna* 106, *A. ramsayi* 101, *A. philippinensis* 66, *A. subpictus* 37, *A. barbirostris* 23 and *A. culicifacies* 1.

Mosquitoes collected from dwelling houses were dissected and examined for malarial infection. Altogether 1,259 specimens of the following species were examined: *A. annularis* 477, *A. pallidus* 322, *A. aconitus* 172, *A. vagus* 110, *A. hyrcanus* 72, *A. ramsayi* 31, *A. subpictus* 25, *A. philippinensis* 24, *A. varuna* 23, *A. barbirostris* 2 and *A. culicifacies* 1. The results were negative. The fact that the investigation was made during the off-season when active transmission was practically over, would account for the negative findings. Earlier investigations carried out in this area and in its immediate neighbourhood have shown that here as in other parts of the deltaic region of Bengal *A. philippinensis* is the primary vector of malaria. This species had been previously found naturally infected with malaria parasites in two localities within the area under review, namely, at Memari in the district of Burdwan (Sur, 1934) and at Singur in the district of Hooghly (Iyengar, 1944, p. 446). It was also recorded as naturally infected in the adjoining area of Arambagh in Hooghly District (Iyengar, 1939, p. 107).

Mosquito breeding places in the villages surveyed were examined for Anopheles breeding and the larvæ collected were identified. Altogether 11,842 Anopheles larvæ were identified as follows: *A. hyrcanus* 6,783, *A. barbirostris* 2,153, *A. annularis* 1,184, *A. ramsayi* 441, *A. aconitus* 481, *A. vagus* 233, *A. pallidus* 220, *A. varuna* 212, *A. subpictus* 91 and *A. philippinensis* 44. The breeding places of *A. philippinensis* were observed to be ponds with subaquatic vegetation and having fairly clean water.

DISTRIBUTION OF MALARIA.

The investigation covered the following ten areas: (1) Amta in Howrah District, (2) Champadanga, (3) Tarkeswar, (4) Haripal, (5) Dhaniakhali, (6) Polba, (7) Pandua and (8) Magra in Hooghly District, (9) Memari and (10) Burdwan-Sadar in Burdwan District. The incidence of malaria, as judged from the spleen rates of children, varies considerably in the ten areas. The data regarding individual villages are given in Tables I to X, while the consolidated results are set forth in Table XI.

From Table XI it will be seen that Amta area is practically free from malaria, its gross spleen rate being 0·5 per cent. The gross spleen rate for the Champadanga area is 14·2 per cent, indicating a low incidence of malaria in that area. In the four areas, Dhaniakhali, Polba, Pandua and Magra, the gross spleen rates are between 55 and 62 per cent, indicating a very high incidence of malaria. In Haripal, Tarkeswar, Memari, and Burdwan-Sadar areas the gross spleen rates are moderately high, i.e. between 35 and 47 per cent. The average spleen rates of the villages in the respective areas are furnished in column 7 of Table XI.

While in many of the areas surveyed the incidence of malaria is more or less uniform in distribution, in some of them, as for example Champadanga, Tarkeswar and Haripal, the incidence of malaria varies markedly in different parts of the same area. The results of the survey in the ten areas therefore need separate detailed discussion.

1. *Amta area.*—Amta area is situated at the extreme south of the tract investigated. It is low lying with many marshes and low pockets. During the rainy season, the condition of this area could be described as 'water-logged'. The spleen rates of 60 villages examined are furnished in Table I. The average spleen rate of the villages examined is 0·6 per cent, in 47 out of the 60 villages the spleen rate being 0. These observations show that the Amta area is practically free from malaria.

2. *Champadanga area.*—This is situated to the north of Amta and on the banks of the Damodar River. The average spleen rate of 50 villages examined is 24·5 per cent, but the rates in different villages show a wide variation, the rates ranging from 0 to 83 per cent (Table II).

On this basis, the area is divisible into the following three more or less homogeneous sections :—

(*a*) River-side section, west of the Damodar : 14 villages surveyed, average spleen rate 4·2 per cent.

(*b*) River-side section, east of the Damodar : 21 villages surveyed, average spleen rate 11·9 per cent.

(*c*) Eastern interior section : 15 villages surveyed, average spleen rate 61·0 per cent.

In the western river-side section, the incidence of malaria is very low, while in the eastern river-side section, malarial incidence is low but somewhat higher than in the former section. In the eastern interior section, on the other hand, there is hyperendemic malaria, the average spleen rate being as high as 61 per cent.

Ordinarily, in the deltaic region of Bengal, the level of the land plays a large part in determining the local malaria endemicity, high-lying areas being more malarious than the low-lying ones. A point of interest in the Champadanga area is that although the eastern river-side section is on a slightly higher level than the interior section which adjoins it on the east, the former has a considerably lower incidence of malaria than the latter. The low incidence of malaria in the river-side section is, however, due to the influence of the River Damodar. During the rainy season, the Damodar rises in flood to a level which is higher than that of the land surface in the river-side section, necessitating a protective embankment along the river bank. The high flood level in the river causes a corresponding rise in the water table in the river-side section, the soil in this area being somewhat porous. This rising of the water table during the wet season would account for the low incidence of malaria in the villages constituting the river-side section. On the other hand, the interior section which does not experience the influence of the flood level in the river because of its distance from the river, shows a high incidence of malaria. An additional factor that prevents the effect of the high flood level in the river being felt in the interior section is the presence of a drainage channel, the Ranabandha Khal, which runs between the river-side section and the interior section.

3. *Tarkeswar area.*—This area is situated north of Champadanga. As in the latter, there is considerable variation in the spleen rates of villages, the rates ranging from 0 to 86 per cent (Table III). The area could be divided into two sections, the river-side section and the interior section. In the former section, the spleen

rates are uniformly low, the average spleen rate of 8 villages surveyed being 4·7 per cent. In the interior section, on the other hand, the incidence of malaria reaches hyperendemic level, the average spleen rate of 11 villages surveyed being 57·4 per cent. There is no marked difference in the levels of the two sections but the difference in malarial endemicity could be ascribed to the same factors as in Champadanga, namely that the high flood level in the Damodar raises the water table in the river-side section of Tarkeswar thus reducing the endemicity of malaria there, while the interior section which is not influenced by the river partly because of its distance and partly due to the presence of a drainage channel, has a high incidence of malaria.

4. *Haripal area.*—Haripal area, situated to the east of Tarkeswar, could be divided into two sections by a line running north and south from a point to the east of Haripal Railway Station. The section to the west of this line is contiguous to the hyperendemic zone of Tarkeswar and shows a high incidence of malaria, the average spleen rate of 13 villages being 59·4 per cent (Table IV). The average spleen rate of 23 villages constituting the eastern section is 18·3 per cent. Considered from the physical features, the western section is high lying and dry, while the eastern section is lower in level and contains many low pockets. Within the latter section itself, there occurs a progressive decline in the level of the land surface in an easterly direction towards the low pockets at the border of the area. As one proceeds eastwards from Haripal Railway Station, the spleen rates of the villages decline correspondingly reaching a low figure (below 10 per cent) near the eastern border.

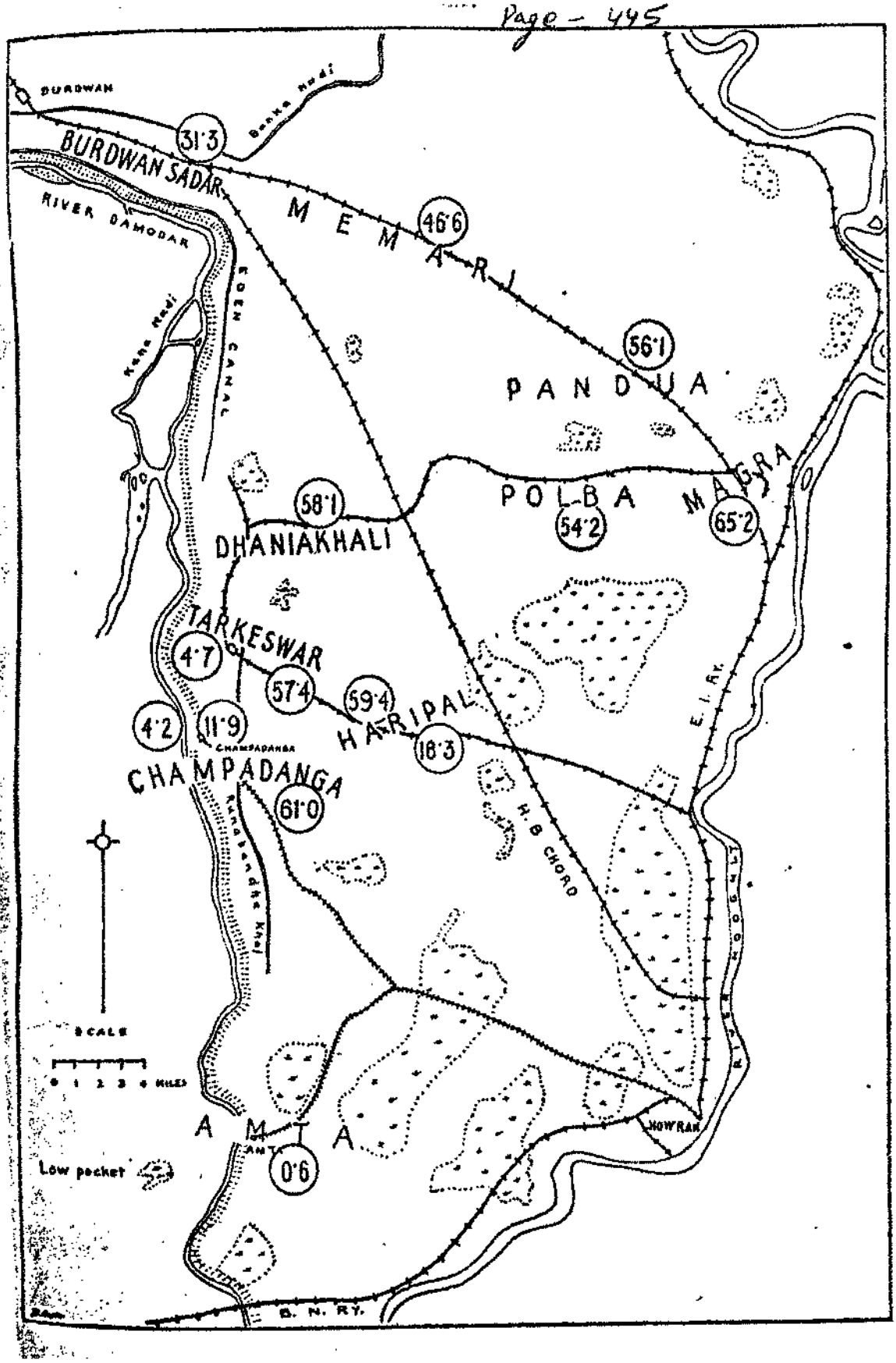
5. *Dhaniakhali area.*—This area situated to the north-east of Tarkeswar is comparatively elevated and dry. The spleen rates of 30 villages examined here range between 29 and 92 per cent (Table V), the average being 58·1 per cent. The majority of the villages in this area have hyperendemic malaria.

6. *Polba area.*—The Polba area situated to the east of Dhaniakhali is similar in character to the latter. The spleen rates of villages in this area are uniformly high except for a few villages in the south-eastern section which have comparatively lower spleen rates. The average spleen rate for 27 villages surveyed (Table VI) is 54·2 per cent.

7. *Pandua area.*—Pandua area situated to the north of Polba is also uniformly dry. The spleen rates of the villages here are high, the average for 62 villages surveyed (Table VII) being 56·1 per cent. In the majority of the villages, malaria is hyperendemic. A few villages situated in the vicinity of low pockets and 'beels' show comparatively lower spleen rates.

8. *Magra area.*—This area lies to the east of Polba and Pandua. Only a small area consisting of three villages was included in this investigation (Table VIII). The general incidence of malaria in this area appears to be high, the spleen rates of the three villages examined being 31, 83 and 81 per cent respectively.

9. *Memari area.*—This area lies between the Pandua area to the east and Burdwan-Sadar area to the west. The average spleen rate of 70 villages surveyed (Table IX) is 46·6 per cent. The incidence of malaria in this area is high, though slightly lower than that observed in the Pandua and Polba areas which adjoin it on the east and south respectively. There are some isolated


BURDWAN
BURDWAN SADAR
RIVER DAMODAR
MEMARI
PANDUA
POLBA
MAGRA
DHANIAKHALI
TARKESWAR
HARIPAL
CHAMPADANGA
AMTA
HOWRAH
B. N. RY.
E. I. RY.
H. B. CHORD
SCALE
Low pocket
31·3
46·6
56·1
58·1
54·2
65·2
4·7
57·4
59·4
4·2
11·9
18·3
61·0
0·6

depressions in the Memari area, and villages situated close to such depressions have lower spleen rates than those situated further away.

10. *Burdwan-Sadar area.*—This area is situated to the west of Memari. From the point of view of levels, this area is higher in elevation than any of the other areas surveyed. It is situated close to the River Damodar and is traversed by several canals such as the Banka and the Eden Canals which are connected with the Damodar and which bring in flood water from the river. The average spleen rate of 15 villages surveyed (Table X) is 31·3 per cent, which is lower than the average for Memari.

DISCUSSION OF THE FINDINGS.

The area investigated is flat and deltaic. The variations in the level of the land are not very marked but the northern and central parts are more elevated than the southern and the south-eastern areas. The former areas have facilities for natural drainage and are, in consequence, comparatively dry and free from large marshes or extensive low pockets capable of holding water during the rainy season. The opposite conditions prevail in the southern and south-eastern areas which are low in level, lack facilities for natural drainage, have large marshes and extensive low pockets that hold water for several months during the rainy season and are, in consequence, wet.

The elevated and dry areas show a high incidence of malaria which often reaches the hyperendemic level. The average spleen rates in such areas range between 47 and 65 per cent. The low-lying wet areas have a low incidence of malaria. The Amta area with an average spleen rate of 0·6 per cent is an example of a low-lying area being practically free from malaria. In Haripal the contrast between the western elevated section and the eastern low-lying section as regards the incidence of malaria is striking. In the former the average spleen rate is 59·4 per cent whereas the figure for the latter is 18·3 per cent. Even within the eastern section of Haripal, there occurs a progressive fall in the local malarial endemicity associated with the decline in the level of the land surface.

These findings are in conformity with observations made elsewhere in deltaic Bengal (Iyengar, 1929). In the Damodar-Hooghly Valley as in other parts of the deltaic region, the level of the ground surface has a considerable influence on malarial endemicity, high areas having a high incidence of malaria and low-lying areas having little or no malaria.

The ultimate factor that determines malarial endemicity has been shown to be the depth of the water table during the rainy season (Iyengar, 1942 and 1944). The occurrence of a high water table in a deltaic area is unfavourable to the extensive breeding of *A. philippinensis*, the local vector of malaria, the amount of breeding varying directly with the distance of the water table from the ground surface. Since, ordinarily, the water table in the elevated area is at some distance from the ground surface while in low-lying areas the opposite conditions prevail, these facts offer a reasonable explanation for the varying incidence of malaria in the elevated and the low-lying tracts of deltaic Bengal.

Nevertheless, the incidence of malaria in elevated tracts may be considerably modified by the influence of factors which tend to raise the water table, such as,

(1) the influx of water, either surface or subsoil, and (2) the impounding of w due to unsatisfactory natural drainage. If these factors be operative du the breeding season of *A. philippinensis* (which is from July to Septem the breeding incidence of the vector mosquito would be reduced and mala incidence lowered. Instances of such conditions were encountered in the Damod Hooghly Valley and are recounted below.

In Champadanga, the eastern river-side section is practically on the same le as the adjoining interior section. The level of the land surface as well as economic conditions being practically the same in both sections, one would norma have expected a more or less equal incidence of malaria in the two sections Champadanga. This however is not the case and the two sections differ marke in this regard. In the river-side section, the incidence of malaria is low, the aver spleen rate being 11·9 per cent. In the interior section on the other hand, th is hyperendemic malaria, the average spleen rate being 61·0 per cent.

Similar conditions prevail in the Tarkeswar area which adjoins Champadan to the north. The average spleen rate of villages in the river-side section Tarkeswar is as low as 4·7 per cent whereas in the interior section, the avera spleen rate is 57·4 per cent. The incidence of malaria as well as that of *A. phili pinensis* are thus high in the interior section and low in the river-side sectio As already explained, the low incidence of malaria in the river-side sectio of these two areas is due to the peculiar conditions prevailing here, namely, t raising of the water table through the subsoil flow of water from the Damod when it rises high in flood. It is reasonable to presume that, but for this facto the two sections would have shown an equal degree of malarial endemicity.

The Burdwan-Sadar area furnishes another example of the effect of influ of water on malarial incidence. This area is higher in level than any of the oth areas investigated and would normally be expected to have a very high incidenc of malaria. The average spleen rate for this area (i.e., 31·3 per cent) is howeve appreciably lower than the rates for other elevated areas, such as Memari, Pandua Polba and Dhaniakhali. The Burdwan-Sadar area adjoins the Damodar and i traversed by several distributaries such as the Banka and the Eden Canals whic bring in flood water from the Damodar. The influx of water through these canal helps in causing a rise in the water table to some extent, this accounting for th lower incidence of malaria in this area in comparison with other elevated areas i the Damodar-Hooghly Valley.

Even in the elevated zones with hyperendemic malaria, villages situated near large *beels* or marshes usually have comparatively low spleen rates, as for example the *beel*-side villages in Pandua and Memari. Storm water held up in these *beels* raises the water table in villages situated close to them thereby lowering the local incidence of malaria, the final effects depending on the size of the depression and the quantity of water retained.

THE PROPOSED FLOOD-FLUSH SCHEME.

The proposed Damodar-Hooghly Flood-flush Scheme envisages the construction of a barrage across the Damodar at Sadarghat near Burdwan Town, a canal to take off the flood water from the river, a system of distributaries to supply the flood water to different parts of the commanded area and drainage channels to

remove excess of water and to drain low-lying areas. The purpose of the scheme is to improve agriculture through irrigation, to enrich the soil with river silt, and to increase the area under cultivation by irrigating areas that lack sufficiency of water and draining low-lying areas which are hitherto out of cultivation on account of excess of water.

Although the scheme is meant primarily for agricultural improvement, the designers state that the scheme would at the same time control the incidence of malaria by reducing the extent of mosquito breeding. This opinion is based on the belief that (1) silt-laden water has a larvicidal effect, (2) Carp-fry introduced with river water would eat up mosquito larvæ, and (3) the current of water produced will have a deterrent effect on mosquito breeding.

These claims cannot be substantiated. We know little about the supposed larvicidal properties of silt-laden water. Even assuming that water heavily charged with silt in suspension has some larvicidal action, it is unlikely that silt will remain in suspension long enough and in sufficient concentration to be effective, especially after the flood water has passed through long lengths of distributaries and been diluted with clean water from other sources. Carp-fry are not known to be larvivorous. Even in regard to the species of fish that are definitely larvivorous, they have been found to be of little practical utility in the control of rural malaria, when not combined with other measures. As regards the deterrent effect of water current, it would be impossible in a flat country like the one under discussion to maintain in all the distributaries and the fields a velocity of water that would be sufficient to deter mosquito breeding. In fact, over a large part of the area, there would be practically no flow of water. Lastly, none of these factors can have any effect on the principal breeding places of the local vector mosquito, *A. philippinensis*, which are confined to the ponds in and near villages.

Although the reason put forward by the designers of the scheme are untenable, it is nevertheless anticipated that the proposed project of flood irrigation would tend to reduce the incidence of malaria by raising the water table through the introduction of excess water. This opinion is based on the results of the present survey and the previous observations which show that the occurrence of a high water table during the wet season is unfavourable to the extensive breeding of *A. philippinensis*, the main malaria carrier in the area under discussion.

In order to derive the fullest benefit from the proposed scheme, however, the following precautions should be taken: (1) The distributaries should be so designed as to produce a marked raising of the water table in as large an area as possible, especially in those areas where malaria incidence is high. (2) In view of the importance of maintaining a high water table during the wet season, the distributaries should run full bore throughout the rainy season, irrespective of the requirements of the crops. (3) The proposed drainage system should be so designed as to drain only the surplus water and not effect any marked lowering in the level of the water table. (4) No attempt should be made to drain away any of the existing low pockets with a view to bringing them under cultivation and the wet season level of water in such pockets should not be lowered below the wet season levels prevailing at the present time. For increasing the area under cultivation efforts should, on the other hand, be concentrated on irrigating the high-lying areas which at present are not suitable for cultivation due to lack of water.

If these safeguards are incorporated in the proposed scheme, it is felt that scheme would most successfully reduce the incidence of malaria in this tract.

SUMMARY.

1. The results of the malaria survey of the deltaic tract constituting the a of the proposed Hooghly-Damodar Flood-flush Scheme are given.

2. Villages situated on comparatively elevated land are highly malaric while those occurring in the low-lying areas are, as a rule, free from malaria. T degree of malaria incidence in this area is related to the depth of the water ta during the rainy season A high water table brought about by lack of natu drainage or by rise in the flood level of the adjoining river or by the influx irrigation water tends to lower the incidence of malaria.

3. The proposed flood and flush scheme should produce a reduction malaria provided certain safeguards detailed in the text are incorporated in t scheme. This reduction will not, however, be caused by the larvicidal effect the silt-laden water or the larvivorous activities of the Carp-fry or the deterre action of flowing water, but by the raising of water table which in turn reduces t breeding incidence of *A. philippinensis*, the local vector of malaria in this area.

REFERENCES.

IYENGAR, M. O. T. (1929) ... Malaria survey of part of Lower Bengal Delta. *Trans. F. E. A. T. M.*, 7th Congress, India, Dec. 1927, **2**, pp. 684–694.

Idem (1939) ... A year's work on dissection of Anopheles for natural malarial infection. *Jour. Mal. Inst. Ind.*, 1, **2**, pp. 105–109.

Idem (1942) ... Studies on malaria in the deltaic region of Bengal. *Ibid.*, 4, **4**, pp. 435–446.

Idem (1944) ... Problems relating to malaria control in deltaic Bengal. *Ibid.*, 4, **5**, pp. 435–477.

SUR, P. (1934) ... ... In Iyengar, 1942.

TABLE I.

Spleen rates of villages in Amta area (Howrah District).

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
I. *Area, west of the Damodar.*—			
1. Benola	37	0	0·0
2. Kristobati	75	0	0·0
3. Nischintapur	62	0	0·0
4. Thalia	102	0	0·0
5. Mainan	116	0	0·0

TABLE I—*contd.*

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
6. Khorap	168	2	1·2
7. Seaghori	74	0	0·0
8. Dhaipur	107	0	0·0
9. Kalbash	122	0	0·0
10. Betai	87	0	0·0
11. Jinity	122	0	0·0
12. Bar Gajipur	108	0	0·0
13. Paschim Gajipur	113	0	0·0
14. Naopara	155	0	0·0
15. Mahishamuri	92	0	0·0
16. Tajpur	272	0	0·0
II. *Area, east of the Damodar.*—			
17. Bhojan	95	0	0·0
18. Talsheara	28	0	0·0
19. Rashpur	114	0	0·0
20. Kamaria	118	0	0·0
21. Kalikata	148	0	0·0
22. Someswar	112	0	0·0
23. Santoshnagar	82	0	0·0
24. Bolai Majhi	26	0	0·0
25. Kansra	127	2	1·6
26. Uttar Ramchandrapur ...	102	0	0·0
27. Baneswarpur	58	0	0·0
28. Kurit	130	2	1·5
29. Anrula	167	0	0·0
30. Balarampur	20	0	0·0
31. Kotalpara	56	0	0·0
32. Bara Mayra	103	1	1·0

TABLE I—*concld.*

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
33. Chakpota	138	0	0·0
34. Chhota Mayra	77	0	0·0
35. Maderia	73	0	0·0
36. Jagannathpur	72	0	0·0
37. Balipota	27	0	0·0
38. Malogram	95	0	0·0
39. Jotkalyan	42	0	0·0
40. Sariala	73	0	0·0
41. Sirajbati	44	0	0·0
42. Harispur	116	5	4·3
43. Dadpur	52	9	17·3
44. Ramdebpur	96	4	4·2
45. Ramchandrapur	119	0	0·0
46. Panpur	102	0	0·0
47. Islampur	132	0	0·0
48. Chandrapur	122	0	0·0
49. Chatra	107	1	0·9
50. Ghoshpur	102	1	1·0
51. Bhandargacha	127	0	0·0
52. Mahisgoth	122	0	0·0
53. Muktirchak	66	1	1·5

TABLE II.

Spleen rates of villages in Champadanga area (Hooghly District).

Name of village.	Number of children examined.	Number with enlarged spleen.	Spleen rate, per cent.
I. *River-side section, west of the Damodar.*—			
1. Rasulpur	50	2	4·0
2. Saiyadpur	73	0	0·0
3. Jangalpara	112	6	5·4
4. Rautara	58	0	0·0
5. Dhapdhara	92	0	0·0
6. Persura	142	10	7·0
7. Harihar	43	0	0·0
8. Serampur	90	13	14·4
9. Balarampur	57	0	0·0
10. Haitamchak	47	6	12·8
11. Sundaresh	52	0	0·0
12. Akri	24	0	0·0
13. Parangri	37	4	10·8
14. Fatehpur	49	2	4·1
II. *River-side section, east of the Damodar.*—			
15. Keshabchak	80	5	6·3
16. Talpur	124	4	3·2
17. Lashkarpur	72	4	5·6
18. Magra	63	2	3·2
19. Muktarpur	96	10	10·4
20. Astara	103	1	1·0
21. Champadanga	125	20	16·0
22. Akargaria	58	8	13·8
23. Shahchak	54	12	22·2
24. Par Srirampur	27	10	37·0

TABLE II—*concld.*

Name of village.	Number of children examined.	Number with enlarged spleen.	Spleen rate, per cent.
25. Bhupati Chak	25	5	20·0
26. Beramul	26	4	15·4
27. Ramnagar	74	24	32·4
28. Hossainchak	16	4	25·0
29. Tajpur	31	3	9·7
30. Binogram	63	2	3·2
31. Ranabadh	32	0	0·0
32. Naiti	62	5	8·1
33. Timne	21	2	9·5
34. Nanur Chak	24	1	4·2
35. Rasidpur	31	1	3·2
III. *Interior section on east.*—			
36. Jagannathpur	14	10	71·4
37. Payratungi	20	9	45·0
38. Khudirampur	23	12	52·2
39. Belbandh	24	6	25·0
40. Darbeshpur	17	13	76·5
41. Nabina	18	15	83·3
42. Dharaspur	12	10	83·3
43. Gobra	16	11	68·8
44. Binodbati	10	6	60·0
45. Chhanapur	46	20	43·5
46. Baja Pultae	18	9	47·4
47. Gangarambati	19	15	83·3
48. Ayma Paharpur	21	16	76·2
49. Basara	19	11	57·9
50. Goborhara	31	13	41·9

TABLE III.

Spleen rates of villages in Tarkeswar area (Hooghly District).

Name of village.	Number of children examined.	Number with enlarged spleen.	Spleen rate, per cent.
I. *River-side section.*—			
1. Tegnari	65	0	0·0
2. Anandpur	107	3	2·8
3. Gauribati	70	0	0·0
4. Howli	65	5	7·7
5. Bhimpur	82	2	2·4
6. Kalaikunda	72	2	2·8
7. Jotsambhu	46	4	8·7
8. Ramnagar	207	27	13·0
II. *Interior section.*—			
9. Dhulian	53	18	34·0
10. Sante	124	24	19·4
11. Baidyapur	172	92	53·5
12. Nirapur	184	96	52·2
13. Madhupur	39	12	30·8
14. Ghoshpur	32	26	81·2
15. Balgarh	150	114	76·0
16. Baghbari	98	84	85·7
17. Kanaipur	60	40	66·7
18. Gopedanga	39	23	59·0
19. Jaynagar	208	151	72·6

TABLE IV.

Spleen rates of villages in Haripal area (Hooghly District).

Name of village.	Number of children examined.	Number with enlarged spleen.	Spleen rate, per cent.
I. *Western high-lying section.*—			
1. Dullo	196	141	71·9
2. Narayanpur	274	202	73·7
3. Kaikala	138	73	52·9
4. Chautara	69	44	63·8
5. Mohanbati	46	24	52·2
6. Krishtopur	104	70	67·3
7. Baramba	42	19	45·2
8. Hora	106	46	43·4
9. Jamaibati	68	56	82·4
10. Dakshin Ghantra	30	12	40·0
11. Basudebpur	120	60	50·0
12. Sadarpur	26	20	76·9
13. Santipur	49	26	53·1
II. *Eastern low-lying section.*—			
14. Bamanpara	78	28	35·9
15. Hamragachi	27	6	22·2
16. Aminpur	30	5	16·7
17. Raghubati	70	23	32·9

TABLE IV—*concld.*

Name of village.	Number of children examined.	Number with enlarged spleen.	Spleen rate, per cent.
18. Meley	168	28	16·7
19. Ramchandrapur	39	15	38·5
20. Gopinagar	60	5	8·3
21. Pitlay	29	12	41·4
22. Gazipur	110	30	27·3
23. Dakshinkul	50	10	20·0
24. Baganbari	84	9	10·7
25. Bandipur	197	51	25·9
26. Nabishyampur	63	15	23·8
27. Jadabbati	62	7	11·3
28. Chaulpara	36	14	38·9
29. Pacha	55	9	16·4
30. Nabasan	30	2	6·7
31. Naupara	107	10	9·3
32. Jagannathpur	75	3	4·0
33. Krishtobati	105	8	7·6
34. Shahpur	95	0	0·0
35. Keshabnagar	49	2	4·1
36. Inayatpur	53	1	1·9

TABLE V.

Spleen rates of villages in Dhaniakhali area (Hooghly District).

Name of village.	Number of children examined.	Number with enlarged spleen.	Spleen rate, per cent.
1. Talbona	65	29	44·6
2. Simla	138	108	78·3
3. Kamalpur ...	102	56	54·9
4. Banpur	49	23	46·9
5. Brahmanpara	99	63	63·6
6. Gothpur	42	17	40·5
7. Anantapur ...	42	12	28·6
8. Haripur	84	42	50·0
9. Mahmudpur ...	61	34	55·7
10. Ala	65	32	49·2
11. Jadupur	14	11	78·6
12. Payesa	65	23	35·4

TABLE V—*concld.*

Name of village.	Number of children examined.	Number with enlarged spleen.	Spleen rate, per cent.
13. Mirzanagar ...	60	22	36·7
14. Inayatnagar ...	20	16	80·0
15. Akkabbapur ...	84	44	52·4
16. Brindabanpur ...	40	25	62·5
17. Kalikapur ...	13	12	92·3
18. Samaspur ...	180	108	60·0
19. Ghanashyampur ...	54	38	70·4
20. Chautara ...	75	30	40·0
21. Bhagavanpur ...	102	48	47·1
22. Rameswarbati ...	294	228	77·6
23. Melki	48	38	79·2
24. Kutubpur ...	19	12	63·2
25. Kantalgaria ...	60	36	60·0
26. Narayanpur ...	65	45	69·2
27. Baje Shahpur ...	18	6	33·3
28. Kagjipara ...	26	18	69·2
29. Paramba	90	53	58·9
30. Shahbazar ...	42	27	64·3

TABLE VI.

Spleen rates of villages in Polba area (Hooghly District).

Name of village.	Number of children examined.	Number with enlarged spleen.	Spleen rate, per cent.
1. Kunchapala ...	86	61	70·9
2. Baladpur ...	43	24	55·8
3. Goai	128	78	60·9
4. Amra	209	119	56·9
5. Akna	94	26	27·7
6. Malpara	48	10	20·8
7. Meghsar	137	49	35·8
8. Dhomarpur ...	102	66	64·7
9. Satithan	162	129	79·6
10. Nanipur	43	19	44·2
11. Dampur	119	56	47·1
12. Sitlay	87	78	89·7
13. Sherpur	15	10	66·7
14. Solagarh	51	27	52·9
15. Jagannathpur ...	63	45	71·4
16. Bakkeswar ...	36	22	61·1
17. Deulpara ...	22	12	54·5
18. Hanopara ...	32	12	37·5
19. Haur	76	64	84·2
20. Memari	50	20	40·0
21. Sikta	98	72	73·5
22. Nagbal	71	40	56·3
23. Dadpur	35	17	48·6
24. Nabagram ...	40	4	10·0
25. Dighansar ...	99	51	51·5
26. Barul	66	36	54·5
27. Katali	33	15	45·5

TABLE VII.

Spleen rates of villages in Pandua area (Hooghly District).

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
1. Punajgarh ...	86	20	23·3
2. Digha	149	128	85·9
3. Dwarbasini ...	348	220	63·2
4. Garaigera ...	12	4	33·3
5. Gomakbati ...	39	29	74·4
6. Alasin	33	27	81·8
7. Pataldanga ..	44	14	31·8
8. Dakshin Sultangacha	36	24	66·7
9. Jaer	81	59	72·8
10. Chaka	25	16	64·0
11. Daspara	13	9	69·2
12. Boragarh ...	46	38	82·6
13. Berela	99	51	51·5
14. Dantchar ...	71	37	52·1
15. Hatni	94	43	45·7
16. Panpara	35	21	60·0
17. Telkopa	34	16	47·1
18. Sodpara	36	30	83·3
19. Chetua	35	16	45·7
20. Bhopur	35	17	48·6
21. Batka	53	28	52·3
22. Bainchi	183	70	38·3
23. Chine	35	19	54·3
24. Goara	80	38	47·5
25. Champahati ...	26	18	69·2
26. Arti	42	33	78·6

TABLE VII—*contd.*

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
27. Ranagaria ...	78	23	29·5
28. Patra	51	26	51·0
29. Kulipukur ...	69	32	46·4
30. Shekpukur ...	47	20	42·6
31. Khirkundi ...	51	26	51·0
32. Matukpur ...	43	26	60·5
33. Marsit	41	27	65·9
34. Simlagar	62	36	58·1
35. Tinne	56	22	39·3
36. Dangalpara ...	44	22	50·0
37. Torgram	41	26	63·4
38. Kantagaria ...	22	10	45·5
39. Jagannathpur ...	22	12	54·5
40. Ilampur	56	26	46·4
41. Thaipara ...	57	30	52·6
42. Botgram ...	48	27	56·3
43. R k i	65	30	46·2
44. Sarai	62	41	66·1
45. Pandua	79	60	75·9
46. Berui	64	45	70·3
47. Neala	42	22	52·4
48. Tamba	50	24	48·0
49. Saibona	6	5	83·3
50. Chhirpala ...	25	16	64·0
51. Daulatpur ...	32	17	53·1
52. Kalisanra ...	37	20	54·1

TABLE VII—*concld.*

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
53. Chandrahati ...	36	25	69·4
54. Champta ...	64	33	51·6
55. Abira	43	21	48·8
56. Khannyan ...	194	94	48·5
57. Muldi	52	26	50·0
58. Dhamasin ...	50	19	38·0
59. Mandaran ...	70	32	45·7
60. Itachoona ...	35	13	37·1
61. Makhaldihi ...	52	34	65·4
62. Matabpur ...	23	17	73·9

TABLE VIII.

Spleen rates of villages in Magra area (Hooghly District).

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
1. Sheikpara ...	35	11	31·4
2. Puranpota ...	12	10	83·3
3. Gajaghanta ...	42	34	81·0

TABLE IX.

Spleen rates of villages in Memari area (Burdwan District).

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
1. Bhaita	115	39	33·9
2. Palsit	20	7	35·0
3. Karanda	27	12	44·4
4. Shekpur	42	7	16·7
5. Belut	58	18	31·0
6. Daluibazar ...	49	19	38·8
7. Paschim Tajpur ...	42	16	38·1
8. Ullara	49	17	34·7
9. Paikpara ...	42	20	47·6
10. Baje Rasulpur ...	35	17	48·6
11. Rajpur	32	15	46·9
12. Telsanra	56	26	46·4
13. Sahanmi	96	44	45·8
14. Keja	83	61	73·5
15. Chaknara ...	36	15	41·7
16. Baidyadanga ...	44	17	38·6
17. Jotkanu	38	24	63·2
18. Shahapur ...	14	2	14·3
19. Genraghata ...	36	6	16·7
20. Nagarkona ...	43	7	16·3
21. Rasalpur ...	28	9	32·1
22. Nim	69	18	26·1
23. Tatalpur	45	19	42·2
24. Kantalgachi ...	84	44	52·4
25. Deuli	58	33	56·9
26. Salda	65	45	69·2

TABLE IX—*contd.*

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
27. Sultanpur ...	26	6	23·1
28. Gopinathpur ...	40	23	57·5
29. Brahmanpara ...	50	28	56·0
30. Dakshin Radhakantapur.	71	41	57·7
31. Amadpur ...	142	65	45·8
32. Bijra	160	85	53·1
33. Ishampur ...	34	23	67·6
34. Mero	25	13	52·0
35. Durgadanga ...	53	5	9·4
36. Ichapur	89	39	43·8
37. Khero	48	8	16·7
38. Kenna	98	62	63·3
39. Kailashpur ...	80	45	56·3
40. Dilalpur	40	20	50·0
41. Nundipur ...	110	40	36·4
42. Kalsi	62	20	32·3
43. Simla	54	32	59·3
44. Sonora	24	22	91·7
45. Choitkhanda ...	70	28	40·0
46. Shamnagar ...	44	22	50·0
47. Kantapur ...	48	28	58·3
48. Maglampur ...	44	19	43·2
49. Kishkindhya ...	36	14	38·9
50. Bagila	71	25	35·2
51. Krishnapur ...	35	18	51·4
52. Baharampur ...	65	38	58·5

TABLE IX—*concld.*

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
53. Bahabpur ...	60	30	50·0
54. Andur	39	19	48·7
55. Kabirpur ...	42	22	52·4
56. Talchina	42	21	50·0
57. Shashinara ...	59	23	39·0
58. Amudpur ...	44	24	54·5
59. Mubarakpur ...	32	19	59·4
60. Nishiragarh ...	63	36	57·1
61. Debipur	77	32	41·6
62. Dharmasimla ...	40	28	70·0
63. Punnyagram ...	69	39	56·5
64. Chaupinra ...	33	21	63·6
65. Gauripur ...	85	39	45·9
66. Jayrampur ...	27	15	55·6
67. Mandaljana ...	32	17	53·1
68. Nalsanra ...	50	32	64·0
69. Ghosh	44	17	38.6
70. Alipur	60	38	63·3

TABLE X.

Spleen rates of villages in Burdwan-Sadar area (Burdwan District).

Name of village.	Number of children examined.	Number with splenic enlargement.	Spleen rate, per cent.
1. Amra	56	16	28·6
2. Brahmanpara ...	63	26	41·3
3. Kundarsona ...	37	17	45·9
4. Belna	35	13	37·1
5. Barsul	100	30	30·0
6. Tatpara	68	32	47·1
7. Saktigarh ...	57	14	24·6
8. Santoshpur ...	21	1	4·8
9. Mollapara ...	10	0	0·0
10. Krishnapur ...	75	30	40·0
11. Sonakur	62	28	45·2
12. Pitundih	69	29	42·0
13. Konarpara. ...	27	6	22·2
14. Pingur	40	10	25·0
15. Dadpur	25	9	36·0

TABLE XI.

Area.	District.	Number of villages surveyed.	Number of children examined.	Number with splenic enlargement.	Gross spleen rate per cent.	Average spleen rate of villages.
1	2	3	4	5	6	7
1. Amta ...	Howrah	60	5,921	32	0·5	0·6
2. Champadanga ...	Hooghly	50	2,441	346	14·2	24·5
3. Tarkeswar ...	"	19	1,873	723	38·6	35·2
4. Haripal ...	"	36	2,940	1,086	36·9	33·1
5. Dhaniakhali ...	"	30	2,116	1,256	59·4	58·1
6. Polba ...	"	27	2,045	1,162	56·8	54·2
7. Pandua ...	"	62	3,639	2,010	55·2	56·1
8. Magra ...	"	3	89	55	61·8	65·2
9. Memari ...	Burdwan	70	3,623	1,798	47·0	46·6
10. Burdwan-Sadar ...	"	15	745	261	35·0	31·3

Indian Journal of Malariology, 1, 4, December 1947.

MALARIA AND SPLEEN RATE IN THE PUNJAB.

BY

KHAN BAHADUR M. YACOB, M.B., B.S., DT.P.H.
(*Director of Public Health, Punjab*),

AND

S. SWAROOP, M.A., Ph.D.
(*Statistical Officer, Punjab Public Health, Punjab*).

[July 18, 1947.]

IN a previous paper (Yacob and Swaroop, 1944), the authors described briefly the method which has been in use in the Punjab for the purpose of forecasting epidemics of malaria. It was mentioned that according to Gill (1928) the spleen rate was one of the factors to be taken into consideration for purposes of forecasting. This rate has been defined as the percentage of children between 2 and 10 years of age exhibiting palpable enlargements of the spleen.

As is well known, malaria is a disease in which man plays the part of a reservoir of infection, which exhibits objective signs in the shape of spleen enlargement, associated with or closely following an attack of malaria. Perhaps this fact was recognized ever since the existence of malarial fever was established by clinical tests and this knowledge has not been confined to the medical profession alone. In the Punjab, malaria has been familiar even to an ignorant Punjabi peasant as *tilli tap* or the 'spleen fever'. There is no doubt that the discovery of the malarial parasite has thrown new light on the epidemiology of malaria but the value of the spleen rate as an index of malarial endemicity has not thereby been minimized.

Although the severity of an epidemic of malaria is well indicated by a rise of the spleen rate, the incidence of the enlargement of spleen is not evenly distributed amongst all classes and all age groups. It has been observed that at the close of an epidemic of malaria, other things being equal, the spleen rate among the less well-to-do classes is relatively high (Gill, 1928). This suggests that economic conditions may be playing some part in the variation of spleen rate. It has been argued that the poorer section of the population may live in villages or outskirts of towns and because of relatively high anopheline infestation in such areas may be

more exposed to infection than the well-to-do living in the interior. But Gill has expressed the opinion that this factor alone is not sufficient to account entirely for the high spleen rate in the poorer classes. Further, a sudden rise of the spleen rate in consequence of an epidemic of malaria is relatively greater among children of two and three years of age, and this relative increase gradually declines with the increase of age up to the age of ten.

SEASONAL AND INTER-EPIDEMIC VARIATION IN THE SPLEEN RATE.

An important observation is that a rise in spleen rate is followed by a material reduction and that conspicuous fluctuation over a series of years is a characteristic feature of the spleen rate in the Punjab. This is well illustrated by two curves in Chart 1 showing separately the spleen rates for the Punjab estimated in the months of June and November of each year from 1914 to 1943.

During each year the first objective sign of an impending epidemic is a slight increase of sickness which generally takes place during the first week of September and rising rapidly reaches its maximum towards the first week of October. The decline is slow and the curve returns to its normal position about the end of January. The spleen rate curve rises slowly and attains its maximum peak about the middle of November.

During malaria epidemics the spleen rate is known to rise suddenly and, thereafter, it undergoes a slow but steady decline until at the end of about 4 to 5 years it may again become stabilized at approximately its original level.

Behaviour of the spleen rate from year to year varies in different areas. In some it may remain permanently high after an epidemic of malaria or may exhibit only minor oscillations while, in others, a decline to a remarkably low level may occur. Gill (*loc. cit.*) is of the opinion that famines or economic stress may be factors in determining the level of the spleen rate.

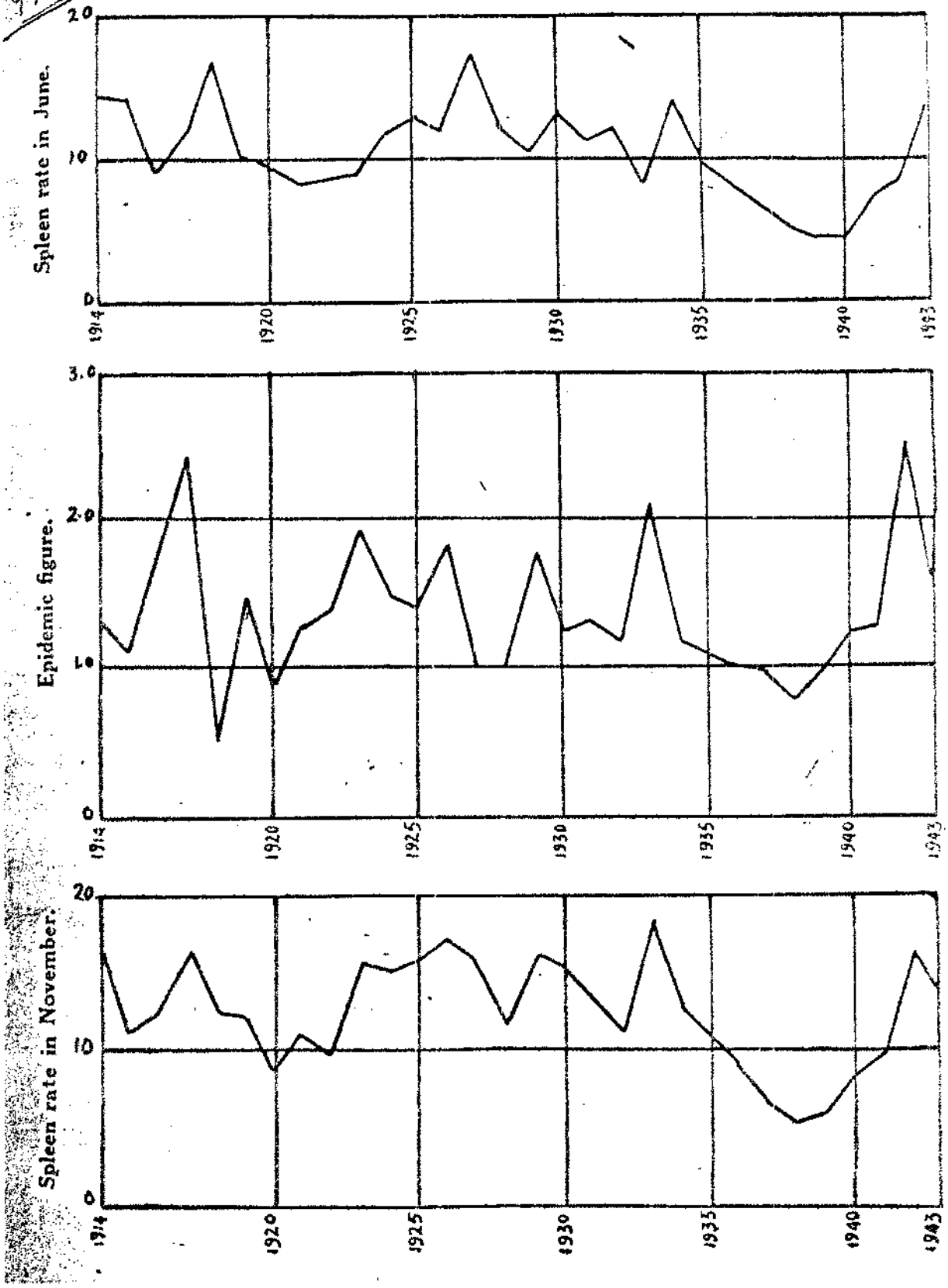
In areas where regional epidemics occur, the spleen rate exhibits great spontaneous fluctuations over a series of years and in such areas an extremely low spleen rate is compatible with the subsequent occurrence of epidemics of malaria of great intensity. The post-epidemic period is succeeded by inter-epidemic periods of variable duration during which the spleen rate remains at or near its pre-epidemic level (Gill, *loc. cit.*).

PROCEDURE FOLLOWED FOR ESTIMATING SPLEEN RATES IN THE PUNJAB.

It was in the year 1913 that arrangements for the carrying out of a spleen census in all male school children under ten years of age attending primary and secondary schools in certain selected areas throughout the province were decided upon. This scheme provided for the estimation of the spleen rate twice a year; first in June, i.e., before the onset of the malaria season, and again in November, i.e., towards the conclusion of the epidemic. The examination is carried out by the medical officers in charge of hospitals or dispensaries. A fuller discussion of the scheme has been given by Gill (1915) who considered that since school children bear a roughly constant relationship to its population this school population provided a representative data for purposes of comparison. Uniformity of procedure has

CHART I.

Chart showing the annual epidemic figures and spleen rates in June and November in the Punjab during the period 1914 to 1943.



been ensured by issuing detailed instructions to the medical officers conducting the census. These instructions are given in Appendix I. It will be seen that a special notation has been devised for recording the degree of enlargement of spleen. The Punjab Government have sanctioned the grant of a small allowance to each medical officer appointed to conduct the examination. On an average 68,000 children attending 490 schools in 260 localities are examined each year.

This scheme of spleen census has been followed in the Punjab for more than three decades, and may well 'claim to be one of the most comprehensive attempts that have hitherto been made to determine upon systematic lines the distribution and relative intensity of malaria in a large area over a long period of time' (Gill, 1928).

In regard to the degree of reliance that may be placed upon the spleen rates estimated in this manner we may quote the following views of Gill (1928):—

'In the first place since malaria is the only common cause of enlargement of the spleen in the Punjab, it is permissible to regard the spleen rate as affording a rough index of the incidence of malaria. Secondly, there is reason to believe that the figures may be accepted as roughly accurate, since the results pertaining to selected schools in many districts have frequently been checked and only in rare instances has an appreciable error been detected; but of greater significance, as being more comprehensive, is the fact that a study of the character of the "spleen composition", which S. R. Christophers has shown to be a function of the spleen rate renders it possible to exclude the occurrence of serious inaccuracies in the figures. Finally, the regular manner in which the spleen rate over wide areas has varied during the past thirteen years, provides independent evidence pointing to the conclusion that the figures represent, with approximate accuracy, the true incidence of splenic enlargement amongst the particular section of the community selected for examination.'

The examining officer remains seated facing the children. Each child comes forward in turn and stands between the knees of the observer, leans slightly forward. The observer's right hand is then passed with a light touch under the left costal arch of the child. The details of the examination are recorded by the medical officer in Schedules A and B prescribed by the Director of Public Health, Punjab (Appendices II and III). When all the children of a school have been examined, the medical officer completes Schedules A and B and returns them, through the civil surgeon concerned, to the office of the Assistant Director of Public Health, Punjab, Epidemiology. The data are consolidated in the form reproduced below and spleen rates are calculated for each school, district and the province as a whole.

1.	Number of children attending the school					...	...
2.	Number of children examined				...	...	...
3.	Number with spleen of class			I	...	...	...
4.	,,	,,	,,	II	...	...	...
5.	,,	,,	,,	III	...	...	...
6.	,,	,,	,,	IV	...	...	...
7.	,,	,,	,,	V	...	...	...
8.	,,	,,	,,	VI	...	...	...
9.	,,	,,	,,	VII	...	...	...
	Spleen rate			...	...	...	...

It is proposed in this paper to examine the statistical significance of the recorded data regarding June and November spleen rates from the year 1914 to 1943 in respect of each district and for the province as a whole with special reference to the forecasting of malaria (Table I).

TABLE I.

Spleen rate in the Punjab in June and November of each year from 1914 *to* 1943.

Years.	Spleen rate in		Years.	Spleen rate in	
	June.	November.		June.	November.
1914	14·46	16·50	1929	10·58	16·28
1915	14·24	11·07	1930	13·23	15·55
1916	9·05	12·40	1931	11·25	13·02
1917	11·88	16·20	1932	12·32	11·08
1918	16·73	12·30	1933	8·27	18·53
1919	10·17	12·10	1934	14·38	12·80
1920	9·77	8·70	1935	9·81	10·80
1921	8·35	11·08	1936	8·19	9·20
1922	8·73	9·80	1937	6·96	6·72
1923	8·98	15·66	1938	5·38	5·32
1924	11·83	15·08	1939	4·60	6·03
1925	12·98	15·50	1940	4·70	8·49
1926	11·97	17·33	1941	7·51	9·46
1927	17·38	15·84	1942	8·68	16·20
1928	12·55	11·39	1943	14·22	13·63

ANALYSIS OF THE DATA.

Provincial figures.—In every malarial infection four factors are involved—

1. Human factor.
2. Parasite factor.
3. Mosquito factor.
4. Climatic factor.

The human factor must be considered not only from the point of view of the main recipient but also as disseminator for man is also the reservoir of infection. Malarial infection whether active or passive usually exhibits objective signs of its presence in the shape of enlargement of spleen. Gill's view is that 'a low spleen rate in the month of June, provided the other factors are favourable, is regarded, so far as communal immunity is concerned, as favourable to the occurrence of an epidemic during the ensuing autumn'. If this contention is to be accepted it should be possible to find some measure of negative correlation between spleen rate in the month of June and the incidence of malaria in the following autumn of the same year.

In Chart 1, the June and November spleen rates as well as the epidemic figure for each year have been plotted. These curves seem to suggest that years of high epidemic figure are followed by years in which a rise in spleen rate is recorded. Examples are the years 1917, 1923, 1926, 1929, 1933 and 1942. The coefficient

of correlation between the June spleen rate of any year and the epidemic figure of the previous year has been found to be as high as 0·7162, a figure statistically significant. Similarly, the coefficient of correlation between spleen rate in November and the epidemic figure of the same year is 0·6579, a highly significant figure. These correlations indicate that years of high malarial incidence lead to a rise in the spleen rate. But for purposes of forecasting we are interested in the relationship between the epidemic figure and the spleen rate estimated in some period prior to the occurrence of the epidemic. The coefficient of correlation between the spleen rate in June and the epidemic figure of the same year is found to be —0·1074, a relation hardly of any significance.

It is thus clear that a spleen rate census taken three months prior to the onset of the outbreak can hardly be used for purposes of forecasting the incidence.

Similarly, the coefficient of correlation between epidemic figure of any year and the spleen rate for the month of November of a previous year is —0·1002, again an insignificantly low figure which cannot be made the basis of forecasting.

Series of coefficients of correlation were worked out between the June or November spleen rates of years prior to the one for which the epidemic figure is considered. Table II shows the coefficients of correlation between the epidemic figure and the spleen rates in the months of June or November of successive previous years.

TABLE II.

Coefficients of correlation between epidemic figure and the spleen rate in June or November months of the preceding years.

Years in which spleen rate was estimated.	Coefficients of correlation between epidemic figure and the spleen rate in the month of	
	June.	November.
1. Same year in which epidemic figure is studied	−0·1074	+0·6579
2. One year previous to the epidemic figure year	−0·0114	−0·1002
3. Two years previous to the epidemic figure year	−0·0017	−0·0268
4. Three years previous to the epidemic figure year ...	−0·2013	−0·0592
5. Four years previous to the epidemic figure year	−0·3166	−0·3742
6. Five years previous to the epidemic figure year	−0·1201	−0·3677
7. Six years previous to the epidemic figure year	−0·0307	−0·1973
8. Seven years previous to the epidemic figure year ...	−0·2119	−0·1011
9. Eight years previous to the epidemic figure year ...	+0·2410	−0·1263
10. Nine years previous to the epidemic figure year	−0·2333	+0·2041

These values fail to provide any relation that could be utilized for purposes of forecasting.

It can, however, be argued that a low value of spleen rate for a single year alone may not be indicative of the possibility of epidemic outbreak but that low values for several years in succession may lead to a rise in the epidemic figure.

The epidemic figure for the province has, therefore, been correlated with spleen rates of one, two, three, etc., up to nine years together in previous years. The coefficients of correlation are shown below :

TABLE III.

Coefficients of correlation between epidemic figure and spleen rate in periods of varying duration.

	Spleen rate in	
	June.	November.
Spleen rate in one previous year	−0·0114	−0·1002
Spleen rate in two previous years	−0·0680	+0·3263
Spleen rate in three previous years	−0·0309	+0·2356
Spleen rate in four previous years	−0·1133	+0·1636
Spleen rate in five previous years	−0·2635	−0·0011
Spleen rate in six previous years	−0·1981	−0·0453
Spleen rate in seven previous years	−0·2147	−0·0871
Spleen rate in eight previous years	−0·2075	−0·0968
Spleen rate in nine previous years	0·1981	−0·1176

Once again none of the coefficients of correlation in Table III is statistically significant and cannot, therefore, be utilized for purposes of forecasting.

Partial coefficient of correlation was also tried as follows :—

1 denotes the spleen rate in June,

2 denotes rainfall in August,

3 denotes epidemic figure of the same year,

Zero order coefficients of correlation are shown below :

$$r_{12} = -0{\cdot}0293 \; ; \; r_{13} = -0{\cdot}1074 \; ; \; r_{23} = 0{\cdot}7940$$

From these $r_{13.2}$ has been found to be −0·1384, an insignificantly low figure. Thus, the partial correlation between spleen rate in June and epidemic figure, after the effect of rainfall is eliminated, is insignificant.

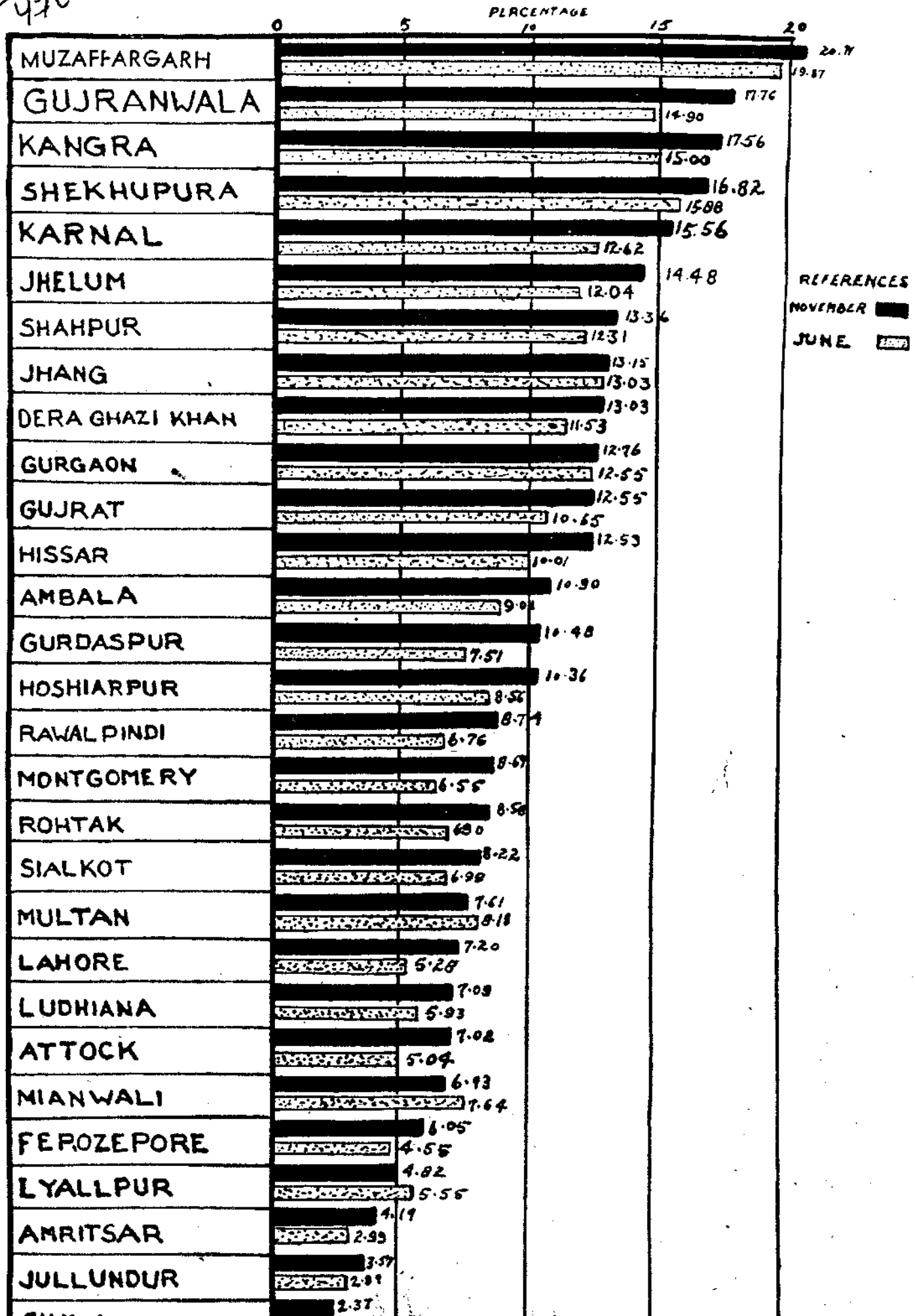
It is, therefore, concluded that for the province as a whole a knowledge of spleen rate before the onset of an epidemic of malaria fails to provide us with any information which could be utilized for purposes of forecasting outbreaks of malaria.

ANALYSIS OF DISTRICT FIGURES.

Spleen rates differ markedly not only from year to year but also from district to district. Variation from year to year is illustrated in Chart 1. The following bar diagram (Chart 2) shows the variation that exists among districts. For this diagram the mean spleen rates are worked out for the period 1935–1945, for each of the two months, viz., June and November, in which the spleen census was taken.

Reg. e-8 / 476

Spleen rates in the months of June and November in the districts of the Punjab during the period 1935 to 1945.



Spleen rate figures for each district are shown in Tables IV and V from 1914 to 1943.

TABLE IV.

Spleen rate in June of each year for each district of the Punjab from 1914 to 1943.

Years.	Hissar.	Rohtak.	Gurgaon.	Karnal.	Ambala.	Simla.	Kangra.
1914	11·00	...	20·10	20·00	11·40	...	25·60
1915	11·40	7·90	15·70	18·80	13·80	2·40	25·50
1916	6·70	8·70	11·60	11·30	13·30	2·60	26·50
1917	9·10	7·80	7·60	13·30	9·70	12·50	14·60
1918	9·80	7·04	14·06	8·50	12·01	14·70	14·20
1919	9·90	3·20	11·05	4·20	9·90	0·00	25·60
1920	11·20	4·90	29·80	9·40	11·20	1·40	15·80
1921	6·00	4·97	18·63	14·42	9·02	1·83	14·29
1922	5·90	10·10	12·50	19·02	11·80	1·04	17·80
1923	4·35	9·04	7·91	30·05	11·49	1·32	15·01
1924	16·49	13·16	8·14	52·72	13·91	0·60	14·81
1925	13·80	9·68	14·10	24·53	16·70	7·28	20·52
1926	14·04	22·45	9·32	39·16	15·20	4·43	15·53
1927	26·50	24·95	19·39	29·08	17·98	3·25	26·80
1928	22·30	22·63	24·71	12·94	17·24	3·69	31·61
1929	11·22	9·34	13·21	13·11	9·73	8·98	24·02
1930	13·85	6·08	10·36	7·34	7·52	0·75	23·70
1931	10·30	6·11	8·78	9·71	3·73	0·96	19·36
1932	14·13	8·55	11·66	11·92	6·82	0·82	29·89
1933	7·55	6·32	6·68	9·57	8·06	0·42	19·92
1934	9·46	11·95	15·13	14·86	9·47	2·69	19·48
1935	11·90	9·44	19·52	12·20	6·83	1·13	18·24
1936	13·20	10·10	27·53	13·86	7·50	1·71	15·09
1937	4·11	6·76	17·07	11·89	5·62	0·31	14·62
1938	3·02	2·74	10·35	10·01	6·62	0·34	14·89
1939	2·05	3·90	6·94	8·35	4·58	2·26	12·55
1940	1·64	2·26	5·25	19·39	9·71	2·53	17·66
1941	2·14	1·77	7·61	12·05	7·44	1·77	16·77
1942	2·78	2·49	1·43	3·65	4·88	2·74	14·73
1943	29·72	11·84	11·68	25·65	21·62	3·04	15·37

TABLE IV—*contd.*

Years.	Hoshiarpur.	Jullundur.	Ludhiana.	Ferozepore.	Lahore.	Amritsar.	Gurdaspur.
1914	17·20	12·10	5·20	4·10	5·40	9·50	5·70
1915	13·50	11·90	2·80	17·60	4·10	2·50	15·00
1916	15·10	13·60	0·73	4·60	1·80	1·20	6·30
1917	8·50	6·90	4·60	6·80	3·20	3·02	13·70
1918	10·70	5·90	5·40	10·70	4·90	12·60	19·20
1919	12·40	6·50	2·10	6·70	2·60	3·60	10·10
1920	12·40	9·50	2·90	9·50	1·70	3·10	11·80
1921	5·62	5·32	6·72	13·55	2·01	2·86	4·50
1922	8·01	1·60	5·20	8·30	1·90	3·20	7·20
1923	6·46	6·54	3·01	9·44	4·52	5·27	7·87
1924	8·65	7·11	5·98	13·28	7·02	10·30	12·65
1925	9·54	3·14	4·93	11·35	8·55	10·68	14·15
1926	9·22	2·93	6·92	7·35	9·33	12·61	14·56
1927	12·39	9·02	11·94	11·64	13·14	18·66	21·47
1928	10·01	3·34	7·86	11·27	10·85	11·99	16·57
1929	6·05	3·73	10·17	6·64	13·31	7·46	12·99
1930	7·73	3·13	4·83	8·60	11·62	6·47	14·40
1931	4·78	1·68	3·03	8·26	8·05	4·11	16·69
1932	8·35	2·85	7·20	9·50	17·13	7·14	19·70
1933	7·31	3·55	5·21	4·07	7·66	3·25	10·75
1934	12·24	3·99	7·39	4·86	8·95	5·42	16·03
1935	10·71	2·67	3·80	3·89	4·63	1·67	7·80
1936	9·64	3·12	4·19	4·45	3·49	1·46	6·80
1937	5·01	2·16	3·25	3·03	4·23	2·13	7·70
1938	5·78	2·93	2·48	3·27	2·62	3·03	8·59
1939	6·25	4·87	2·61	2·22	2·27	1·77	5·25
1940	6·94	0·62	4·28	2·94	2·81	2·34	3·19
1941	11·88	2·31	7·38	2·42	4·05	5·06	11·44
1942	9·57	1·76	8·32	4·27	6·22	2·33	7·51
1943	9·43	6·53	11·49	9·73	11·50	4·40	9·77

TABLE IV—*contd.*

Years.	Sialkot.	Gujranwala.	Sheikhupura.	Gujrat.	Shahpur.	Jhelum.	Rawalpindi.
1914	10·90	16·80	...	6·50	21·40	16·50	37·20
1915	8·00	17·30	...	15·10	20·00	12·60	25·60
1916	6·90	7·40	...	14·00	18·10	6·40	10·70
1917	4·30	22·10	...	38·10	20·40	16·80	9·60
1918	9·90	30·50	...	9·80	30·60	25·60	6·70
1919	6·70	11·50	...	6·80	18·20	12·40	3·80
1920	8·10	14·10	10·60	7·50	10·70	13·60	2·20
1921	7·27	11·41	5·69	5·19	6·47	6·83	8·78
1922	8·70	9·10	6·40	5·70	10·40	14·20	17·20
1923	6·61	8·05	7·57	7·67	4·23	9·18	12·76
1924	11·41	13·94	18·44	7·79	5·10	11·26	7·44
1925	10·27	16·61	27·52	9·34	10·18	11·78	5·70
1926	9·93	11·40	10·46	9·77	9·86	11·03	4·46
1927	20·55	16·15	13·24	14·31	7·64	25·02	13·79
1928	13·52	9·57	10·72	9·16	8·46	14·79	11·41
1929	13·90	7·53	8·30	8·30	7·50	15·15	10·48
1930	8·03	11·31	15·13	12·84	40·14	14·24	14·28
1931	3·49	10·44	15·02	13·55	15·29	10·46	5·53
1932	11·57	10·18	22·87	9·02	8·62	8·89	8·64
1933	7·96	5·38	9·87	7·10	6·16	7·51	5·39
1934	18·17	23·45	24·86	21·27	25·26	17·88	9·95
1935	13·43	9·81	26·34	17·03	17·78	8·83	7·87
1936	9·37	8·30	21·76	14·53	8·51	8·80	6·38
1937	7·01	2·45	11·41	8·56	9·78	5·98	8·12
1938	3·87	4·97	5·32	6·52	5·86	6·95	7·01
1939	7·16	7·07	3·47	6·60	3·33	6·08	5·46
1940	5·16	5·66	5·93	5·13	1·68	4·57	6·31
1941	6·23	11·37	12·53	8·58	8·98	11·91	5·87
1942	5·14	18·57	20·18	12·84	12·58	24·27	5·94
1943	5·20	29·86	26·04	11·60	16·74	21·90	12·99

TABLE IV—*concld.*

Years.	Attock.	Mianwali.	Montgomery.	Lyallpur.	Jhang.	Multan.	Muzaffargarh.	D. G. Khan.
1914	23·00	16·00	18·60	30·40	16·30	7·90	39·70	17·00
1915	18·80	24·30	29·50	5·20	18·80	22·50	30·40	21·50
1916	3·60	17·40	19·30	7·70	17·20	10·40	13·60	10·90
1917	17·60	20·70	28·20	9·70	8·40	11·20	24·90	14·20
1918	10·50	31·00	42·50	19·00	24·60	29·00	64·30	53·50
1919	8·20	19·60	20·80	11·00	12·30	13·90	46·50	33·06
1920	4·30	28·60	17·60	8·30	11·30	10·50	31·40	17·90
1921	3·81	17·27	17·42	5·27	13·95	14·43	21·00	29·33
1922	5·90	22·30	10·20	6·10	9·30	7·30	23·20	22·80
1923	3·96	11·10	9·61	3·75	8·71	4·03	21·36	47·34
1924	7·36	9·50	21·71	8·90	8·92	8·52	18·21	22·71
1925	17·37	20·22	19·23	10·81	11·86	12·76	34·23	26·65
1926	12·54	13·80	9·52	10·52	8·34	13·67	37·90	13·08
1927	29·14	17·21	8·66	6·41	7·69	11·34	35·36	24·75
1928	18·98	11·00	11·73	4·91	6·13	3·39	17·00	27·75
1929	15·95	9·58	9·50	4·21	10·97	7·40	13·68	10·90
1930	17·97	26·65	24·91	12·05	21·35	10·37	38·96	25·34
1931	15·50	30·93	24·51	10·72	7·10	21·38	33·63	21·01
1932	13·42	29·77	18·42	9·84	11·47	14·29	24·41	14·24
1933	9·76	26·03	11·82	3·65	7·81	9·83	21·97	9·70
1934	12·19	17·54	21·03	9·09	12·64	19·32	49·15	15·68
1935	6·13	10·75	9·18	3·41	6·58	12·62	26·40	12·97
1936	5·69	6·29	6·53	3·92	6·68	7·72	16·49	12·41
1937	5·70	6·31	6·13	3·97	5·45	11·12	20·80	13·58
1938	4·00	3·60	5·57	2·95	7·25	4·66	9·26	9·60
1939	3·35	1·27	5·08	3·06	5·58	3·73	6·08	4·82
1940	3·74	1·29	3·34	1·83	9·59	2·71	8·83	6·83
1941	4·57	5·50	3·68	5·66	11·25	6·37	19·47	14·87
1942	3·31	12·39	2·99	4·96	20·54	15·10	25·74	9·16
1943	7·02	17·40	13·69	7·19	22·71	10·01	31·16	10·68

TABLE V.

Showing spleen rate in November of each year for each district of the Punjab from 1914 *to* 1943.

Years.	Hissar.	Rohtak.	Gurgaon.	Karnal.	Ambala.	Simla.	Kangra.
1914	9·60	9·50	17·10	23·80	15·20	5·50	31·20
1915	6·20	7·60	12·80	11·80	13·50	1·90	32·30
1916	7·20	9·10	10·30	11·60	11·60	15·60	27·50
1917	9·60	4·80	9·80	7·10	13·80	3·50	11·05
1918	9·40	6·80	7·90	3·80	7·70	0·50	26·70
1919	14·40	5·70	35·40	7·50	12·90	1·50	18·50
1920	8·01	6·50	23·50	11·20	9·70	1·90	18·50
1921	6·50	7·06	17·10	22·40	12·80	1·40	18·80
1922	6·50	11·20	10·60	26·80	11·05	1·50	16·70
1923	16·15	13·41	13·51	54·90	17·53	1·46	25·94
1924	16·41	13·42	15·86	49·55	21·70	1·32	27·45
1925	14·56	21·18	12·76	52·34	24·48	7·01	23·31
1926	29·18	24·12	23·47	29·90	18·69	1·06	21·94
1927	25·17	21·50	25·51	25·48	16·72	3·18	29·10
1928	15·31	11·31	15·88	14·48	16·76	3·89	31·93
1929	13·59	7·67	10·58	12·20	7·94	11·36	32·75
1930	17·40	8·30	13·72	11·05	8·69	0·00	26·61
1931	15·33	6·83	14·32	12·09	8·84	0·57	29·60
1932	9·32	7·36	10·21	13·09	11·26	0·45	20·22
1933	10·82	13·75	13·58	19·84	13·24	0·00	25·99
1934	10·47	11·33	18·71	13·38	13·71	1·66	19·63
1935	2·52	8·91	27·39	23·62	10·81	0·62	18·55
1936	6·99	9·05	24·80	13·82	6·45	1·09	23·56
1937	6·16	6·31	14·71	11·54	6·33	1·59	17·56
1938	3·00	4·01	9·31	6·84	7·04	3·02	13·76
1939	2·66	3·60	7·29	13·11	14·55	5·66	14·64
1940	4·28	2·62	9·13	16·79	11·10	3·32	22·31
1941	3·61	1·83	1·56	10·87	6·50	2·73	25·00
1942	26·09	15·81	10·37	23·48	21·80	2·51	21·73
1943	27·78	22·51	13·53	24·24	15·03	3·35	14·48

TABLE V—*contd.*

Years.	Hoshiarpur.	Jullundur.	Ludhiana.	Ferozepore.	Lahore.	Amritsar.	Gurdaspur.
1914	20·80	13·40	2·90	15·90	6·10	10·30	7·90
1915	14·50	12·70	1·20	6·40	2·80	1·30	13·70
1916	12·40	5·01	2·40	12·02	5·50	2·70	16·20
1917	11·90	7·10	3·60	8·90	5·70	7·90	21·30
1918	11·40	7·60	5·60	10·90	3·01	8·20	15·40
1919	14·90	9·30	4·70	9·70	2·90	2·60	13·80
1920	9·50	7·50	4·60	10·90	3·40	3·10	9·10
1921	8·40	8·70	8·30	0·20	3·30	2·01	10·50
1922	8·05	11·30	2·80	16·30	4·20	3·80	9·40
1923	9·98	10·15	13·44	23·42	11·35	6·17	15·77
1924	11·50	4·82	9·26	14·87	7·38	11·04	18·86
1925	11·33	4·14	9·30	9·91	11·36	13·03	19·34
1926	10·88	5·29	10·07	13·15	11·12	20·74	23·03
1927	12·50	5·51	12·21	8·26	12·10	13·10	18·46
1928	8·52	3·15	7·96	12·51	9·60	9·57	14·14
1929	8·19	3·58	7·60	9·35	13·24	8·79	13·81
1930	9·03	3·45	4·45	8·90	13·07	8·33	27·02
1931	8·11	2·53	5·57	12·29	17·50	9·86	23·13
1932	8·98	3·55	4·09	7·64	14·08	5·40	22·90
1933	12·36	5·08	9·95	6·41	12·05	6·94	17·39
1934	7·46	2·73	4·10	3·54	9·60	3·92	11·01
1935	10·09	2·54	7·22	5·89	5·45	1·91	10·94
1936	10·11	3·32	4·72	3·54	4·10	1·73	11·77
1937	8·56	2·55	3·59	1·85	3·00	2·53	8·74
1938	5·53	3·02	2·25	2·28	3·32	4·06	6·71
1939	8·86	5·84	4·08	3·35	4·32	6·70	7·01
1940	18·69	3·54	7·36	4·03	2·22	4·91	8·59
1941	17·72	2·13	5·87	3·75	6·22	2·57	12·07
1942	15·31	6·11	17·28	17·55	18·80	5·04	19·57
1943	8·31	5·41	9·76	7·57	10·94	5·33	11·44

TABLE V—*contd.*

Years.	Sialkot.	Gujranwala.	Sheikhupura.	Gujrat.	Shahpur.	Jhelum.	Rawalpindi.
1914	10·70	19·60	...	7·90	28·00	26·30	20·50
1915	7·90	10·90	...	10·60	19·40	4·50	13·80
1916	9·40	25·20	...	18·50	23·40	17·90	20·90
1917	11·06	42·70	...	20·40	29·20	25·10	9·40
1918	8·10	18·60	...	7·10	20·80	15·60	5·90
1919	9·30	13·30	...	7·06	19·20	20·30	3·10
1920	7·40	11·50	9·40	6·03	5·90	10·06	2·10
1921	11·30	7·20	11·80	6·80	15·70	11·50	15·40
1922	9·10	8·90	11·40	6·60	8·07	12·20	14·70
1923	17·00	13·40	15·96	9·57	4·76	11·41	13·04
1924	20·46	9·24	21·17	8·76	14·36	19·51	8·65
1925	10·41	16·73	14·74	15·38	11·48	16·03	8·94
1926	30·42	19·99	21·68	14·71	10·04	25·15	10·84
1927	19·37	13·35	13·18	9·44	10·93	20·10	12·02
1928	8·91	5·75	11·78	7·02	8·34	15·99	12·15
1929	8·91	17·05	14·07	13·09	41·42	17·11	12·65
1930	8·79	23·80	21·46	13·35	21·58	16·29	11·97
1931	7·77	12·42	23·95	12·17	11·74	9·17	10·85
1932	8·86	9·31	18·67	8·26	4·40	9·46	9·96
1933	37·99	32·58	28·09	28·86	22·38	23·92	13·43
1934	23·62	17·34	19·54	17·97	21·82	12·79	10·62
1935	22·63	10·63	22·16	20·55	13·56	13·55	8·18
1936	7·68	9·52	19·27	11·73	11·53	6·60	8·79
1937	4·48	5·66	10·45	8·07	7·89	7·55	16·77
1938	6·86	6·95	5·11	6·52	5·40	9·70	7·12
1939	6·07	6·17	5·13	5·80	3·06	9·97	7·54
1940	11·20	7·46	13·03	12·69	4·38	10·79	8·27
1941	5·83	22·72	19·09	15·41	9·28	25·08	7·52
1942	8·09	31·92	32·19	18·22	12·98	24·53	10·39
1943	8·02	29·78	21·80	11·49	13·64	15·10	4·08

TABLE V—*concld.*

Years.	Attock.	Mianwali.	Montgomery.	Lyallpur.	Jhang.	Multan.	Muzaffargarh.	D. G. Khan.
1914	18·70	28·80	28·90	30·20	22·00	16·30	39·00	15·20
1915	9·09	17·05	29·60	10·70	13·05	15·50	22·07	14·70
1916	14·60	24·60	8·30	7·40	14·05	12·70	19·60	14·08
1917	13·30	22·70	50·80	20·60	16·60	53·90	34·70	43·50
1918	17·03	21·60	27·40	11·60	13·30	18·20	39·90	41·50
1919	7·90	17·50	22·00	11·80	13·50	19·01	47·20	30·20
1920	5·30	18·90	30·50	8·10	5·20	8·30	22·40	17·60
1921	7·70	25·60	12·90	9·40	15·90	6·30	28·80	52·60
1922	6·60	9·80	10·80	8·90	5·80	12·10	21·10	24·20
1923	4·29	15·95	25·71	13·36	11·01	12·15	25·89	28·36
1924	6·10	12·76	17·28	12·91	13·21	33·57	38·03	25·42
1925	15·09	24·19	11·40	9·77	10·78	15·08	41·60	27·15
1926	26·29	12·37	13·22	8·17	7·55	17·40	45·54	14·53
1927	22·40	13·64	17·58	8·33	6·01	3·08	35·91	13·76
1928	15·99	8·35	14·30	4·83	5·93	6·98	17·40	27·67
1929	26·10	43·03	26·80	13·61	28·89	21·78	49·77	40·34
1930	17·05	30·23	37·59	13·99	16·77	11·71	39·29	29·62
1931	9·31	25·83	21·27	11·17	9·51	13·80	23·12	16·87
1932	13·45	34·46	13·06	5·70	11·62	8·40	25·25	16·37
1933	19·44	25·08	29·79	6·08	17·35	35·24	55·10	21·11
1934	14·55	13·81	15·31	5·86	9·94	13·39	31·09	18·43
1935	5·46	8·04	6·94	3·76	6·06	8·08	21·93	9·52
1936	8·59	8·02	9·42	3·83	9·91	8·69	22·15	19·28
1937	4·49	3·93	6·28	2·35	5·55	5·90	13·11	12·00
1938	3·80	2·57	4·95	1·91	5·00	3·73	9·17	7·45
1939	4·42	2·06	4·11	2·43	8·88	2·60	7·61	6·72
1940	8·12	3·61	7·27	2·85	12·39	7·97	14·39	19·71
1941	4·18	7·58	5·50	4·03	11·70	7·30	29·30	15·45
1942	7·56	10·42	13·78	8·23	20·89	13·72	25·27	17·33
1943	13·58	15·30	11·18	10·41	24·96	8·36	25·70	5·95

The coefficients of correlation were worked out between spleen rates in June and November and the district epidemic figures. Table VI shows the results. The coefficients relating to the month of June are, in the majority of cases, insignificant. Simla District, however, shows a fairly high degree of positive correlation and Gurgaon District a negative type of association. In the case of these two districts alone, data collected by spleen census may be utilized for purposes of forecasting the incidence of malaria.

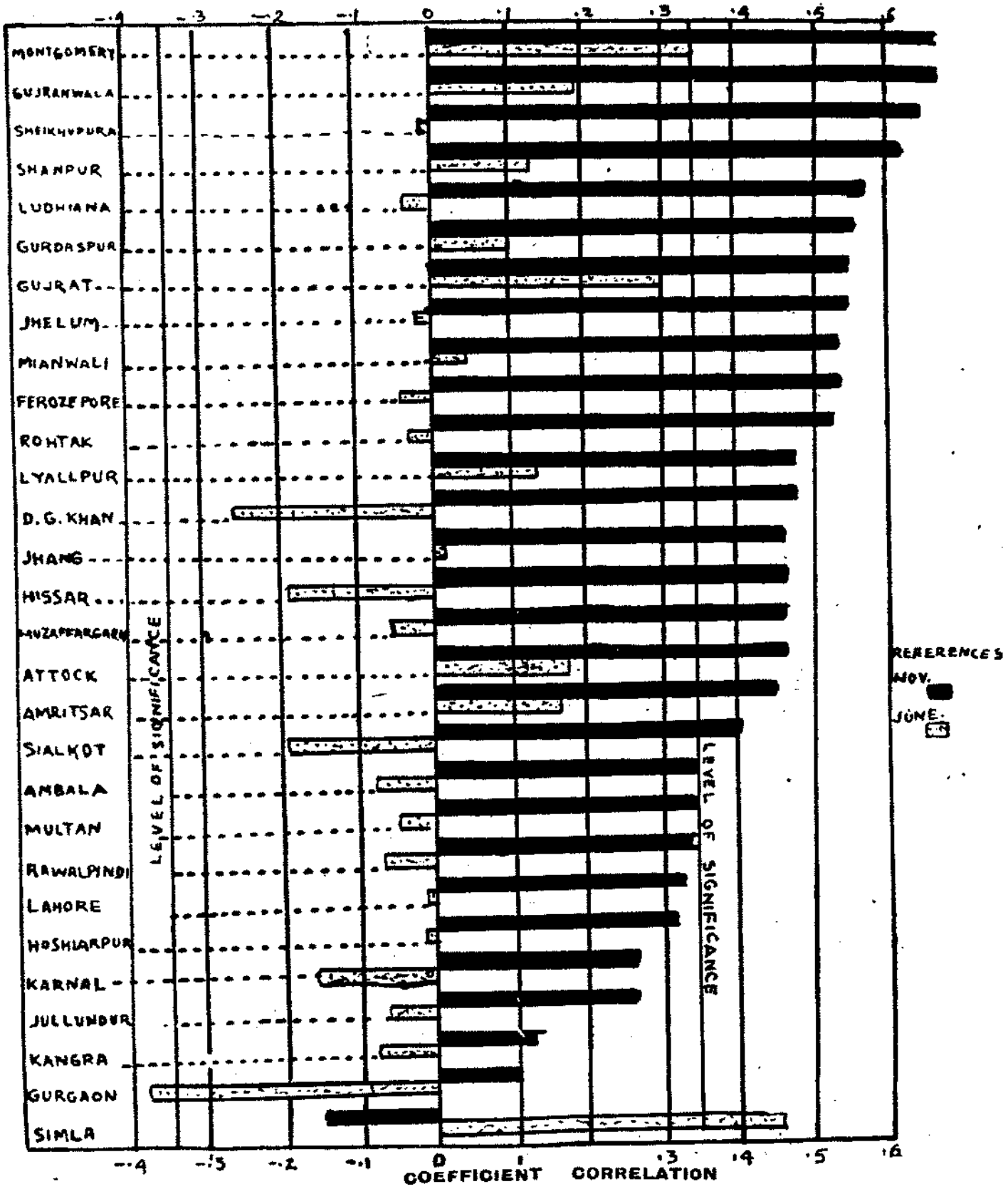
TABLE VI.

Coefficients of correlation between malaria epidemic figure and spleen rate in the Punjab in the months of June and November during the period 1914 *to* 1943.

District.	Coefficients of correlation.	
	June.	November.
Hissar	−0·1939	+0·4691
Rohtak	−0·0266	+0·5287
Gurgaon	−0·3757	+0·1092
Karnal	−0·1586	+0·2723
Ambala	−0·0759	+0·3549
Simla	+0·4580	−0·1495
Kangra	−0·0824	+0·1347
Hoshiarpur	−0·0157	+0·3201
Jullundur	−0·0566	+0·2680
Ludhiana	−0·0367	+0·5664
Ferozepore	−0·0422	+0·5356
Lahore	−0·0074	+0·3304
Amritsar	+0·1658	+0·4622
Gurdaspur	+0·1022	+0·5602
Sialkot	−0·1936	+0·4123
Gujranwala	+0·1881	+0·6661
Sheikhupura	−0·0099	+0·6432
Gujrat	+0·2982	+0·5489
Shahpur	+0·1349	+0·6226
Jhelum	−0·0198	+0·5462
Rawalpindi	−0·0698	+0·3437
Attock	+0·1755	+0·4666
Mianwali	+0·0528	+0·5378
Montgomery	+0·3440	+0·6726
Lyallpur	+0·1394	+0·4790
Jhang	+0·0126	+0·4700
Multan	−0·0516	+0·3535
Muzaffargarh	−0·0556	+0·4667
Dera Ghazi Khan	−0·2630	+0·4787

CHART 3.

Coefficients of correlation between annual epidemic figures and spleen rate in the months of June and November in the districts of the Punjab during the period 1914 *to* 1943.



CONCLUSION.

Records collected during spleen rate census in the months of June and November since the year 1914 have been examined with a view to their being utilized for purpose of forecasting the incidence of malaria. It has not been possible on the basis of information provided by spleen census to evolve a suitable forecasting factor. But it is not possible to reject outright the underlying theory that 'an epidemic of malaria is essentially the outcome of the loss of equilibrium between infection and immunity'. This theory has abundant support from the researches relating to other diseases and would, in particular, mention Greenwood *et al.* (1936) in the field of experimental epidemiology. Perhaps similar studies may ultimately lead towards the evolution of a method for predicting fluctuations in epidemic curve when 'infection and immunity' in a community are measured in some more precise terms. The use of the spleen census is, therefore, at present of no more than epidemiological interest inasmuch as it does show where an outbreak of malaria has already occurred.

ACKNOWLEDGMENT.

The help rendered by Mr. Kartar Singh, B.A., is gratefully acknowledged.

REFERENCES.

GILL, C. A. (1915) ... ... Report on Malaria in the Punjab with special reference to its prevalence among children.

Idem (1928) ... ... *The genesis of epidemics and natural history of disease.* London: Baillière, Tindal and Cox.

GREENWOOD, M., HILL, A. B., TOPLEY, W. W. C., and WILSON, J. (1936). Experimental epidemiology. *Special Report No. 209 of the Medical Research Council.*

YACOB, M., and SATYA SWAROOP (1944). The forecasting of epidemic malaria in the Punjab. *J. Mal. Inst. Ind.*, **5**, 3, pp. 319–335.

APPENDIX I.

Instructions for the guidance of medical officers conducting the spleen census.

1. Before commencing to carry out the spleen census the instructions given below should be carefully studied.

2. The spleen census will be carried out twice during the year: (*a*) in the month of June or July, and (*b*) in November. The actual date of the examination may be fixed by mutual agreement between the headmaster of the school and the medical officer.

The time should be so arranged as to be convenient to all parties, but an effort should be made to select a time when a maximum number of children will be attending school.

3. It will probably be found convenient to carry out the spleen census during school hours whilst the scholars are working in their class-rooms or in the open.

4. The children to be examined are to be strictly limited to those attending the following schools, which must be situated in the town, notified area, or village in which the medical officer's hospital or dispensary is located:

(1) Secondary schools recognized by the Education Department.

(2) Primary schools.

5. All the available *male* children attending these schools of ten years of age and under are to be examined, but no boys over ten, nor girls of any age, are to be included in the spleen census.

6. The following method of conducting the examination has been found useful and is recommended: The examining officer remains seated facing the scholars. Each child comes forward in turn and stands between the knees of the observer leans slightly forward over the latter's right knee,

and at the same time looks upwards. The observer's right hand is then passed with a light touch under the left costal arch of the child. In the case of tall children the examination is more easily carried out when the observer is standing up.

7. The details in regard to the name, age, father's name and caste should first be entered in Schedule B, and then the condition of the spleen should be ascertained in regard to whether it is enlarged or not. If the spleen is not felt, a cross (×) should be placed opposite the name of the child in column 6 of Schedule B. If the spleen is palpable the cross will be placed in column 7. In the latter case the approximate size of the spleen should then be determined according to the following plan:

(*a*) If the spleen is felt but does not reach more than one finger's breadth below the margin of the ribs it belongs to Class II, and a cross is inserted in the column labelled Class II.

(*b*) If the spleen reaches two fingers' breadth below the costal margin a cross is made in the column for Class III spleens.

(*c*) If the spleen reaches three fingers' breadth below the ribs the cross is made in the column for Class IV spleens.

(*d*) If the spleen reaches four fingers' breadth below the ribs the cross is made in the column for Class V spleens.

(*e*) If the spleen extends to the umbilicus the cross is made in the column for Class VI spleens.

(*f*) When the spleen extends below the umbilicus the spleen belongs to Class VII, and a cross is inserted in this column.

8. When all the children of one school have been examined, the medical officer will fill in on the first page of Schedule B the number of male children, of ten years of age and under, attending the school, together with the number examined by him.

9. A copy of Schedule A will then be completed and attached firmly to the Schedule B relating to the children of the same school. When more than one school is examined by the same medical officer the spleen census of each school will be carried out in an exactly similar manner. The Schedules A and B after completion will be forwarded without delay to the Punjab Epidemiological Bureau, Punjab, Lahore.

10. As it is of great importance that the schedules should be accurately and completely prepared, it is hoped that an effort will be made to comply with the above procedure. It will be noted that the grant of the fee for conducting the spleen census is dependent upon the work being performed in a satisfactory manner.

11. The spleen census in November next and future years will be carried out in a similar manner. Steps should therefore be taken in time to obtain a supply of the schedules and to carry out the spleen census at the appropriate seasons.

12. Copies of the schedules may be obtained from the Punjab Epidemiological Bureau, Punjab, Lahore.

APPENDIX II.

Schedule A.

For use in connection with the spleen census of school children.

Please read the instructions.

Year.....

Month.....

District.....

Locality.....

School.....

Date of examination.....

Station.....

Signature of Medical Officer.....

Date of despatch.....

APPENDIX III.

Schedule B.

For use in connection with the spleen census of school children.

Please read the instructions.

School.....

Locality.....

Number of male children of ten years and under attending the school.....

Number of male children of ten years of age and under examined.....

Date of examination.....

1	2	3	4	5	6	7	8					
							Degree of enlargement of spleen.					
Serial number.	Name.	Age.	Father's name.	Caste.	Spleen not enlarged (Class I).	Spleen enlarged.	Class II.	Class III.	Class IV.	Class V.	Class VI.	Class VII.
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

Indian Journal of Malariology, 1, 4, December 1947.

PRELIMINARY FORECASTS OF THE INCIDENCE OF MALARIA IN THE PUNJAB.

BY

KHAN BAHADUR M. YACOB, M.B., B.S., DT.P.H.
(*Director of Public Health, Punjab*),

AND

S. SWAROOP, M.A., PH.D.
(*Statistical Officer, Punjab Public Health Department*).

[July 18, 1947.]

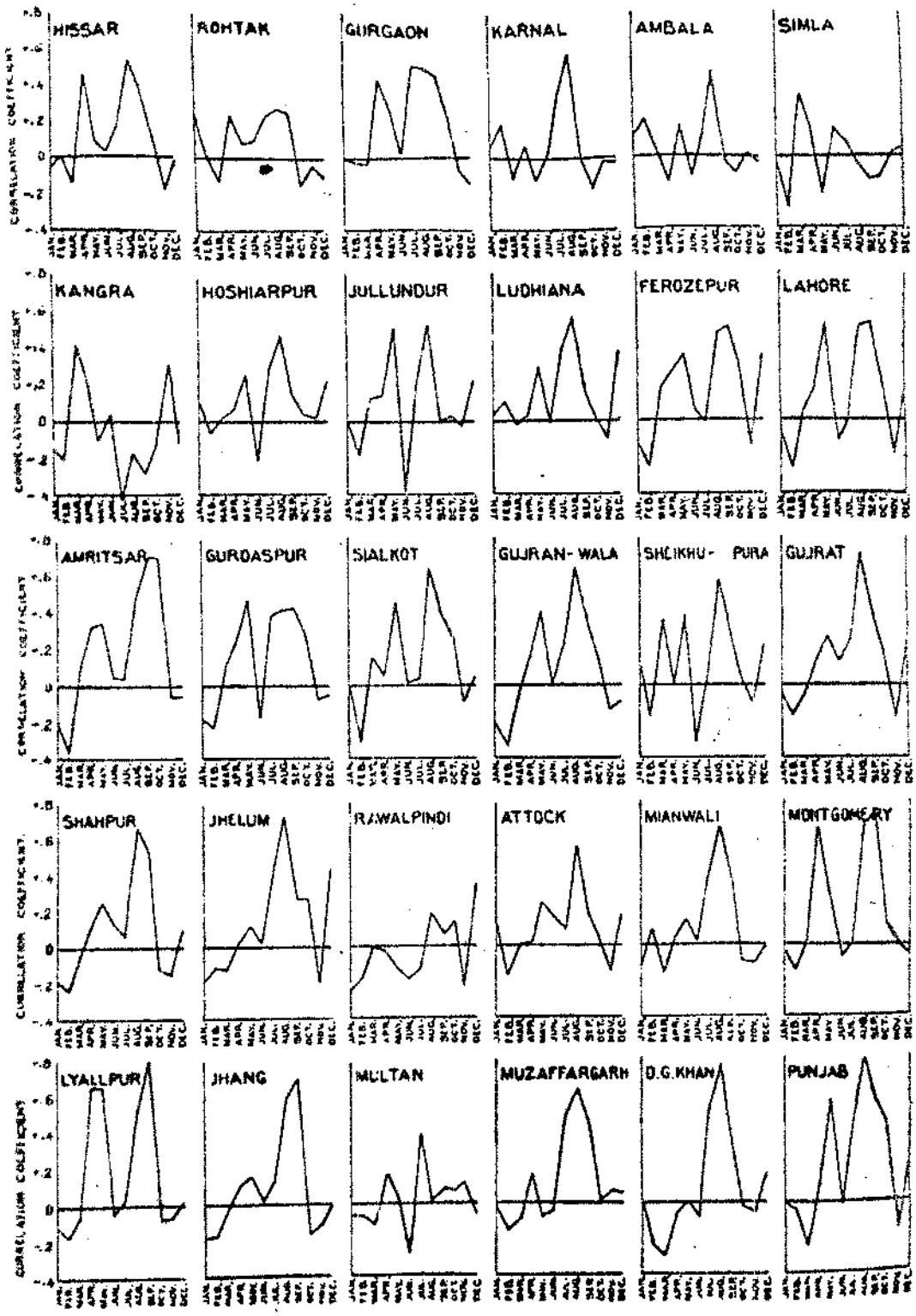
IN the Punjab, two malaria forecasts, viz. preliminary and final, are issued each year to indicate localities where epidemic outbreaks of the disease may be expected. The preliminary forecast is issued on or about August 31, and the final on or about September 15, i.e. soon after the final rainfall data for the month of August become available. In the preliminary forecasts use is made of the rainfall data generally only up to the end of July. It has recently been shown that, for the majority of districts, although rainfall in the month of August is highly correlated with the development of malaria outbreaks in the following autumn, there does not exist any statistically significant relationship between July rainfall and the subsequent malaria epidemic (Yacob and Swaroop, 1946). It would seem, therefore, that the preliminary forecast, based as it is on July rainfall alone, may not prove of use in the case of the majority of the districts where the relation between July rainfall and autumnal malaria is statistically of no significance.

In this paper it is proposed to demonstrate how a more reliable preliminary forecast may be prepared for the districts of the Punjab. The method developed would in fact enable the department to issue forecasts in June instead of in August, i.e. 2 months earlier than has been the practice. This method is based on a new relationship which has been found to exist between rainfall in the month of April or May and the development of subsequent malaria epidemics in the autumn months of the same year. In a previous paper (Yacob and Swaroop, *loc. cit.*), the authors had given figures for the coefficients of correlation between rainfall in each month of the year and the epidemic figure. These coefficients of correlation were calculated separately for each district. Chart 1 has been prepared with the help of these correlations. It shows in a graphic manner the degree to which rainfall in each month of the year is correlated with the annual epidemic figure.

Page - 392

CHART 1.

Seasonal variation in the coefficients of correlation between monthly rainfall and malaria epidemic figure in the districts of the Punjab.



Figures stated by Gill (1928) show that for the districts of Simla and Kangra the July-August rainfall is from the statistical point of view not significantly correlated with the epidemic figure. Therefore, the forecasting of malaria epidemics for these districts with the help of rainfall data relating to July and August is out of question. This chart shows that in both these districts rainfall in the month of March is related in a direct manner with the epidemic figure. It would seem possible, therefore, in these districts to predict malaria outbreaks in future with the help of this relationship.

In certain districts rainfall in summer months is almost as highly correlated with the epidemic figure as that in July or August; instances are Hissar, Gurgaon, Jullundur, Ferozepore, Lahore, Gurdaspur, Montgomery and Lyallpur. The last two districts, viz. Montgomery and Lyallpur, are both canal irrigated tracts. In the districts of the south-eastern Punjab, namely Hissar and Gurgaon, it is the rainfall in April and not in May that is correlated.

The conclusion is that in the majority of districts greater use could be made—at least for issuing preliminary forecasts—of the March, April or May rainfall figures than for July figures.

EQUATIONS FOR PURPOSES OF PREDICTION.

The coefficients of correlation shown in Chart 1 were worked out on the experience of the period from 1914 to 1943. Since no use was made of the figures for the years 1944, 1945 and 1946 the incidence actually recorded in these 3 years should enable us to test the degree to which preliminary forecasts can be successful when based on the figures of March to May rainfall. The usual regression equations have accordingly been worked out so that if the value of monthly rainfall is substituted in these, the expected or the predicted value of epidemic figure for the year could be estimated in numerical terms. These equations are given in Table I.

TABLE I.

Regression equations together with the months for which rainfall data are utilized.

District.	Month for which rainfall figures have been used.	Equations.
Hissar	April	$Y = 1{\cdot}3145\ X + 0{\cdot}9821$
Gurgaon ...	April	$Y = 1{\cdot}2546\ X + 1{\cdot}2612$
Simla	March	$Y = 0{\cdot}1324\ X + 0{\cdot}6122$
Kangra ...	March	$Y = 0{\cdot}0622\ X + 0{\cdot}9164$
Hoshiarpur ...	May	$Y = 0{\cdot}1243\ X + 1{\cdot}1040$
Jullundur ...	May	$Y = 0{\cdot}3413\ X + 1{\cdot}0427$
Ludhiana ...	May	$Y = 0{\cdot}2978\ X + 1{\cdot}1718$

TABLE I—*concld.*

District.	Month for which rainfall figures have been used.	Equations.
Ferozepore ...	May	Y = 0·4955 X + 1·2767
Lahore	May	Y = 0·6803 X + 0·9230
Amritsar ...	May	Y = 0·3831 X + 1·0686
Gurdaspur ...	May	Y = 0·3742 X + 1·2885
Sialkot	May	Y = 0·3964 X + 1·4227
Gujranwala ...	May	Y = 0·6873 X + 1·5565
Sheikhupura ...	May	Y = 0·4344 X + 1·2486
Gujrat	May	Y = 0·2876 X + 1·6784
Shahpur ...	May	Y = 0·3585 X + 1·2017
Attock	May	Y = 0·1531 X + 1·5056
Montgomery ...	April	Y = 2·5424 X + 0·8371
Lyallpur ...	May	Y = 0·6385 X + 0·7998

Monthly rainfall is denoted by letter X and the letter Y stands for the expected value of epidemic figure. One advantage of these equations is that the use of the personal factor, which had been contended in previously (Yacob and Swaroop, 1944) and which was a defect in the usual method of forecasting, has been eliminated.

In working out these regression equations for each district, rainfall figure is to be considered for that particular month for which the highest coefficient of correlation has been obtained. Thus for Kangra and Simla districts the rainfall in the month of March must be taken into consideration and a preliminary forecast could thus be issued in the middle of April. For the districts of Hissar, Gurgaon and Montgomery, rainfall in the month of April only has been taken into consideration and thus forecast could be issued in the middle of May. In the remaining districts for which equations have been worked out, rainfall in the month of May shows the highest coefficient of correlation and has been used in the calculation of the regression equations. It must be pointed out that there still remain certain districts in which none of the months of March, April and May shows a significant degree of association. For these districts no method of issuing preliminary forecasts has yet been evolved. Of these districts, Rohtak, Ambala, Rawalpindi and Jhang are those in which even the July rainfall is not correlated. Theoretically only those coefficients of correlation should be used which emerge into statistical significance. For practical purposes, however, even values approaching the conventional significance level, but not fully significant from the statistical point of view, may also be useful and hence correlation coefficients exceeding +0·25 have been utilized.

TEST OF THE RELIABILITY OF THE NEW FORECASTING EQUATIONS.

For each of the districts shown in Table I, relevant monthly rainfall figures for 1944, 1945 and 1946 are set out in Table II. Column (2) shows the month to which figures relate for each district. By substituting these values in the regression equations of Table I, the expected values of corresponding epidemic figures which would have been predicted for individual districts, if forecasts had been issued on the basis of the available rainfall data, are given in Table III.

TABLE II.

Monthly rainfall figures for individual districts of the Punjab for the years 1944, 1945 *and* 1946.

District.	Month for which rainfall figure is used.	Monthly rainfall figure in inches.		
		1944	1945	1946
(1)	(2)	(3)	(4)	(5)
Hissar	April	0·91	0·15	0·15
Gurgaon	April	1·03	0·11	0·08
Simla	March	4·19	3·34	2·85
Kangra	March	6·07	3·27	2·69
Hoshiarpur ...	May	0·06	0·36	1·25
Jullundur ...	May	...	0·07	0·79
Ludhiana	May	...	0·05	0·64
Ferozepore ...	May	0·06	0·09	0·36
Lahore	May	0·03	0·14	0·54
Amritsar	May	...	0·14	0·77
Gurdaspur ...	May	0·66	0·57	1·70
Sialkot	May	0·27	1·01	1·10
Gujranwala ...	May	0·03	0·84	0·93
Sheikhupura ...	May	0·07	0·21	0·48
Gujrat	May	0·29	1·01	0·96
Shahpur	May	0·10	0·64	1·24
Attock	May	0·18	0·46	1·26
Montgomery ...	April	0·73	0·70	0·03
Lyallpur	May	0·17	0·22	0·51

TABLE III.

Expected and the actual values of epidemic figures in certain districts of the Punjab for the years 1944, 1945 *and* 1946.

District.	1944		1945		1946	
	Expected epidemic figure.	Actual epidemic figure.	Expected epidemic figure.	Actual epidemic figure.	Expected epidemic figure.	Actual epidemic figure.
	(2)	(3)	(4)	(5)	(6)	(7)
Hissar	2·178	1·084	1·179	1·016	1·179	0·760
Gurgaon	2·553	1·066	1·399	1·066	1·362	0·925
Simla	1·167	1·133	1·054	0·667	0·990	0·921
Kangra	1·294	0·874	1·120	0·821	1·084	0·914
Hoshiarpur	1·111	0·748	1·149	0·933	1·259	1·005
Jullundur	1·043	0·828	1·067	1·049	1·312	0·824
Ludhiana	1·172	0·861	1·187	1·133	1·362	0·959
Ferozepore	1·306	0·952	1·321	1·588	1·455	0·835
Lahore	0·943	1·073	1·018	1·123	1·290	0·859
Amritsar	1·069	0·956	1·122	1·035	1·364	0·864
Gurdaspur	1·535	1·246	1·502	1·255	1·925	1·111
Sialkot	1·530	1·292	1·823	1·359	1·859	1·409
Gujranwala	1·577	2·867	2·134	1·428	2·196	1·149
Sheikhupura	1·279	1·929	1·340	1·220	1·457	1·027
Gujrat	1·762	2·390	1·969	1·343	1·954	1·177
Shahpur	1·238	3·005	1·431	1·036	1·646	0·858
Attock	1·533	1·601	1·576	1·284	1·699	1·143
Montgomery	2·693	2·054	2·617	1·725	0·913	1·175
Lyallpur	0·908	1·070	0·940	1·124	1·125	0·849

The actual recorded epidemic figures for the same years are also set out in Table III. The degree of correspondence between the expected and the recorded figures should provide us with an objective test of the reliability of forecasting by means of regression equations to the exclusion of any other relevant data which may be used for forecasting.

Coefficients of correlation have been worked out between the series of expected and recorded epidemic figures for each of the three years, viz. 1944, 1945 and 1946. These are shown below :—

	1944	1945	1946
Coefficient of correlation between actual and predicted epidemic figures of districts	0·2509	0·7590	0·5521

The coefficients of correlation are significant for the years 1945 and 1946. On the other hand, the correlation for the year 1944 is low. It may be stated here that in working out these regression equations only the rainfall figures during the months of March, April and May have been taken into account, and such other relevant data as relate to the existence of floods or waterlogged conditions which can be known before the advent of malaria season have been ignored altogether. This information is utilized in issuing final forecasts.

The reasons for the low value of coefficient of correlation for the year 1944 may be examined. This was an unusual year in one important respect. The annual report of the Director of Public Health for that year shows that ' as a result of heavy rainfall in July and August in 1944, which was responsible for floods in the River Jhelum and chiefly also on account of the rise in level of subsoil water, Shahpur District as a whole and waterlogged areas particularly experienced a severe and wide outbreak of malaria '.

The districts which are well known to be waterlogged are Shahpur, Gujranwala, Gujrat and Gurgaon. Of these, Shahpur, Gujrat and Gujranwala have become waterlogged because of the extension of the canal system. In the proceedings of the Waterlogging Board, Punjab, is shown the extent to which large tracts have been affected in this manner in various districts. The report for the year 1944 gives the following information relating to these districts which have been affected by the rise of subsoil water table following the opening of canals. Figures of certain other districts like Gurgaon where waterlogging exists also but which are not served by canals are not shown in this table.

TABLE IV.

Serial number.	Name of district.	Description of area.	Thur in acres, Rabi, 1944.	Sem in acres, Rabi, 1944.
(1)	(2)	(3)	(4)	(5)
1	Sheikhupura ...	Cultivated	16,973	683
		(A)	96,083	207
		(B)	145,135	1,584
		Total ...	258,191	2,474

' A ' denotes *banjar* which was never broken (i.e. not broken since the advent of the canal or the settlement immediately preceding that) and ' B ' denotes other *banjar*, i.e. land which was formerly cultivated but has gone out of cultivation on account of sem (waterlogging) or thur (soil efflorescence).

TABLE IV—*contd.*

Serial number.	Name of district.	Description of area.	Thur in acres, Rabi, 1944.	Sem in acres, Rabi, 1944.
(1)	(2)	(3)	(4)	(5)
2	Montgomery ...	Cultivated	17,223	...
		(A)	68,664	2
		(B)	34,863	66
		Total ...	120,750	68
3	Shahpur ...	Cultivated	5,619	883
		(A)	22,333	2,832
		(B)	28,203	2,911
		Total ...	56,155	6,626
4	Lyallpur ...	Cultivated	7,284	510
		(A)	38,169	...
		(B)	13,249	108
		Total ...	58,702	618
5	Gujranwala ...	Cultivated	7,647	68
		(A)	148,884	1,678
		(B)	100,179	2,890
		Total ...	256,710	4,636
6	Lahore ...	Cultivated	277	...
		(A)	17,712	486
		(B)	16,761	93
		Total ...	34,750	579
7	Gujrat ...	Cultivated	1,342	960
		(A)	3,707	1,466
		(B)	7,325	4,892
		Total ...	12,374	7,258

'A' denotes *banjar* which was never broken (i.e. not broken since the advent of the canal or the settlement immediately preceding that) and 'B' denotes other *banjar*, i.e. land which was formerly cultivated but has gone out of cultivation on account of sem (waterlogging) or thur (soil efflorescence).

TABLE IV—*concld.*

Serial number.	Name of district.	Description of area.	Thur in acres, Rabi, 1944.	Sem in acres, Rabi, 1944.
(1)	(2)	(3)	(4)	(5)
8	Gurdaspur ...	Cultivated	19	396
		(A)	47	1,128
		(B)	18	1,515
		Total ...	84	3,039
9	Ludhiana ...	Cultivated	153	74
		(A)	269	451
		(B)	195	214
		Total ...	617	739
10	Sialkot ...	Cultivated	44	78
		(A)	1,595	427
		(B)	357	692
		Total ...	1,996	1,197
11	Hoshiarpur ...	Cultivated	...	...
		(A)	...	151
		(B)	...	7
		Total ...	...	158

'A' denotes *banjar* which was never broken (i.e. not broken since the advent of the canal or the settlement immediately preceding that) and 'B' denotes other *banjar*, i.e. land which was formerly cultivated but has gone out of cultivation on account of sem (waterlogging) or thur (soil efflorescence).

In view of these considerations it seems clear that the preliminary forecast was upset by very special circumstances arising out of floods and conditions pertaining to waterlogging. This information could have been utilized in issuing final forecasts. If we exclude the districts heavily effected by waterlogging and floods, namely, Gurgaon, Gujranwala, Gujrat and Shahpur, the coefficients of correlation of the remaining series of figures work out at a value which is of statistical significance.

	1944	1945	1946
Coefficient of correlation between actual and predicted epidemic figures of districts (excluding Gurgaon, Gujranwala, Gujrat and Shahpur)	0·6082	0·7551	0·5200

All the three coefficients of correlation are statistically significant. These considerations indicate that the regression equations set out in Table I do provide us with an altogether new and useful method of issuing preliminary forecasts. It is suggested that this method may be adopted in future for issuing preliminary forecasts. Two advantages as already pointed out are :—

(1) that the method does not involve a personal factor inasmuch as a numerical value of the probable epidemic figure is worked out from a regression equation and there is no scope for exercising personal judgment.

(2) forecast can be issued two or three months earlier than has been possible so far.

SUMMARY AND CONCLUSIONS.

In the Punjab, the probable incidence of malaria outbreaks has so far been predicted in preliminary forecasts issued after full information regarding the July rainfall and only partial information regarding the August rainfall became available. It has been shown that the July rainfall, by itself alone, does not provide a satisfactory measure of predicting subsequent malaria epidemics. The method so far in use has been criticized also on the ground that it is not objective, inasmuch as personal factor is involved.

A new method of issuing preliminary forecasts has been devised. It eliminates personal factor and forecasts can be issued at least two months earlier than has been possible so far. It is based on the relation that rainfall in the month of March, April or May is related to the development of malaria outbreaks in the subsequent autumn. Mathematical equations have been worked out so that by simply substituting the value of the recorded rainfall figure, a numerical measure of the probable epidemic figure for malaria can be worked out. Calculation of these equations was based on the experience of the period 1914 to 1943. The recorded experience during the three years 1944, 1945 and 1946 has been utilized to test the reliability of the forecasting method now developed. The expected incidence in 1944, 1945 and 1946 has been worked out in numerical terms with the help of these equations. This is the incidence that would have been predicted if preliminary forecasts were issued for these three years. This predicted experience has been compared with the actual epidemic figure. It has been demonstrated that a statistically significant degree of success has been obtained. The new method of issuing preliminary forecasts is, therefore, recommended for adoption.

ACKNOWLEDGMENT.

The help rendered by Mr. Kartar Singh, B.A., is gratefully acknowledged.

REFERENCES.

GILL, C. A. (1928) ... ... *The genesis of epidemics and natural history of diseases.* Baillière, Tindall and Cox, London.

DIRECTOR OF PUBLIC HEALTH, PUNJAB (1944). A review of health conditions and public health work in the Punjab during the year 1944. Supdt., Govt. Ptg., Punjab.

WATERLOGGING BOARD, PUNJAB (1945). Proceedings of the thirty-third meeting of the Waterlogging Board, Punjab, for the year 1944. Supdt., Govt. Ptg., Punjab.

YACOB, M., and SWAROOP, S. (1944) Degree of accuracy realized in malaria forecasts in the Punjab for the years 1923 to 1942. *Ind. Med. Gaz.*, **79**, 6, June 1944, pp. 282–288.

YACOB, M., and SWAROOP, S. (1946) Malaria and rainfall in the Punjab. *Journal of the Malaria Institute of India*, **6**, 3, June 1946, pp. 273–284.

Indian Journal of Malariology, 1, 4, December 1947.

CONTROL OF RURAL MALARIA WITH D.D.T. INDOOR RESIDUAL SPRAYING IN KANARA AND DHARWAR DISTRICTS, BOMBAY PROVINCE. FIRST YEAR'S RESULTS.

BY

D. K. VISWANATHAN,

AND

T. RAMACHANDRA RAO.

(*Malaria Organization, Bombay Province.*)

[November 14, 1947.]

CONTENTS.

	PAGE
INTRODUCTION ...	503
AREA AND TOPOGRAPHY ...	504
POPULATION ...	506
HOUSING CONDITIONS ...	506
EPIDEMIOLOGY IN KANARA DISTRICT ...	507
EPIDEMIOLOGY IN DHARWAR DISTRICT ...	507
DETAILS OF THE SCHEME ...	509
Organization ...	509
Spraying material used ...	510
Technique of spraying ...	511
Dose ...	511
Frequency of spraying ...	511
Structures sprayed ...	512
Costs ...	512
RESULTS ...	513
Densities of Anopheles adults ...	513
Effect on spleen and parasite rates ...	514
Effect on infant parasite rates ...	519
Dispensary data ...	520
DISCUSSION ...	520
SUMMARY ...	525
REFERENCES ...	526

INTRODUCTION.

DIFFERENT methods of malaria control considered most likely to yield fruitful results were tried in Kanara District in Bombay Province on a sufficiently large

scale and the results published (Viswanathan, 1946*b*). But these were found either inadequate or laborious and expensive. The nearest approach to a successful method was found to be the rationally spaced programme of spray-killing with pyrethrum extract, $\frac{2-2}{1-2}$ (2 consecutive days of spraying separated by one and two sprayless days alternately), which was based on a series of field studies on the habits of the vector species, viz. *A. fluviatilis* (Viswanathan and Ramachandra Rao, 1943; Viswanathan, Ramachandra Rao and Ramarao, 1944-1945). However, the results of the pilot experiment with D.D.T. described by Viswanathan and Parikh (1946) were so successful and offered such great promise of effective and economically feasible control of the disease in that unusually difficult area that the Government of Bombay was pleased to approve of a scheme to tackle the disease by the use of D.D.T. all over Kanara District as well as the adjoining district of Dharwar in parts of which malaria was as great a problem as in Kanara, though the epidemiology was somewhat different.

In the immensity of the area covered and the magnitude of the population involved the scheme is perhaps one of the largest malaria control projects in rural tropics attempted under the auspices of a civilian government, except the extremely special case of the eradication of *A. gambiæ* in Brazil (Soper and Wilson, 1943). The sociological implications of the success of such a large scheme are many-sided and far-reaching.

The scheme was put into operation in July 1946 and formally inaugurated in a public meeting in Dharwar in September by the Prime Minister of Bombay at which a message of good wishes from Mahatma Gandhi was also read out.

The details of the scheme, such as the type of organization, the formulations of D.D.T. employed, the frequency of dosage and season of spraying, costs and the results of the first year's work are described in this paper. The epidemiology of malaria in Dharwar District, which has not been published hitherto, more especially in its variation from that of Kanara, already extensively published by Jaswant Singh and Jacob (1944) and the Bombay Provincial Malaria Organization, is also described.

AREA AND TOPOGRAPHY.

Kanara and Dharwar are the two southernmost districts of Bombay Province and have areas of 3,910 and 4,576 square miles respectively. Kanara can be very broadly divided into three topographical zones from west to east (Map):

(1) a narrow low-lying coastal strip of heavy rainfall,

(2) a mountainous forest-clad zone with deep valleys and heavy rainfall, and

(3) a gently undulating plateau with moderate rainfall.

The coastal strip is comparatively free from malaria but the two remaining zones exhibit hyperendemicity throughout. Dharwar District has two clearly defined zones:

(1) a western gently undulating zone, contiguous with the last zone of Kanara and having almost identical epidemiological features, and

(2) an eastern plateau of flat terrain and low rainfall.

MAP.

BIJAPUR DT
BELGAUM DISTRICT
NAR-GUND
RON
NAVALGUND
DHARWAR
GADAG
HUBLI
HYDERABAD STATE
SUPA
HALIYAL
KAL-GHATGI
MUNDAR-GI
GOA
W
BANKAPUR
YELLAPUR
KARWAR
II
III
HANGAL
HAVERI
MADRAS PROVINCE
ANKOLA
I
SIRSI
KUMTA
RANE-BENNUR
KOD
SIDDAPUR
HONAVAR
ARABIAN SEA
MYSORE STATE
BHAT-KAL
KANARA-DHARWAR BOUNDARY
I-II-III ZONES IN KANARA DT.
W-E WEST & EAST ZONES IN DHARWAR DT.
DEC-JUN SEASON
JULY-NOV SEASON

Hyperendemic conditions prevail in most of the villages of the western zone of Dharwar, also called the 'malnad', but in the eastern zone the distribution of the disease is patchy, becoming localized in close proximity to perennial streams or to wet cultivation under tanks.

POPULATION.

Dharwar District has 13 talukas and pethas, having a total population of 1,201,016 in 1,251 inhabited villages and townships, and Kanara District has 11 talukas and pethas with a total population of 441,157 in 1,250 inhabited villages, the grand total for both districts being a population of 1,642,173 living in 2,501 villages according to 1941 census. In Table I are given the population data for each taluka and petha, and also the population and the number of villages included in the scheme. In order to make the benefits of the scheme available to the maximum number of people, two important criteria were fixed for selecting villages for control operations: (1) that the village should have a population of at least 100 in Kanara District and 200 in Dharwar District and (2) that it should exhibit a spleen rate of over 10 per cent. In Kanara it was not found necessary to apply the latter criterion except to a few villages in the coastal strip but in Dharwar District it was very essential, because of the existence of a large number of non-malarious villages, more especially in the eastern zone. On these bases, a total of 350 villages having a population of 443,062 was included in the scheme in Dharwar District and a total of 514 with a population of 282,147 in Kanara District. The percentages of villages included were 28 and 41 in Dharwar and Kanara respectively and the percentages of population directly protected were 37 and 64. Considering the fact that more than half the population of Dharwar and nearly a third of that in Kanara actually live in non-malarious villages, the total population which is directly benefited by the scheme is well over three-quarters of the entire malaria-stricken population of the two districts put together. The scheme will however indirectly benefit a considerably larger number since, in view of the migration of population from non-malarious areas into malarious localities for shorter or longer periods, control of malaria in such a large tract as now included in the scheme will inevitably also tend to benefit the people living normally in non-malarious areas. It is roughly computed that at least a million people will derive the benefit of the scheme both directly and indirectly.

HOUSING CONDITIONS.

While there is considerable variation in the types of houses in larger towns, rural houses may be broadly classified as below:—In Kanara District, they are mainly of two types: (1) Large rambling structures usually of two and sometimes three floors, constructed of heavy mud walls, with tiled gabled roofs. The uppermost floor is only used for purposes of storage and only rarely for living purposes. The lower floors have many rooms, all ill-lighted and ill-ventilated. The walls are covered with mud plaster and sometimes limewashed. (2) Small bamboo and thatch huts are used by the working classes. They are well ventilated, as the so-called walls are no better than fences made of vertical pieces of bamboo or arecanut bark. The roof is of thatch. Both types of houses are located usually in isolated

groups in close proximity to arecanut gardens and the attendant streams and channels. Cattle are not usually tied at night in either of the two types of houses, but in separate detached large cattlesheds. Therefore the contact between man and cattle is not as close as in Dharwar District.

The size of the houses in Dharwar District may very considerably depend upon the affluence of the farmer, but cattle are almost invariably tied at night inside the house itself. About half the house is set apart for cattle and usually there is no partition separating cattle from men, the portion used by the latter having a slightly elevated floor. The walls are thick and made of mud or brick and mud and the flat roof is of closely set bamboo covered with thick layers of mud. There is usually a door in front and another at the back and practically no windows. Separate detached cattlesheds are very uncommon.

In Dharwar, the villages are very compact showing an attempted arrangement of streets and lanes. In Kanara, the houses are extremely scattered, each farmer living on his own piece of agricultural land. Even in villages where attempts at concentration of houses have been made there are usually four or five groups widely separated from one another. There are some villages with as many as 12 to 13 such hamlets. The extreme *scatter* of the houses in Kanara militates against the success of any scheme of rural reconstruction, most of all, malaria control especially by antilarval methods.

EPIDEMIOLOGY IN KANARA DISTRICT.

As already stated, the entire district, except the coastal area, is characterized by hyperendemic conditions. *Fluviatilis* is the sole vector with very high infection rates (ranging from 6 to 12 per cent), and a high anthropophilic index (63·6 per cent). It occurs in comparatively small numbers and it has been estimated that an adult density of 4·0 per 10 man-hours in human dwellings is enough to maintain transmission leading to hyperendemic conditions. A good proportion of this species rests outdoors during day time. The number found resting in cattlesheds by day is very small. Among indoor resting places they have a tendency to select the lower parts of the walls, usually not more than 10 feet from the ground. No part of the year is intrinsically unsuitable for transmission and the only limiting factor has been found to be the non-availability of suitable breeding grounds which in turn depends mainly on topography and rainfall. The district can be divided into distinct epidemiological zones (Viswanathan, 1946*a*). Two broad malarious zones can be distinguished in a general way—(1) the eastern rice-growing plateau having a season of transmission from July to November and (2) the forest-clad hilly section having a season from December to June. Haliyal and Mundgod talukas and half of Sirsi Taluka belong to the former group and the rest of the malarious part of the district to the latter. There are, however, a few local areas with longer or shorter season of transmission, such as Supa Petha, Yellapur Taluka and Dandeli (from October to June) and Sirsi Town (October to December).

EPIDEMIOLOGY IN DHARWAR DISTRICT.

The distribution of malaria in the district closely follows the topographical divisions mentioned earlier. The whole of the western undulating plateau is

malarious with spleen rates ranging from 20 per cent to 100 per cent. The eastern limit of this zone roughly follows the Bangalore-Poona highway. Rice is extensively cultivated in large sections of this zone and the ricefields are either directly rain fed or irrigated from numerous tanks. The rest of the district is a plateau with limited rice cultivation under a few tanks, the main crops being jawar, cotton, and other dry crops. Malaria in this zone is not universal but restricted to a few villages here and there which are in close proximity to tanks or perennial streams. The whole of Kalghatgi, Hangal and Kod talukas and a major portion of Dharwar, Hubli, Bankapur, Haveri and Ranebennur talukas are in the first zone and the rest of the district in the second.

The anopheline fauna includes *A. annularis, barbirostris, culicifacies, fluviatilis, hyrcanus* var. *nigerrimus, jamesi, jeyporiensis, pallidus, splendidus, stephensi, subpictus, tessellatus, turkhudi, vagus* and *varuna.*

A. culicifacies, stephensi and *subpictus* are far more abundant in Dharwar District than in Kanara. *Jeyporiensis* which forms the bulk of the adult Anopheles population in Kanara is extremely rare except in the westernmost parts of Dharwar. *Fluviatilis* which occurs in comparatively small numbers in Kanara is very abundant in the eastern part of Dharwar District and associated with this abundance is its marked predilection to rest in cattlesheds, a behaviour which appears to be characteristic of the species in other parts of the Deccan, e.g. Poona and Bijapur. *Fluviatilis* in Poona area, for instance, was found to be markedly zoophilic, the anthropophilic index being only 0·19 per cent.

Culicifacies has been found naturally infected in Dharwar District and appears to be the main if not the sole vector in the eastern zone. In the western zone bordering on Kanara District, however, *fluviatilis* has also been found infected. As large numbers of *culicifacies* have been dissected in the neighbouring talukas of Haliyal and Mundgod in Kanara District and not a single infection found so far, it would appear that the western part of Dharwar District is a sort of transition zone between the *fluviatilis* transmitted malaria zone and the *culicifacies* zone. While the former species has occasionally been found infected in the latter area the latter species has not so far been found infected in the former area.

The season of transmission in Dharwar District is more sharply limited than in Kanara and occurs mainly during the monsoon and the immediate post-monsoon months, i.e. July to November. During the monsoon months there is very little effective flushing of breeding places because of the comparatively low rainfall and the breeding places dry up rapidly after the close of the rains. In the vicinity of perennial streams densities of *culicifacies* remain high all through the year but transmission is however restricted largely to the period July to November.

The adult densities of *culicifacies* resting indoors during day time is usually quite high during the months of transmission, in all types of dwellings, human, mixed or animal. Not enough work has been done to estimate the critical density of this species below which transmission ceases. But considering the similarities in the habits and habitats of *culicifacies* in Dharwar and in Tanjore District (Madras Presidency) where the studies of Russell and Ramachandra Rao (1942) indicated that an average critical density of 5·0 per man-hour was required to maintain transmission, the same density has been assumed as a working limit

DHARWAR DISTRICT

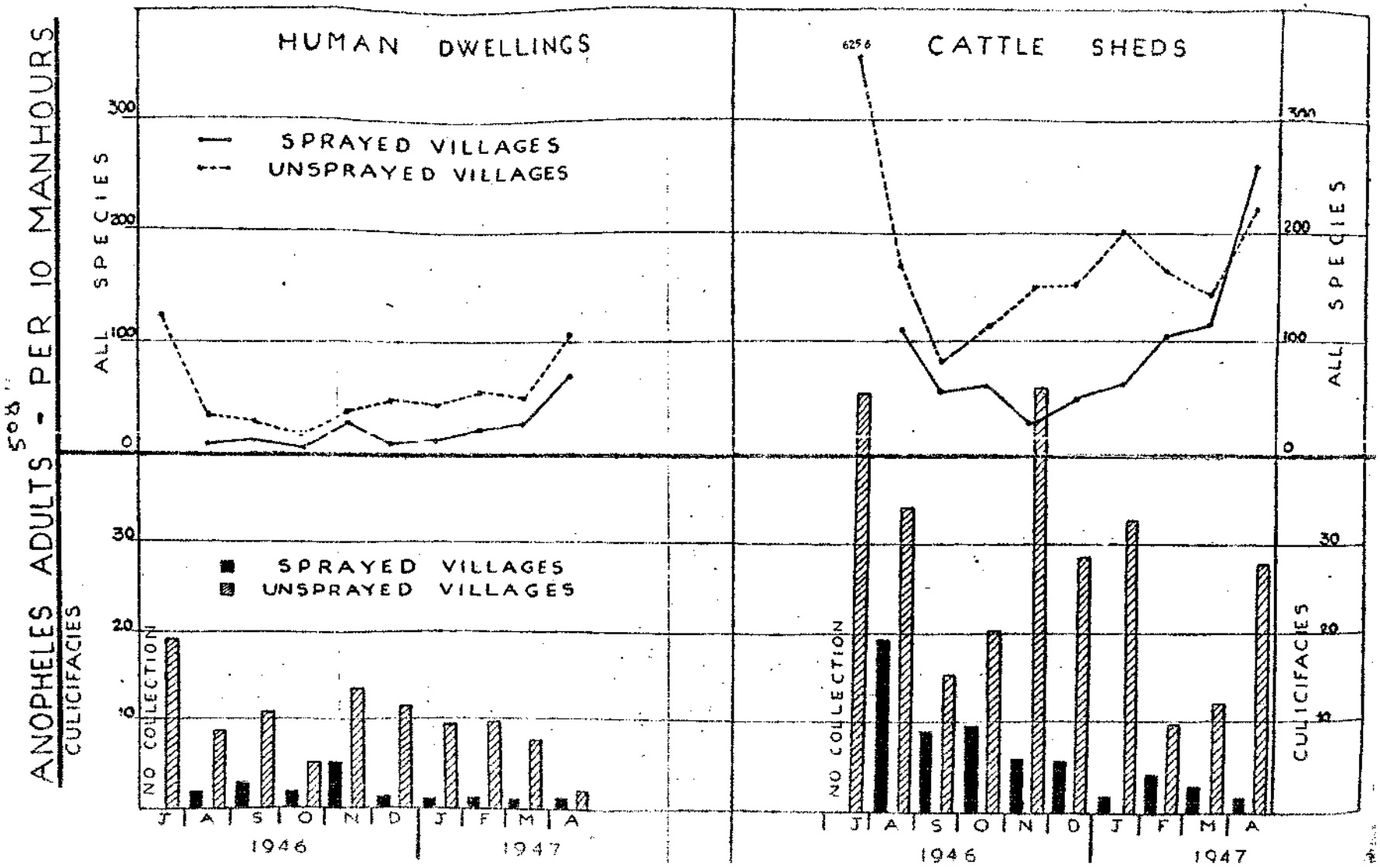
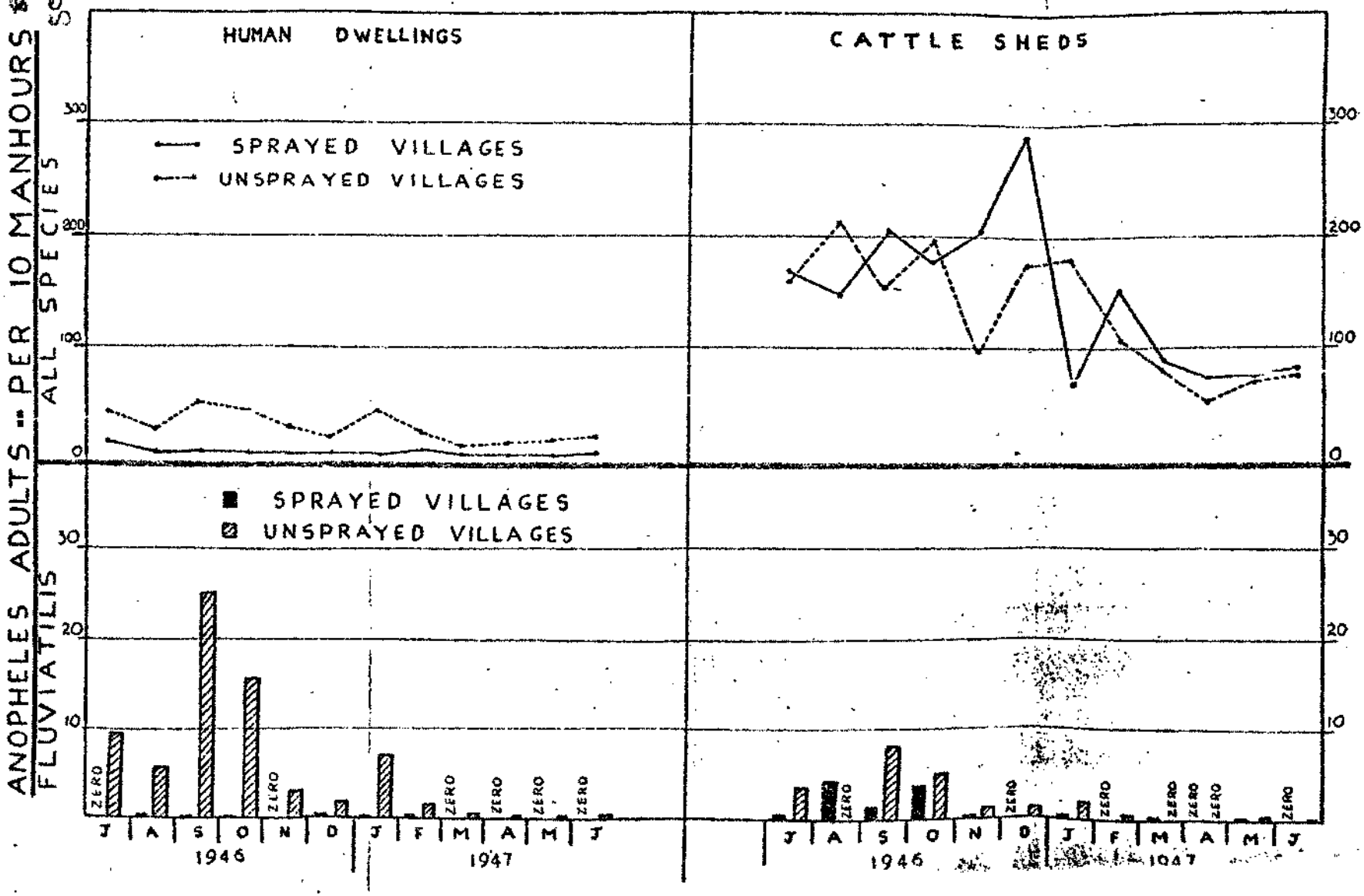


Chart 1.

KANARA DISTRICT



in Dharwar also. Experience has now shown that average densities of over 5·0 per man-hour are quite common in Dharwar District during the monsoon months.

No precipitin tests have been carried out so far but the species is so abundant in cattlesheds and mixed dwellings that it is presumably predominantly zoophilic. It rests below roofs as readily as on the lower parts of the walls.

DETAILS OF THE SCHEME.

ORGANIZATION.

The staff sanctioned for the scheme consists of—

Medical officers in charge of units	5
Assistant medical officers	8
Havildars (senior malaria field workers)	26
Sepoys (malaria field workers)	120
Head clerk	1
Clerks	9
Truck drivers	5
Truck cleaners	5

The general direction and technical supervision of the scheme are carried out by the authors of this paper.

The distribution of the field staff is as follows :—

(A) JULY–DECEMBER.

	Unit 1.	Unit 2.	Unit 3.	Unit 4.	Unit 5.
Headquarters ...	Dharwar	Dharwar	Haveri	Ranebennur	Sirsi
Jurisdiction talukas ...	Dharwar, Ron, Gadag, Mundargi, Supa.	Kalghatgi, Haliyal.	Haveri, Hubli, Bankapur.	Ranebennur, Kod.	Sirsi, Mundgod, Hangal, Yellapur.
Staff :—					
Medical officer ...	1	1	1	1	1
Assistant medical officers	2	2	1	1	2
Havildars	7	4	4	4	7
Sepoys	30	20	20	20	30
Drivers	1	1	1	1	1
Cleaners	1	1	1	1	1

(B) JANUARY–JUNE.

	Unit 1.	Unit 2.	Unit 3.	Unit 4.	Unit 5.
Headquarters ...	Karwar	Dharwar	Siddapur	Honavar	Sirsi
Jurisdiction talukas ...	Karwar, Ankola, Supa.	Whole of Dharwar District. (Assessment of results.)	Siddapur.	Honavar Kumta, Bhatkal.	Sirsi, Yellapur.
Staff :—					
Medical officer ...	1	1	1	1	1
Assistant medical officers	2	1+1 at head-quarters for appraisal of results.	1	1	2
Havildars	9		4	6	7
Sepoys	40		20	30	30
Drivers	2		1	1	1
Cleaners	2		1	1	1

Unit 1 had a small sub-unit with headquarters at Supa and unit 5 had another at Yellapur, both in Kanara District.

SPRAYING MATERIAL USED.

The formulation of D.D.T. spray used was chiefly the medium kerosene extract (M.K.E.)-D.D.T.-soap emulsion (formula of the Malaria Institute of India). D.D.T. technical was purchased in bulk from the Government Medical Stores. M.K.E. was secured from Assam Oil Co. in tank wagons. Stock emulsion was prepared according to the following formula :—

D.D.T. technical ...	...	100 lbs. (70–80 per cent para para).
M.K.E.	...	33 gallons.
Soap solution (20 per cent)	...	$3\frac{3}{4}$ gallons.

The complete solution of D.D.T. in M.K.E. took 24 to 48 hours and required constant agitation. To this the soap solution was added gradually and with continuous stirring. Bar soaps, or more frequently fine soap chips, were used and the solution of soap in water was hastened by the application of heat. When the soap solution was completely added, the stock emulsion was kept well stirred and agitated. Approximately 40 gallons of stock emulsion resulted from the above ingredients. The consistency of the stock emulsion varied to some extent depending upon the temperature of the atmosphere. In cooler weather the soap showed a tendency to congeal and the whole stock mixture was of a thicker consistency than in warmer weather. This did not however affect the final spray mixture so long as care was taken to mix the stock emulsion very thoroughly before each supply was drawn from it.

In the field, one part of the stock mixture is diluted with 4 parts of water, filtered through a sieve or a piece of cloth. Thus 200 gallons of final mixture were prepared from 100 lbs. of D.D.T., yielding a final 5 per cent concentration. The final mixture was thoroughly emulsified by pumping the entire mixture through the spraying nozzle dipped into the bucket.

The spraying equipment consists of stirrup pumps connected to a spraying lance with 10 to 12 feet of rubber pressure hose. The lance is 2¼ feet long and was provided with a stop cock to shut the spray off when required. The nozzle gives a fairly uniform cone-shaped spray of about 40°. The aperture is of 3/64 inch diameter and under normal working pressure discharges 600 to 650 c.c. of the spray fluid in one minute. Two sepoys were required to man each pump, one to pump and the other to spray.

Technique of spraying.

Dose.—Preliminary work showed that a deposit of about 56 milligrams of D.D.T. was necessary per square foot of the wall surface. A gallon of the final mixture was therefore sprayed over 4,000 square feet. The sizes of houses vary very considerably in both Kanara and Dharwar districts and there could be no uniformity in the quantity per house. An average of 4 village structures for one gallon of final mixture was considered a reasonable rate, as the interior of most of these houses was found to have about 1,000 square feet of spraying surface. But the quantities applied have in some large towns averaged even one gallon for two houses. A speed of spraying calculated to leave the requisite deposit was determined after careful testing and was enforced irrespective of the size of the structure to be sprayed.

The total quantities of D.D.T. actually used for one full year by the several units were—

	D.D.T. technical.	D.D.T. 50 per cent suspension powder.
	lbs.	lbs.
Unit 1	12,029	238
Unit 2*... ...	6,344	152
Unit 3	13,790	146
Unit 4	12,212	514
Unit 5	12,761	455
Total ...	57,136	1,505

* Spraying programme for only 6 months while all other units were employed in spraying all through the year.

Frequency of spraying.—The intervals between sprayings varied from 6 weeks to 10 weeks. Though every effort was made to spray every structure at exactly

2 months' intervals, the programme could not strictly be followed due to delay in transport of materials, breakdown in transport, etc. The frequency has lately been altered to once in 2 months in *fluviatilis* areas and once in 6 weeks in *culicifacies* areas.

On account of the epidemiological grounds already described, the entire malarious part of Dharwar District was sprayed from July to December, each village receiving three rounds of spray. In Kanara, the bulk of the villages in the hilly forest-clad zone was sprayed thrice from January to June. The villages in Haliyal and Mundgod talukas and the rice tract of Sirsi Taluka were also sprayed thrice from July to December. The whole of Yellapur Taluka and Supa Petha were sprayed from October to June, most of the villages receiving 4 to 5 rounds of spray.

Structures sprayed.—All human, mixed and animal dwellings in Dharwar District were sprayed but only human and mixed dwellings in Kanara. All resting places of mosquitoes up to 10 feet above the ground were sprayed in Kanara, whether they were walls, furniture and household articles, baskets, firewood stocks, shelves or low roofs. In Dharwar District also it was rarely necessary to spray higher than 10 feet above the ground level as most of the roofs were low. But when the roofs were high, they were sprayed only so far as the sepoy could reach with the fully extended arm.

Costs.

The sanctioned annual budget for the entire scheme was :—

	Rs.
Pay of officers	16,800
Pay of establishment	84,480
Allowances and honoraria (including dearness and travelling allowances)	32,720
Contingent charges—recurrent	2,00,000
Non-recurrent	50,000
TOTAL ...	3,84,000

The actual expenditure under several heads for the twelve-month period from July 1, 1946 to June 30, 1947, was as follows :—

	Rs.	A.	P.
Labour and supervision :—			
Pay of officers	13,263	5	0
Pay of establishment	47,968	11	0
Allowances	65,538	11	0
Contingent charges :—			
Recurrent (including cost of D.D.T., M.K.E., etc.)	2,37,025	9	4
Non-recurrent	11,538	0	6
TOTAL ...	3,75,334	4	10

The total population directly benefiting from the scheme, i.e. those living in the houses actually sprayed, was 725,179 but as already discussed in this paper at least a million people derived the benefits of the scheme directly or indirectly. On this basis the average cost of spraying three rounds during the season works to 6 annas *per capita* per annum, which, at the prevailing levels of wages and prices, is extremely low indeed. The *per capita* cost for a single round of spraying is Re. 0-2-0. The average density of population per house in the scheme area is about 5. Hence the cost of spraying one house for 3 rounds during the malaria season may be reckoned as Re. 1-14-0 and Re. 0-10-0 per round. It may be pointed out that the above *per capita* costs may only be applied to large scale projects. They however include the payment of salaries to the entire personnel including officers, staff and labour employed in the scheme which are not generally reckoned in most computations of this kind. The cost on behalf of the salary and allowances of the Assistant Director of Public Health and the Entomologist is alone excluded in the above reckoning as their services are available for the whole province. Since the population of the two scheme districts is about one-tenth of that of the province, if one-tenth of the salaries of the two officers is added to the cost of the scheme, it will only increase the *per capita* cost by one-half of a pie (or 1/384 of a rupee) which is insignificant.

RESULTS.

Densities of Anopheles adults.

In Tables II and III are set out data collected to assess the effect of D.D.T. residual spraying on densities of anopheline adults resting indoors. Table II refers to the data of Kanara District and Table III to those of Dharwar District. In both districts routine collecting stations were established in selected villages and timed collections were periodically made by trained insect collectors. The total time spent in collection though variable from place to place is large enough in any month to give a fair average. The data have also been given in Charts 2 and 3.

Kanara District.—It is quite evident from the data that there was a marked reduction in the densities of *fluviatilis*, the average monthly density not exceeding 0·2 per 10 man-hours or an average of one specimen per every 50 hours' search. In unsprayed villages, the incidence continued to be normal, in fact, the density was well above the assumed critical limit of 4·0 per 10 man-hours from July to September and again in January.

The cattlesheds in Kanara District which were not sprayed continued to yield good number of anophelines including fair number of *fluviatilis*. The spraying of neighbouring houses apparently had no effect on the mosquitoes which habitually frequent cattlesheds. But why there was not a greater reduction of *fluviatilis* in cattlesheds in sprayed villages is not easy to explain. Such a reduction had been noticed by Viswanathan and Parikh (*loc. cit.*) in the previous year's work.

Dharwar District.—The densities of the vector species, *culicifacies*, show distinct reductions both in houses and cattlesheds, but the degree of reduction is not of the

same order as that of *fluviatilis* in Kanara District. The reduction in human dwellings has varied roughly from 63 per cent to 82 per cent and in cattlesheds from 43 per cent to 95 per cent. These figures are of course very rough approximations but it can be noticed that during August, September and October when *culicifacies* production was perhaps at its highest the reduction was comparatively less.

Another important feature is the comparatively low *culicifacies* densities recorded even in the unsprayed villages, densities which are clearly below the assumed critical limit of 5·0 per man-hour (50 per 10 man-hours). While the whole question of the critical limits of *culicifacies* prevalence in relation to malaria transmission in Dharwar District remains to be studied in greater detail, it may be pointed that densities much higher than 5·0 per man-hour have been recorded in numerous villages of the district in connection with other investigations which are in progress. One of the reasons for the comparatively low prevalence in the unsprayed villages was because the routine villages had to be selected from among a small number of suitable ones which were available after the spraying operations commenced. Most of the malarious villages of the district had been taken up for spraying and the choice of unsprayed villages was limited to areas of non-endemicity or very low endemicity. Such comparison villages will naturally have low prevalence of *culicifacies*. The tremendous clamour of the people of the two districts for including their villages in the scheme may ultimately make it totally impossible to leave any for purposes of comparison.

Effect on spleen and parasite rates.

Kanara District.—In Tables IV and V are presented the latest spleen and parasite rates in sprayed and unsprayed villages respectively of Kanara District. The variations in the spleen rates in the sprayed villages are considerable, the highest being 45·0 per cent in a village in Siddapur Taluka and 5·0 in a village in Haliyal Taluka. The figures in Siddapur Taluka are comparatively higher because this was the first year when any type of antimalaria measures was undertaken in any of these villages included in it. The spleen rate for all the sprayed places in all the talukas put together is only 14·4 per cent as against a rate of 72·2 per cent in the unsprayed villages. Considering the fact that almost all the villages in Kanara were hyperendemic before the commencement of antimalaria operations, the reduction of the cumulative spleen rate to 14·4 per cent is highly significant.

The average parasite rates in the sprayed and unsprayed villages were 3·8 per cent and 14·6 per cent respectively.

The spleen and parasite rates* periodically recorded during previous years in respect of a few places are given below (*see* also Chart 3).

---

* The type of antimalaria measures in progress were :—

Sirsi Town—Antilarval :—All types and pyrethrum spraying.

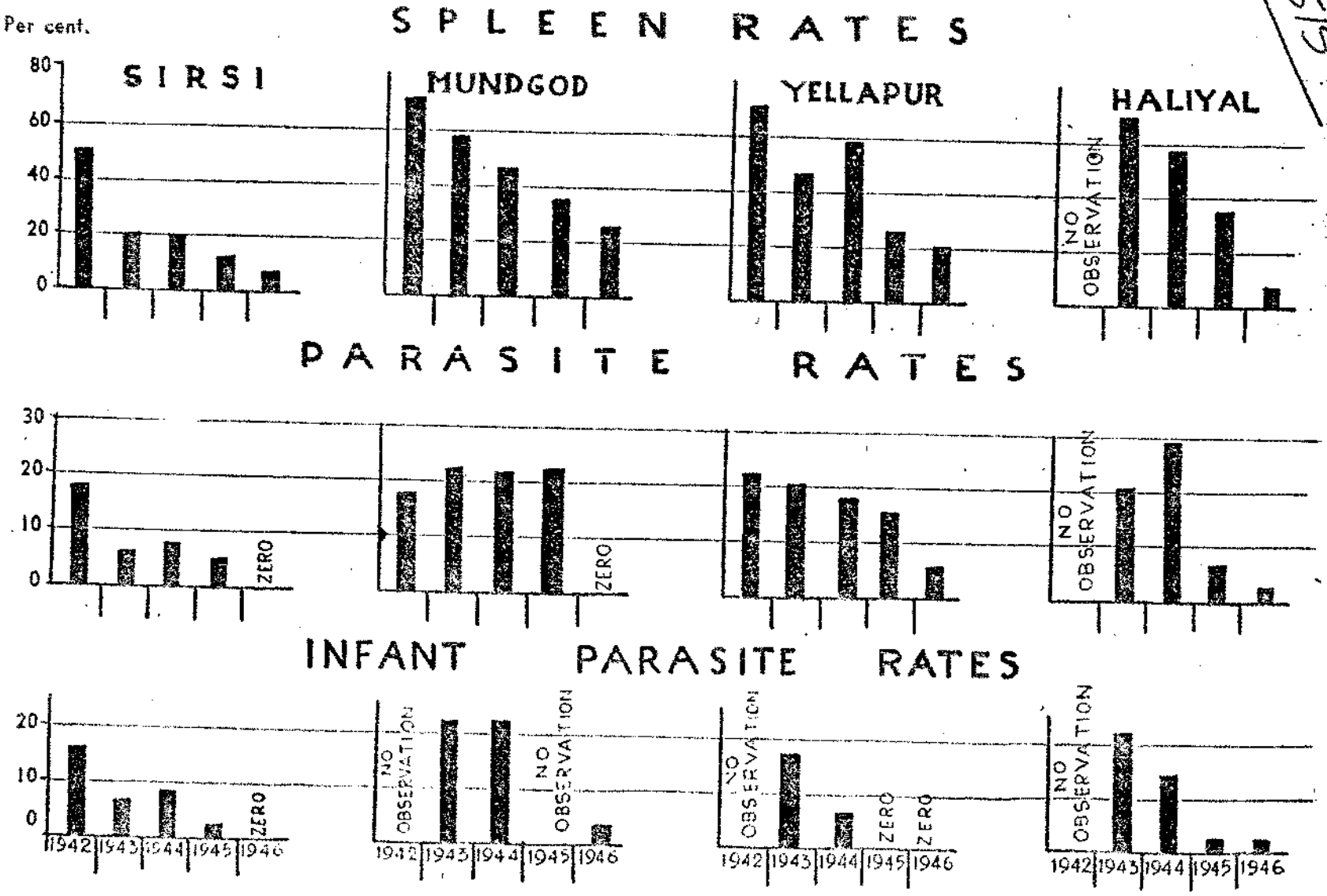
Yellapur Town—Antilarval :—Cleanweeding and flushing.

Mundgod Town—Antilarval :—Cleanweeding, partial coppercyaniding and pyrethrum spraying 1943–45.

Haliyal Town—Antilarval :—Cleanweeding 1943–45. Pyrethrum spraying 1944-45. D.D.T. spraying 1945.

CHART 3.

KANARA DISTRICT



515

Spleen rates.

	1942.	1943.	1944.	1945.	1946.
Sirsi Town ...	50	20	20	12	8
Yellapur Town ...	70	45	58	24	19
Mundgod Town ...	75	58	45	35	25
Haliyal Town ...	...	67	56	34	7
Parasite rates.					
Sirsi Town ...	18	6	8	5	5
Yellapur Town ...	22	20	18	15	5
Mundgod Town ...	18	22	22	23	0
Haliyal Town ...	...	20	29	7	3

Malaria control operation in one form or another has been in progress in these places, but the rates recorded subsequent to the inauguration of the D.D.T. scheme are the lowest.

Comparative spleen and parasite rates in a few sprayed villages, where such figures were available for 1942-43 season, are given below :—

Villages.	Spleen rates.		Parasite rates.	
	1942-43.	1946.	1942-43.	1946.
Dandeli ...	66·2	6·6	...	2·3
Pala ...	76·2	10·9	37·3	3·9
Chigalli ...	80·0	21·8	...	3·8
Siddapur ...	32·4	38·0	26·2	1·9
Kansur ...	92·7	13·3	50·0	6·6
Tyagali ...	80·0	24·2	48·5	9·3
Mavingundi ...	100·0	16·6	42·9	4·0
Halgeri ...	68·4	13·3	45·9	3·3

Dharwar District.—The spleen and parasite rates of the latest survey for the sprayed and unsprayed villages are presented in Tables VI and VII. The cumulative spleen rate in all the villages in all the talukas put together was 19·6 per cent

in sprayed villages and 28·3 in the unsprayed ones; the average parasite rates were 4·4 and 7·6 per cent respectively. As a detailed survey in Dharwar District had not been made prior to 1945, comparative figures for previous years are not available, but those for 1945-46 and 1946-47 in a few villages are given below:—

SPLEEN RATES IN DHARWAR DISTRICT.

	1945-46.	1946-47.
Dharwar Taluka.—		
Alnavar	40·0	30·8
Kelgeri	69·5	39·6
Mansur	60·3	26·3
Mugad	44·1	32·9
Navlur	71·0	27·4
Mummingatti	42·8	14·3
Tegur	68·6	44·8
Narendra	38·8	14·5
Kalghatgi Taluka.—		
Kalghatgi	57·4	8·7
Dastikop	41·5	13·5
Begur	36·7	16·3
Machapur	87·5	19·0
Modkihonnally	47·8	16·6
Ramanbal	26·3	24·2
Hubli Taluka.—		
Amargol	46·9	20·2
Unakal	45·1	26·9
Gabbur	22·0	9·5
Gokul	35·0	12·8
Adargunchi	8·8	5·0
Shervad	7·5	8·3

SPLEEN RATES IN DHARWAR DISTRICT—*contd.*

	1945-46.	1946-47.
Ranebennur Taluka.—		
Halgeri	27·3	8·0
Kuppelur	23·1	8·0
Itagi	45·0	22·4
Karur	21·3	10·0
Asundi	51·6	13·0
Motebennur	27·0	17·0
Ranebennur	11·0	1·2
Kod Taluka.—		
Rattihalli	19·6	6·0
Masur	53·2	30·0
Hirekerur	48·6	20·8
Tawargi	50·0	24·0
Hausbhavi	36·3	16·7
Chikkerur	39·7	16·0
Shiggaon Taluka.—		
Tadas	48·1	34·4
Shiggaon	13·0	20·8
Mundargi Petha.—		
Dambal	61·9	14·0
Mundargi	13·8	17·9
Haveri Taluka.—		
Haveri	23·1	8·5
Agadi	5·3	19·0

SPLEEN RATES IN DHARWAR DISTRICT—*concld.*

	1945-46.	1946-47.
Gadag Taluka.—		
Advisomapur	34·7	19·4
Asundi	29·4	19·5
Shikop	68·7	47·2
Gadag	9·7	10·2
Hirekop	81·8	43·9
Malsamudra	46·4	28·8
Nagasamudra	50·0	31·0
Papanashi	61·8	39·6

Reliable data for comparison of spleen rates of 1945-46 and 1946-47 seasons are not available for unsprayed villages, most of those surveyed in 1945-46 and found to be malarious having been included in the spraying schedule. But the general trend of malaria incidence does not appear to have undergone any distinct natural decline, because (1) the spleen rates in the unsprayed villages in Dharwar District were still high and (2) the spleen rates of villages in the neighbouring taluka of Khanapur in Belgaum District which were surveyed in July 1947 were still extremely high (Table VIII).

EFFECT ON INFANT PARASITE RATES.

The details of the infant parasite surveys carried out at the end of the first season of spraying in the sprayed and unsprayed villages of Kanara District are given in Tables IX and X. The infant parasite rate among 367 blood smears examined in the sprayed villages was 0·8 per cent while in 30 smears obtained from infants in 19 unsprayed villages it was 13·3 per cent. The number examined in the unsprayed villages due to the extremely sparse population there was small and particularly as villages with a population of over 100 had been taken up for spraying.

Similar data for Dharwar District is given in Tables XI and XII. It may be added that the unsprayed villages in which the infant blood smears were collected had a comparatively low spleen rate but not a single smear out of 237 examined was found with malaria parasites in this district among the sprayed villages, while in the former group the infant parasite rate was about 2 per cent.

The infant parasite rates in larger centres where periodical studies have been made in Kanara District were as follows :—

	1942.	1943.	1944.	1945.	1946.
Sirsi Town ...	16	6	8	2	0
Yellapur Town ...	...	16	6	0	0
Mundgod Town ...	...	22	22	...	3
Haliyal Town ...	...	22	14	2	2

Dispensary data.

It is too early as yet for the effects of the D.D.T. spraying on malaria incidence to be reflected in the data of attendance of malaria patients in the several public dispensaries in the districts. In only a few places such as Sirsi, Mundgod, Yellapur, Haliyal, Supa, Dandeli and Manchikeri was any type of malaria control operation in progress in previous years and therefore the 1946 figures may be regarded as the cumulative result of the work, including partly the effect of the D.D.T. work of the 1946-47 season. Even in such places the figures are vitiated to some extent by the inclusion of cases which originated in a large number of uncontrolled villages in the neighbourhood. In other places in Kanara District and in all places in Dharwar District the 1946 figures have been influenced only by the D.D.T. operations in progress during the few months in the latter part of 1946. In the coastal talukas of Kanara the 1946 figures bear no relation to the D.D.T. work at all, as the latter was commenced at the close of 1946 or soon thereafter.

The annual numbers of malaria patients treated in the several dispensaries of the two districts from 1943 to 1946 have been recorded in Table XIII for comparison of data for ensuing years.

DISCUSSION.

The activities and results recorded in this paper mark the end of one phase in the evolution of the Bombay Provincial Malaria Organization and the beginning of another. It is also a record of the largest rural malaria control project undertaken in India harnessing the wartime discovery and use of D.D.T. on a mass

scale. These activities may be looked upon as of a pioneer nature with fruitful facilities for extension on similar lines all over the province on the completion of malaria surveys now in progress in representative areas.

In the first five-year period since the creation of the Malaria Organization in 1942, investigations and experimental control measures revealed that antilarval work in *fluviatilis*-transmitted malarious localities was only possible where there was much concentration of human population, that paddy fields which were previously reckoned as unimportant breeding grounds will have to be included in a programme of antilarval control (Ramachandra Rao, 1945) and that for smaller communities such a programme was not economical. It was also established that cleanweeding of hill-streams and channels, the most favoured breeding grounds of *fluviatilis*, was not adequate for complete malaria control on account of the paddy fields also breeding *fluviatilis* and besides, repeated cleanweeding over a number of years tended to scour the bed and sides of channels during the monsoon on account of the removal of vegetation. In certain areas a judicious combination of antilarval measures combined with spraying with pyrethrum twice a week in the peripheral inhabited areas gave fairly satisfactory results at a cost of Re. 1 *per capita* per annum. In smaller communities spraying with pyrethrum had to be carried out on a spaced programme of two consecutive days of spraying separated by one and two sprayless days alternately every week. This method also cost about Re. 1 per head per annum. This rational spacing of spray-killing was necessitated by the outdoor resting habits of the vector species.

The advent of D.D.T. and the pilot experiments carried out in 1945 rendered malaria control in rural areas much more economically feasible, with the result that the conclusions derived from the activities of the first five-year period were no longer operative.

While in the first five-year phase only experimental control schemes were undertaken in a few selected centres, the present scheme operates in 2 out of the 20 districts of the province and benefits roughly 10 per cent of the total provincial population. The effects both by way of reduced malarial prevalence and appreciation by the public as well as by the state are of far-reaching value in the rapid expansion of similar schemes throughout the province. The Government of Bombay has sanctioned five malaria squads which are now engaged in carrying out surveys in the districts of Bijapur, Sholapur, Ahmedabad, Kaira and Nasik. A survey has already been completed in Thana District and a district-wide comprehensive scheme of malaria control is now engaging the attention of the Government of Bombay. When the survey in all the districts mentioned above is completed and schemes are submitted and sanctioned by Government, 8 out of the 20 districts of the province will have the benefit of a complete programme of rural malaria control. It is gratifying to record that the programme of activities of the malaria organization of this province has been cited as a model for other provinces to follow.

Although the scheme has been in operation for only a year and therefore too early to formulate a definite opinion as regards results the data recorded in this paper are sufficiently promising and in keeping with the theoretical expectations of a scheme of this kind. In Kanara District the cumulative spleen rates

in the sprayed villages is 14·4 per cent, while in unsprayed it is 72·2 per cent. A good number of the sprayed villages included in the above spleen census, it may be added, was subject to some kind of malaria control or other during the previous years as well. In Dharwar District where control was taken in hand for the first time the spleen rate in the sprayed villages is 19·6 per cent as against 28·3 per cent in unsprayed villages. In Kanara District the unsprayed villages are highly malarious and were not included in the scheme by reason merely of the fact that they were sparsely populated and widely scattered and hence in the early stages it was not considered economically feasible to include them, while in Dharwar District practically all highly malarious villages have been included in the scheme and hence one would not expect the same difference in spleen rates between sprayed and unsprayed villages as in Kanara District. However, the data recorded will serve for comparison in future years. There is no indication so far of any natural decline of malaria in the tract. When a mass scheme of this kind is undertaken it is extremely difficult to leave out any large group of malarious tracts inasmuch as the people have become so conscious of the results of the scheme that considerable resentment is expressed if any village is omitted solely for the purpose of scientific comparison. But whatever villages have been left out either on account of lack of data in the first instance or on account of sparse population continue to exhibit the same degree of incidence of malaria as judged by the spleen rates.

The infant parasite rates in Kanara District are 0·8 per cent in the sprayed villages and 13·3 per cent in the unsprayed villages. Previous infant parasite rates recorded in Kanara District are 15·2 per cent in Sirsi Town (Jaswant Singh and Jacob, *loc. cit.*); 32·3 per cent in Sirsi rural areas (Viswanathan and Parikh, *loc. cit.*) and 22 per cent in Haliyal Town (Viswanathan, 1945). These previous records were compiled in restricted areas whereas the present data are more comprehensive. It has to be pointed out in this connection that since only small villages with population less than 100 are excluded from the scheme, the availability of infants in such areas is extremely small. In Dharwar District not a single positive smear was encountered amongst 237 infants from the sprayed villages. The unsprayed villages have such low degree of malarial endemicity that one would not expect any significant parasite rate among infants.

As regards Anopheles densities there is a reduction of about 90 per cent in *fluviatilis* in Kanara District and of 70 to 80 per cent of *culicifacies* in Dharwar District. Both these reductions effectively keep down the density of the vector species in each area below the assumed critical threshold of transmission of 4 per 10 man-hours in the case of *fluviatilis* and 5 per man-hour in the case of *culicifacies*. In assessing the utility of the scheme from Anopheles densities recorded in indoor resting places the points to be borne in mind are :—

(*a*) Does the indoor density in sprayed dwellings represent the true proportions which escape destruction ?

(*b*) If the answer is in the negative, is it correct to use the indoor density figures for such assessment ?

Recent work of Kennedy (1947) and Muirhead Thomson (1947) has shown that spraying with D.D.T. may have a repellent effect on anophelines in that the

individual mosquitoes which enter houses for the purpose of feeding and get a momentary contact with the sprayed surface have a tendency to fly away quickly and that the dose received is not adequate to destroy them. It is also possible that specimens of the vector species might take the beeline to the host of predilection at night, complete feeding and move outdoors immediately thereafter. If they come in contact with the sprayed surface prior to feeding they may immediately move out without either getting infected or transmitting infection. If they come in contact after completion of feeding they still escape destruction but they would have either got infected or transmitted the infection. If such is proved to be the general experience, application of D.D.T. as an indoor residual spray will have no practical effect whatever and low densities of anophelines recorded from indoor resting places are no clues whatever to the quantum of malaria transmission. On the other hand, on theoretical grounds even if a large number of insects are caught after D.D.T. spraying it may only be a reflection of heavy breeding and such a record may still be consistent with effective reduction in malaria transmission so long as their longevity is reduced well below the period necessary for the development of the parasites in the insects. A true assessment therefore will have to include both basic field studies as made by Muirhead Thomson (*loc. cit.*) as well as epidemiological data which measures the incidence of malaria in a community. Judged from the latter standard the reduction in the transmission of malaria in the scheme area under report is undoubted and one may therefore indirectly conclude that with respect to the vector species in this area, viz. *fluviatilis* and *culicifacies*, D.D.T. is effective as an indoor residual spray in the dosage in which it is now applied. Repeated night collections in the scheme area have failed to show *fluviatilis* specimens in Kanara District. But this work has to be carried out on a more extended basis both in Kanara and in Dharwar districts.

It is apposite to record here the relations with the public in the practical implementation of the scheme. On the whole, public co-operation has been most cordial and the forceful exhortation of the Honourable the Prime Minister and the Minister of Health at the time of inauguration of the scheme coupled with the message of blessing received from Mahatma Gandhi have been not a little useful in this respect. In Dharwar District where the cattlesheds are also sprayed, the freedom that the cattle enjoy from ticks and other vermin as a result of spraying and their comparative better health has been even more appreciated by the farmers than the freedom from malaria. Among all the benefits arising out of the scheme the destruction of bugs is best appreciated by the public. It may be mentioned here that in none of the villages included in the scheme has there been any case of human plague although these two districts have reported plague cases in the previous years. One year's experience is however too meagre and future experience will show whether indoor residual spraying with D.D.T. as practised at present for malaria control will equally serve for plague control as well if the seasons coincide. If the measure is found to be beneficial in this respect in future as well, the mechanism of action would naturally be through the destruction of fleas which overflow from their hosts, the rats. The evidence will be even more marked if in the scheme area there is plague among rats but not among humans. The demand for inclusion of every village in the district whether malarial or not is a frequent embarrassing feature especially when a democratic Government is in power.

Advance notice is furnished to the villagers through the agency of the *Mamlatdars* of the Revenue Department and the village officers. In addition one member of the squad is made to visit the village the day previous to that programmed for spraying and give personal notice. In spite of this it has been the experience that on several occasions as many as 10 per cent of the houses remain locked and unavailable for spraying. Complaints of non-spraying inevitably arise on this account and ways and means are under contemplation to minimize the number of structures omitted from the spraying to the lowest limit possible. There is also a demand from the public for elaborate spraying at all places irrespective of the resting habits of the vector species of mosquitoes and hence the staff have to be disciplined both in patience and persuasion to satisfy the public on the one hand and to minimize the expenditure of material on the other and produce maximum results. Since a number of villages are included in the daily spraying programme it is inevitable that some portions of the villages are scheduled for spraying during the afternoon hours at a time when the people are having their food. Not infrequently they call for a postponement of the spray either late in the evening or even to the following day. This too calls for patient handling but in course of time it is expected that the public on appreciating results to their own satisfaction will more actively co-operate with the staff. Again the practice of smearing walls with mud or cowdung or of plastering them should not be undertaken during the spraying season inasmuch as the D.D.T. particles will be covered over and not be available for residual toxic action. Numerous leaflets have been distributed in all the villages appealing for public co-operation in all these respects. On the whole any staff engaged in a scheme of this kind will have to be repeatedly told of the great need to exercise utmost patience in dealing with the public and abstain from being over sensitive to public criticism. They must realize that in the earlier stages at all events appreciation will be hardly so vocal as criticism.

The frequency of spraying once in two months in the case of *fluviatilis* and once in six weeks in the case of *culicifacies* was evolved as a result of pilot experiments and judging from the present data this frequency seems to be adequate for the dosage now practised. The dosage also was determined from the pilot experiments and while any lessening of the dosage has been found to bring about the early reappearance of the vector species, increased dosage is not also considered necessary in view of the various factors prevailing in rural areas under the housing conditions described previously and it will not be possible to expect any prolongation of the period of residual toxicity beyond two months. While in order to ensure economy of material used, a working speed for labour has been determined and enforced, for the reasons already stated by Viswanathan and Parikh (*loc. cit.*) it is not considered strictly necessary to enforce a very uniform spread of the spraying mixture.

Various formulations of D.D.T. have been tried such as D.D.T. suspension powder containing 50 per cent D.D.T. and emulsion containing 20 per cent D.D.T. concentrate (Torch brand) diluted with water to a final concentration of one per cent of D.D.T. Best results continue to be achieved by the use of a 5 per cent emulsion of D.D.T. made out of a D.D.T. concentrate in M.K.E. and applied in a dosage of 60 milligrams per square foot. Amidst the dark cloud of malarial hyperendemicity in the scheme area there was the silver ray that one-half of the

area had its season in one half of the year and the other in the other half, thus making it possible to employ trained staff all the year round. But this circumstance is not likely to be available elsewhere and the seasonal employment of trained labour will be inevitable. But there is no question about the need to keep the trained higher personnel in service all the year round. Indeed one visualizes with the advent of D.D.T. the possibility of calling the squads public health squads and not merely malaria squads, so that provision may be found for their suitable employment all the year round.

The working cost of 6 annas per head per annum of the scheme is the lowest on record for rural malaria control in an area where the malaria season extends for at least 6 months in the year especially at the present high levels of price of materials and wages for labour. There is no more ground for the tilt of the administrator. 'If malaria is preventable, why not prevent it', since not only is it feasible for the state to provide the funds, but for public health departments to demonstrate tangible results in vast rural areas. Indeed, expression may be given to what is not more than an impression at present, that D.D.T. indoor residual spraying will not only control malaria but possibly also minimize fly-borne diseases and the incidence of human plague. While the insufflation of rat-burrows with D.D.T. may effectively control an epizootic of plague and consequently plague amongst humans as well without affecting the rat-population, D.D.T. indoor residual spraying will not help in the prevention of the epizootic but may prevent human plague. In fact, the occurrence of rat-falls in not a few villages in the present scheme area without any case of human plague tends to offer a pointed evidence towards such a hypothesis. This, however, will have to be watched over a series of years. If this is confirmed, two diseases can be effectively controlled by a single measure provided the seasons coincide.

It is often suggested that the advent of D.D.T. had rendered species sanitation obsolete and obviated the need for detailed entomological surveys and investigations. This is indeed a misconception. The frequency of spraying is dependent on the species. Its daily output, its resting habits and its vulnerability to D.D.T. all play a significant part in the determination of frequency, dosage and quantities consumed which affect costs. The total omission of cattlesheds from spraying as well as its restriction to not more than 10 feet height in Kanara is an instance of the application of the principle of species sanitation based on the habits of the local vector, *fluviatilis*.

Finally, it has to be recorded that during more than a year's continuous spraying no evil effects have been observed either among men and domestic animals or among the labour employed.

SUMMARY.

The first year's results of a large rural malaria control project in Kanara and Dharwar districts of the Bombay Province, India, with D.D.T. indoor residual spraying, together with the details of the area and topography, population involved, epidemiological features, type of organization, methods and costs are described.

Fluviatilis and *culicifacies* are the vectors and the seasons of transmission are July to November in one section and December to June in the other.

Nearly a population of a million living in an area of 8,486 square miles derived the benefits of the scheme at an average cost of 6 annas *per capita* per annum.

The staff was divided into five units each in charge of a trained medical officer.

The formulation of D.D.T. used was the D.D.T.-medium kerosene extract-soap formula devised by the Malaria Institute of India. The stock emulsion containing 25 per cent D.D.T. was diluted in the field to give a final 5 per cent mixture. The dosage adopted was approximately 56 milligrams per square foot, and the spraying frequency was once in two months during the transmission season. Depending upon the bionomics of the vector species, all human, mixed and animal dwellings in Dharwar District and only human dwellings in Kanara were sprayed.

An average reduction of 90 per cent of *fluviatilis* in the sprayed structures in Kanara and of 70 to 80 per cent of *culicifacies* in Dharwar was noticed.

The cumulative spleen rates in the sprayed and unsprayed villages in Kanara were 14·4 and 72·2 per cent respectively; in Dharwar they were 19·6 and 28·3 respectively. The parasite rates were 3·8 and 14·6 respectively in Kanara and 4·4 and 7·5 respectively in Dharwar.

Infant parasite rates were 0·8 per cent in the sprayed villages and 13·3 per cent in the unsprayed ones in Kanara and were 0 per cent and 2·1 per cent respectively in Dharwar.

The relations with the public in the implementation of the scheme are discussed.

REFERENCES.

JASWANT SINGH, and JACOB, V. P. (1944).	*J. Mal. Inst. Ind.*, **5**, 2, pp. 267–303.
KENNEDY, J. S. (1947) ...	*Bull. Ent. Res.*, **37**, 4, pp. 593–607.
MUIRHEAD THOMSON, R. C. (1947).	*Trans. Roy. Soc. Trop. Med. Hyg.*, **40**, 5, pp. 511–536.
RAMACHANDRA RAO, T. (1945) ...	*J. Mal. Inst. Ind.*, **6**, 1, pp. 77–82.
RUSSELL, P. F., and RAMACHANDRA RAO, T. (1942).	*Amer. J. Trop. Med.*, **22**, 5, pp. 535–558.
SOPER, F. L., and WILSON, D. B. (1943).	*Anopheles gambiæ* in Brazil, 1930 to 1940. The Rockefeller Foundation, New York.
VISWANATHAN, D. K. (1945) ...	*J. Mal. Inst. Ind.*, **6**, 1, pp. 1–38.
Idem. (1946*a*) ...	*Ibid.*, **6**, 3, pp. 253–257.
Idem. (1946*b*) ...	*Ibid.*, **6**, 4, pp. 371–382.
VISWANATHAN, D. K., and PARIKH, R. O. (1946).	*Ibid.*, **6**, 4, pp. 383–389.
VISWANATHAN, D. K., and RAMACHANDRA RAO, T. (1943).	*Ibid.*, **5**, 2, pp. 255–260.
VISWANATHAN, D. K., RAMACHANDRA RAO, T., and RAMARAO, T. S. (1944).	*Ibid.*, **5**, 4, pp. 449–461.
Idem (1945) ...	*Ibid.*, **6**, 2, pp. 243–245.

TABLE I.

Population and number of villages included in the D.D.T. scheme, Dharwar and Kanara districts, during 1946-47.

Taluka.	Total population (1941 census).	Total number of inhabited villages.	Actually included in the scheme.				Season of spraying.
			Population.	Percentage.	Villages.	Percentage.	
Kanara District.							
Sirsi, rice tract ...	43,274	238	17,233	78	24	55	Rice tract July–Nov.
Sirsi, garden tract			16,613		81		Garden tract Dec.–June.
Siddapur ...	34,126	195	30,027	88	107	55	Dec.–June.
Yellapur ...	15,227	123	11,951	78	52	43	Oct.–June.
Haliyal ...	28,204	92	23,481	83	37	40	July–Nov.
Mundgod ...	10,894	61	7,849	72	22	36	
Supa ...	14,812	126	9,141	62	31	25	Oct.–June.
Karwar ...	68,376	61	35,424	52	28	46	Dec.–June.
Ankola ...	42,213	80	14,305	34	24	30	
Kumta ...	71,745	126	35,299	49	28	22	
Honavar ...	66,980	91	42,971	64	54	59	
Bhatkal ...	45,306	57	36,488	81	26	51	
Total for Kanara District.	441,157	1,250	282,117	64	514	41	
Dharwar District.							
Dharwar ...	130,070	124	72,505	56	26	21	July–Nov.
Kalghatgi ...	41,986	85	31,969	76	45	53	
Hubli ...	169,616	73	28,460	17	25	34	
Bankapur ...	81,442	138	28,518	35	20	15	
Haveri ...	112,973	127	62,238	55	44	35	
Hangal ...	70,796	144	35,468	50	44	31	
Ranebennur ...	121,422	120	78,044	64	51	43	
Kod	104,929	168	44,577	43	47	28	
Gadag ...	127,375	59	27,717	22	19	32	
Ron	105,930	84	10,013	10	14	17	
Mundargi ...	36,759	42	23,490	64	15	36	
Navalgund ...	68,235	56	*Nil*		*Nil*		
Naragund ...	29,483	31	*Nil*		*Nil*		
Total for Dharwar District.	1,201,016	1,251	443,062	37	350	28	
TOTAL FOR BOTH THE DISTRICTS.	1,642,173	2,501	725,179		864		

TABLE II.

Density of anopheline adults, Kanara District.

Month.	SPRAYED VILLAGES.						UNSPRAYED VILLAGES.						REMARKS.
	HUMAN DWELLINGS.			CATTLESHEDS.			HUMAN DWELLINGS.			CATTLESHEDS.			
	Time spent, hours.	Per 10 man-hours.		Time spent, hours.	Per 10 man-hours.		Time spent, hours.	Per 10 man-hours.		Time spent, hours.	Per 10 man-hours.		
		Fluviatilis.	All anophelines.		*Fluviatilis.*	All anophelines.		*Fluviatilis.*	All anophelines.		*Fluviatilis.*	All anophelines.	
1946.													
July ...	135·0	0·0	12·1	57·0	0·4	163·3	64·5	9·3	38·1	22·0	3·6	161·9	
August ...	134·0	0·2	3·4	81·5	3·6	148·4	155·0	5·3	21·8	87·66	0·0	213·4	
September ...	168·0	0·1	7·4	87·0	1·3	204·6	201·0	24·6	48·4	94·0	8·0	152·9	
October ...	143·5	0·1	4·3	80·5	3·7	174·3	239·75	15·2	41·1	108·8	4·9	192·7	
November ...	18·8	0·0	2·8	70·5	0·1	202·1	214·0	2·9	29·2	83·3	0·9	97·4	
December ...	209·0	0·2	3·3	33·2	0·0	287·9	221·75	1·6	18·53	77·7	1·2	172·5	
1947.													
January ...	841·5	0·1	1·6	266·5	0·2	67·9	244·0	7·0	42·1	91·0	2·0	178·8	
February ...	346·0	0·2	6·0	102·5	0·0	155·5	194·0	1·4	24·0	61·0	0·5	110·0	
March ...	411·0	0·0	2·7	119·0	0·3	89·7	158·5	0·4	13·9	49·5	0·0	82·2	
April ...	413·0	0·0	2·2	137·5	0·0	75·4	187·0	0·2	16·0	60·5	0·0	52·72	
May ...	403·0	0·0	1·4	124·0	0·1	74·9	217·0	0·2	16·4	72·0	0·4	73·0	
June ...	298·0	0·0	4·1	99·5	0·0	84·1	266·5	0·3	20·0	89·0	0·1	77·6	

TABLE III.

Density of anopheline adults, Dharwar District.

Month.	SPRAYED VILLAGES.						UNSPRAYED VILLAGES.						Remarks.
	Human and mixed dwellings.			Animal dwellings.			Human and mixed dwellings.			Animal dwellings.			
	Time spent, hours.	Per 10 man-hours.		Time spent, hours.	Per 10 man-hours.		Time spent, hours.	Per 10 man-hours.		Time spent, hours.	Per 10 man-hours.		
		Culicifacies.	All anophelines.		*Culicifacies.*	All anophelines.		*Culicifacies.*	All anophelines.		*Culicifacies.*	All anophelines.	
1946.													
July ...	...	...	...	...	...	...	34·0	19·1	123·5	17·0	46·5	625·6	No data in sprayed structures in July 1946.
August ...	66·5	1·9	5·7	28·3	19·1	110·4	62·5	8·6	33·3	28·5	33·7	168·1	
September ...	160·0	2·9	11·6	148·0	8·9	56·9	157·0	10·7	28·9	152·0	15·1	83·3	
October ...	191·0	1·2	4·8	123·0	9·5	61·3	185·5	5·1	15·0	120·5	20·1	117·1	
November ...	300·0	5·0	26·2	100·0	6·8	27·1	291·5	13·7	38·8	84·5	47·1	152·9	
December ...	439·7	1·1	7·2	104·3	5·5	54·4	227·3	11·4	47·0	70·5	28·5	152·8	
1947.													
January ...	395·0	0·7	9·4	96·0	1·6	62·8	331·5	9·2	41·9	63·0	32·4	198·6	
February ...	303·5	0·8	22·2	77·3	4·5	108·7	240·7	9·6	53·7	64·0	9·9	165·5	
March ...	388·0	0·8	25·9	88·0	3·1	117·8	213·0	7·6	50·4	61·0	12·1	143·4	
April ...	249·8	1·0	73·4	37·3	1·6	290·7	219·8	1·8	107·5	20·5	27·5	220·9	

TABLE IV.

Spleen and parasite rates in sprayed villages, 1946-47.

Taluka.	Village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.	REMARKS.
	Kanara District.							
Sirsi	Sirsi Town ...	314	26	8·2	237	11	4·6	...
Siddapur	Harsikatta ...	20	9	45·0	20	4	20·0	No antimalaria measures of any kind had been done in these villages before.
	Siddapur ...	105	40	38·0	105	2	1·9	
	Kansur ...	15	2	13·3	15	1	6·6	
	Bilgi ...	45	7	15·5	45	2	4·4	
	Mavingundi ...	25	4	16·0	25	1	4·0	
	Halgeri ...	30	4	13·3	30	1	3·3	
	Tyagli ...	20	7	24·2	29	2	9·3	
	Total ...	269	73	27·1	269	13	4·8	
Mundgod	Mundgod ...	112	20	17·9	50	0	0·0	
	Pala ...	82	9	10·9	81	3	3·7	
	Chigalli ...	78	17	21·8	78	3	3·8	
	Total ...	272	46	16·9	209	6	2·7	
Yellapur	Yellapur ...	138	26	18·8	49	1	2·4	
	Kirwatti ...	52	8	15·4	51	2	3·9	
	Total ...	190	34	17·9	100	3	3·0	
Haliyal	Dandeli ...	90	6	6·6	88	2	2·3	
	Yedoga ...	50	8	16·0	50	2	4·0	
	Kanchanhalli	50	12	24·0	50	3	6·0	
	Haliyal ...	234	16	6·8	198	6	3·0	
	Targaon ...	100	5	5·0	50	1	2·0	
	Total ...	524	47	8·6	436	14	3·2	
	GRAND TOTAL ...	1,569	226	14·4	1,251	47	3·8	

Note.—Of the 47 positive blood smears, 14 were *vivax*, 24 *falciparum* and 9 *malariæ*.

TABLE V.

Spleen and parasite rates in unsprayed villages [illegible] 1940-47.

Taluka.	Village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.	REMARKS.
	Kanara District.							
Siddapur	Malanhalli ...	14	10	...	14	6	...	
	Gattikai ...	9	8	...	9	3	...	
	Honchadde ...	...	...	...	2	0	...	
	Pudanbail ...	...	...	...	5	1	...	
	Total ...	23	18	78·3	30	10	33·3	
Sirsi	Hutgar ...	12	2	16·6	...	...	...	
	Gowdalli ...	6	6	100·0	...	...	...	
	Janmane ...	26	3	11·5	26	2	7·7	
	Hudalkop ...	13	11	84·4	13	4	30·8	
	Sankeri ...	11	6	54·5	...	...	...	
	Vadgeri ...	13	11	84·4	13	1	7·7	
	Ullala ...	11	10	90·9	11	2	18·2	
	Hangar ...	11	3	27·2	11	2	18·2	
	Ublekop ...	12	11	91·6	12	3	25·0	
	Umblekop ...	6	6	100·0	6	0	0·0	
	Total ...	121	69	57·0	92	14	15·3	

TABLE V—*concld.*

Taluka.	Village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.	REMARKS.
Mundgod	Lakkolli ...	7	6	85·7	7	0	...	
	Nyasargi ...	21	17	80·9	21	0	...	
	Ajjihalli ...	17	13	76·5	17	4	...	
	Maradgi ...	11	9	81·8	11	1	...	
	Singanhalli ...	16	13	81·2	16	0	...	
	Malvalli ...	21	18	85·7	21	3	...	
	Alhalli ...	13	10	76·9	10	1	...	
	Convalli ...	17	13	76·5	17	2	...	
	Total ...	123	99	80·5	120	11	9·1	
Haliyal	Modalgeri ...	19	17	89·4	19	7	36·7	
	Guttigeri ...	22	9	40·9	21	1	4·8	
	Joginkop ...	15	12	80·0	15	3	20·0	
	Tegginhalli ...	19	13	68·4	19	2	10·5	
	Chibbalgeri ...	23	16	69·5	23	4	17·4	
	Bidkihal ...	21	17	80·9	20	2	10·0	
	Total ...	119	84	...	117	19	16·2	
Yellapur	Kalsur ...	6	6	...	6	0	0·0	
	Bargadde ...	15	13	...	15	1	6·7	
	Mundwad ...	12	11	...	12	3	25·0	
	Jenginkeri ...	8	7	...	8	2	25·0	
	Hunshettikop ...	9	8	...	9	0	0·0	
	Total ...	50	45	90·0	50	6	12·0	
GRAND TOTAL ...		436	315	72·2	409	60	14·6	

Note.—Of the 50 positive blood smears for which species identification is available, 18 were *vivax*, 22 *falciparum* and 10 *malariæ*.

TABLE VI.

Spleen and parasite rates in sprayed villages, 1946-47.

Taluka.	Village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.	REMARKS.
	Dharwar District.							
Dharwar	Ainawar ...	104	32	30·8	91	4	4·4	
	Mugad ...	88	29	32·9	81	3	3·7	
	Navalur ...	80	23	28·8	80	2	2·5	
	Rayapur ...	62	17	27·4	62	1	1·6	
	Tegur ...	107	48	44·8	92	5	5·4	
	Kelgeri ...	53	21	39·6	51	3	5·8	
	Mummigatti ...	91	13	14·3	...	...	...	
	Mummigatti ...	91	13	14·2	58	2	3·4	
	Narendra ...	55	8	14·5	53	2	3·7	
	Mansur ...	41	11	26·3	41	2	4·8	
	Total ...	681	202	29·7	609	29	3·9	
Dharwar Town	Sarswatpur ...	57	5	8·8	51	1	2·0	
	Gandhichaowk	83	1	1·2	...	...	...	
	Line Bazaar ...	127	3	2·4	...	...	...	
	Hosyellapur ...	75	12	16·0	73	2	2·6	
	Total ...	342	21	6·1	124	3	2·4	

TABLE VI—*contd.*

Taluka.	Village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.	REMARKS.
Hubli	Bhairedevarkop	60	21	35·0	40	3	7·5	
	Amargol ...	84	17	20·2	52	2	3·8	
	Unkal ...	156	42	26·9	91	0	0·0	
	Keshwapur ...	90	4	4·4	81	0	0·0	
	Kodgunchi ...	39	3	7·7	39	1	2·5	
	Adargunchi ...	80	4	5·0	58	1	1·7	
	Gabbur ...	42	4	9·5	42	1	2·4	
	Nulvi ...	96	5	5·2	90	3	3·3	
	Sherwad ...	72	6	8·3	72	2	2·7	
	Rayanal ...	47	6	12·6	47	2	4·2	
	Revdihal ...	28	4	14·2	28	1	3·5	
	Gokul ...	54	7	12·8	42	2	4·7	
	Total ...	948	123	13·0	682	18	26·4	
Kalghatgi	Dasnur ...	34	6	17·9	34	2	5·9	
	Jammihal ...	38	8	21·1	38	2	5·2	
	Belvantra ...	54	7	12·8	44	2	4·5	
	Machapur ...	21	4	19·0	21	1	4·9	
	Kalghatgi ...	149	13	8·7	103	2	2·0	
	Ramanhal ...	33	8	24·2	33	1	3·0	
	Begur ...	55	9	16·3	42	1	2·4	
	Dastikop ...	59	8	13·5	54	2	3·7	
	Modkihonnalli	54	9	16·6	45	2	4·5	
	Jimmur ...	42	8	19·0	42	2	4·7	
	Total ...	539	80	14·8	456	17	3·7	

TABLE VI—*contd.*

Taluka.	Village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.	REMARKS.
Gadag	Advisomapur	77	15	19·4	52	4	7·6	
	Kurtkoti ...	55	10	18·2	48	3	6·2	
	Hirekop ...	41	18	43·9	41	4	9·7	
	Chikop ...	36	17	47·2	36	3	8·3	
	Nagsamudra ...	45	14	31·1	45	3	6·5	
	Asundi ...	82	16	19·5	52	3	5·7	
	Papnashi ...	48	19	39·6	48	4	8·3	
	Malsamudra ...	52	15	28·8	52	3	5·8	
	Total ...	426	124	29·1	374	27	7·2	
Mundargi Petha	Mundargi ...	78	14	17·9	54	4	7·4	
	Dambal ...	85	34	40·0	85	8	9·4	
	Bardur ...	57	12	21·1	46	3	6·4	
	Kaknur ...	44	8	18·2	44	3	6·8	
	Total ...	264	68	25·8	229	18	7·9	
Kod	Tawargi ...	50	12	24·0	...	...	...	
	Hirekerur ...	120	25	20·8	...	...	...	
	Hausbhavi ...	120	20	16·7	...	...	...	
	Chikkerur ...	75	12	16·0	...	...	...	
	Rattihalli ...	100	6	6·0	...	...	...	
	Masur ...	100	30	30·0	...	...	...	
	Total ...	565	105	18·6				

TABLE VI—*concld.*

Taluka.	Village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.	REMARKS.
Ranebennur	Ranebennur ...	173	2	1·2	...	...	...	
	Chalgeri ...	70	5	7·1	...	...	...	
	Karur ...	60	6	10·0	...	...	...	
	Motebennur ...	117	20	17·0	...	...	...	
	Kuppelur ...	50	4	8·6	...	...	...	
	Halgeri ...	75	6	8·0	...	...	...	
	Asundi ...	62	8	13·0	...	...	...	
	Itagi ...	67	15	22·4	...	...	...	
	Total ...	674	66	9·8				
Bankapur	Tadas ...	93	32	34·4	...	...	...	
	Timmapur ...	46	15	32·6	...	...	...	
	Dhundashi ...	124	72	58·1	...	...	...	
	Salvan-Somapur	84	43	51·2	...	...	...	
	Total ...	347	162	46·7				
Haveri	Agadi ...	126	24	19·0	...	...	...	
	Haveri ...	236	20	8·5	...	...	...	
	Total ...	362	44	12·2				
GRAND TOTAL ...		5,058	995	19·7	2,454	106	4·3	

TABLE VII.

Spleen and parasite rates in unsprayed villages, 1946-47.

Taluka.	Village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.	REMARKS.
	Dharwar District.							
Dharwar	Somapur ...	75	13	17·3	...	...	...	
	Guladkop (School)	61	5	8·3	61	2	3·2	
	Maradgi ...	52	6	11·5	...	...	...	
	Kadabgatti ...	44	24	54·5	42	8	19·0	
	Guladkop ...	54	27	50·0	46	7	15·2	
	Inamatehebballi	93	18	21·6	54	3	5·5	
	Kumbarganvi ...	55	51	92·7	51	6	11·7	
	Yerikop ...	53	11	20·7	53	3	3·6	
	Garag ...	64	11	17·2	64	1	1·6	
	Tadkod ...	55	7	12·7	35	2	5·7	
	Ambali ...	27	26	96·5	...	...	...	
	Arawatgi ...	17	16	94·1	...	...	...	
	Kagilkeri ...	38	36	94·7	...	...	...	
	Kumbarkop ...	39	34	87·2	...	...	...	
	Total ...	727	285	39·2	406	32	7·9	
Hubli	Nagshattikop ...	49	4	8·2	35	1	2·8	
	Bengeri ...	60	4	6·6	54	...	...	
	Birnal ...	38	1	2·6	38	...	...	
	Anchatgeri ...	43	33	76·3	43	9	20·9	
	Gangyal ...	30	28	93·3	30	7	23·3	
	Total ...	220	70	31·8	200	17	8·5	
Kalghatgi	Hirehonnalli ...	58	8	13·8	58	1	1·7	
	Bisnalli ...	22	11	50·0	22	1	4·5	
	Rangapur ...	27	4	14·8	27	1	3·6	
	Total ...	107	23	21·5	107	3	2·8	
Gadag	Hulkoti ...	78	23	29·5	78	6	10·2	
	Bhinakankatti ...	56	12	21·4	40	4	10·0	
	Gadag ...	108	11	10·2	62	4	6·4	
	Hirehandihal ...	49	14	28·5	42	3	7·1	
	Total ...	291	60	20·6	222	17	7·7	

TABLE VII—*concld.*

Taluka.	Village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Number examined.	Number showing malaria parasites.	Parasite rate, per cent.	REMARKS.
Mundargi	Kadampur ...	42	11	26·6	42	4	9·5	
	Shirol ...	39	8	20·5	39	3	7·8	
	Meundi ...	60	13	21·6	52	4	7·8	
	Total ...	141	32	22·7	135	11	8·2	
Bankapur	Advisomapur ...	48	17	35·4	...	...	...	
	Shiggaon ...	168	35	20·8	...	...	...	
	Bisanhalli ...	38	6	15·8	...	...	...	
	Ankadkhana ...	72	14	19·4	...	...	...	
	Total ...	326	72	22·1				
Haveri	Budgatti ...	48	9	18·8	...	...	...	
	Yallapur ...	98	9	23·6	...	...	...	
	Yatnihalli ...	47	12	25·5	...	...	...	
	Basankatti ...	39	9	23·1	...	...	...	
	Malapur ...	22	4	18·2	...	...	...	
	Sulladkatti ...	112	21	18·8	...	...	...	
	Total ...	366	64	17·5				
Kod	Yallapur ...	30	4	13·3	...	...	...	
	Sungubbi ...	20	3	15·0	...	...	...	
	Hiremorab ...	20	4	20·0	...	...	...	
	Total ...	70	11	15·7				
Ranebennur	Aladgeri ...	30	8	26·7	...	...	...	
	Chikmagnur ...	32	9	28·1	...	...	...	
	Belkankonda ...	25	4	16·0	...	...	...	
	Total ...	77	21	27·3				
GRAND TOTAL ...		2,391	676	28·3	1,068	80	7·5	

Note.—Of the 80 positive blood smears, 26 were *vivax*, 53 *falciparum* and 1 *malariæ*.

TABLE VIII.

Results of a spleen survey in Khanapur Taluka, Belgaum District, carried out in August 1947, just prior to extension of D.D.T. scheme.

Serial number.	Name of village.	Number examined.	Number with enlarged spleen.	Spleen rate, per cent.	Average enlarged spleen.
1	Londa ...	69	13	19·0	2·4
2	Mendiguli ...	48	24	50·0	2·0
3	Merdi ...	36	16	44·4	1·4
4	Karjgi ...	12	10	83·3	3·0
5	Halga ...	34	14	41·2	1·3
6	Carbanhatti ...	25	9	35·6	1·2
7	Nagargalli ...	25	25	100·0	4·3
8	Kumbhardi ...	17	16	94·1	3·0
9	Surwanwadi ...	11	10	91·0	3·9
10	Buwankoji ...	12	11	91·6	3·8
11	Tawargatti ...	30	30	100·0	4·3
12	Nandgad ...	137	20	40·0	1·8
13	Chotoli ...	30	21	70·0	2·6
14	Belewad ...	21	7	33·3	1·5
15	Kunkikop ...	20	6	30·0	2·0
16	Bidi ...	40	25	62·5	1·5
17	Junjwad ...	28	11	39·2	1·5
18	Halsi ...	43	15	35·0	2·2
19	Wadi ...	27	6	22·2	2·1
20	Bastwad ...	14	12	85·7	3·2
21	Khanapur ...	120	45	37·5	1·6
22	Ladewadi ...	14	3	21·4	1·6
23	Kawandal ...	26	8	30·8	2·3
24	Rumarwadi ...	18	1	5·5	...
25	Jundhol ...	26	8	30·8	2·1
26	Karambal ...	28	6	21·4	1·5

TABLE IX.

Infant parasite rates in sprayed villages, 1946-47.

Taluka.	Village.	Number examined.	Number showing malaria parasite.	Parasite rate, per cent.	REMARKS.
	Kanara District.				
Yellapur	Yellapur Town ...	94	0	0·0	
Sirsi	Sirsi Town ...	110	0	0·0	
Mundgod	Chigalli ...	15	0	0·0	
	Pala ...	15	0	0·0	
Haliyal	Dandeli ...	21	0	0·0	
	Yadogi ...	10	0	0·0	
	Tergaon ...	22	1	4·6	
	Haliyal ...	50	1	2·0	
Mundgod	Mundgod ...	30	1	3·3	
	TOTAL ...	367	3	0·8	

TABLE X.

Infant parasite rates in unsprayed villages, 1946-47.

Taluka.	Village.	Number examined.	Number showing malaria parasite.	Parasite rate, per cent.	REMARKS.
	Kanara District.				
Mundgod	Nyasargi ...	2	0	0·0	
	Alhalli ...	2	2	100·0	
Sirsi	Janmane ...	1	0	0·0	
	Vadgeri ...	2	0	0·0	
	Hundalkop ...	1	0	0·0	
	Uplekop ...	2	1	50·0	
	Hangar ...	1	0	0·0	
	Ullal ...	1	0	0·0	
	Hutgar ...	1	0	0·0	
Haliyal	Guttigeri ...	2	0	0·0	
	Joginkop ...	2	0	0·0	
	Teggunberalli ...	2	0	0·0	
	Chibbalgeri ...	1	0	0·0	
Yellapur	Bargadde ...	4	1	25·0	
	Mundwad ...	1	0	0·0	
	Tenginkeri ...	3	0	0·0	
	Hunshettinkop ...	1	0	0·0	
	Kalsar ...	1	0	0·0	
	TOTAL ...	30	4*	13·33	

* *Vivax* 1, *falciparum* 1, *malariæ* 1.

TABLE XI.

Infant parasite rates in sprayed villages, 1946-47.

Taluka.	Village.	Number examined.	Number showing malaria parasite.	Parasite rate, per cent.	REMARKS.
	Dharwar District.				
Dharwar	Narendra ...	12	0	0·0	
Hubli	Bhairedevarkop	16	0	0·0	
	Amargol ...	22	0	0·0	
	Kodgunchi ...	6	0	0·0	
	Adargunchi ...	21	0	0·0	
	Raynal ...	12	0	0·0	
Kalghatgi	Kalghatgi ...	35	0	0·0	
	Begur ...	14	0	0·0	
	Dastikop ...	18	0	0·0	
	Modakihonnalli ...	15	0	0·0	
Gadag	Adavisomapur ...	16	0	0·0	
Mundargi	Mundargi ...	26	0	0·0	
	Dambal ...	24	0	0·0	
	TOTAL ...	237	0	0·0	

TABLE XII.

Infant parasite rates in unsprayed villages, 1946-47.

Taluka.	Village.	Number examined.	Number showing malaria parasite.	Parasite rate, per cent.	REMARKS.
	Dharwar District.				
Dharwar	Inamati Hebbali	20	0	0·0	
	Garag ...	22	0	0·0	
	Tadkod ...	12	0	0·0	
Hubli	Anchatgeri ...	12	1	8·3	
	Ganbyal ...	6	1	16·6	
Gadag	Hulkoti ...	22	0	0·0	
	TOTAL ...	94	2*	2·1	

* *Vivax* 1, *falciparum* 1.

TABLE XIII.

Number of malaria patients treated in public dispensaries in Kanara and Dharwar districts.

Dispensary.	1943.	1944.	1945.	1946.	REMARKS.
Kanara District.					
Sirsi	5,567	8,763	6,509	4,327	In these villages some kind of antimalaria measures have been in operation from 1943-44.
Mundgod ...	4,145	2,934	2,045	1,796	
Yellapur ...	3,750	3,083	2,742	2,717	
Haliyal ...	7,603	5,632	4,159	3,782	
Supa	2,369	1,907	1,772	1,397	
Dandeli ...	2,871	2,337	1,610	910	
Manchikeri ...	2,304	1,792	1,819	1,826	
Kumta ...	9,956	10,279	9,401	4,269	Spraying operation commenced only in Dec.-Jan. 1946-47.
Karwar ...	3,306	2,672	3,639	3,709	
Ankola ...	3,626	5,175	2,868	1,761	
Gokarn ...	2,151	4,924	2,176	2,261	
Honnavar ...	3,951	5,798	4,866	...	
Siddapur ...	1,190	1,630	2,305	1,786	
Bhatkal ...	4,746	5,710	6,407	5,263	
Dharwar District.					
Dharwar ...	4,747	4,719	4,878	2,863	
Kalghatgi ...	783	1,296	1,956	692	
Haveri ...	9,437	7,919	5,267	2,622	
Hangal ...	4,963	7,321	3,141	1,767	
Ranebennur ...	7,311	9,611	7,416	3,578	
Hirekerur ...	2,993	3,392	1,321	1,479	
Shiggaon ...	4,602	3,603	2,613	1,016	

INDEX OF AUTHORS

PAGE

A

ADHIKARI, A. K. Suppressive mepacrine treatment to the staff of B. A. Railway in 1945 337

AFRIDI, M. K. A critical review of therapeutic trials on paludrine carried out in India during 1946 347

AFRIDI, M. K., and BHATIA, M. L. Malaria control of villages around Quetta (Baluchistan) with D.D.T. 279

AFRIDI, M. K., and DALIP SINGH. A scheme for the control of malaria in villages in Delhi Province 423

AFRIDI, M. K., RAMAKRISHNAN, S. P., GOSWAMI, A., and MENON, M. K. An enquiry on certain aspects of paludrine 221

B

BAILY, J. D. *See* VISWANATHAN, D. K., and BAILY, J. D.

BASU, B. C. The frequency of distribution of gametocytes of the Indian strains of malaria parasites 123

BASU, B. C. Abnormal development of malarial oocysts in *A. stephensi* ... 129

BHATIA, M. L. *See* AFRIDI, M. K., and BHATIA, M. L.

BHATIA, M. L. *See* PURI, I. M., and BHATIA, M. L.

BOGHANI, B. P. *See* PAREKH, J. G., and BOGHANI, B. P.

C

COVELL, G. The Malaria Institute of India, 1938–47 1

COVELL, G. A brief review of the history and development of the more important antimalarial drugs 231

COVELL, G. Bats, clover, water lettuce and malaria 243

D

DAKSHINAMURTY, S. Measurements of malaria. Part I 301

DALIP SINGH. *See* AFRIDI, M. K., and DALIP SINGH.

PAGE

DATTA, P. N. *See* DE, M. N., and DATTA, P. N.

DE, M. N., and DATTA, P. N. Final report on the study of 58 cases of malaria treated with paludrine 373

DE BURCA, B., and FORSHAW, H. W. Winter variations of the larva of *A. fluviatilis* from Northern India and Bombay Presidency ... 417

DE BURCA, B., and JACOB, V. P. Further notes on malaria in Fort Sandeman 413

F

FORSHAW, H. W. *See* DE BURCA, B., and FORSHAW, H. W.

G

GANGULI, N. Preliminary note on investigation of malaria in Bengal-Orissa border, south of Khargpur 289

GHOSH, B. N. Preliminary report on the result of treatment of malaria with paludrine 369

GOSWAMI, A. *See* AFRIDI, M. K., RAMAKRISHNAN, S. P., GOSWAMI, A., and MENON, M. K.

I

IYENGAR, M. O. T. *See* JAFAR, M., and IYENGAR, M. O. T.

J

JACOB, V. P. *See* DE BURCA, B., and JACOB, V. P.

JAFAR, M. Preliminary report on the use of paludrine in the field ... 365

JAFAR, M., and IYENGAR, M. O. T. The incidence of malaria in a deltaic area of Lower Bengal between the Damodar and the Hooghly rivers ... 441

K

KRISHNASWAMI, A. K. *See* PURI, I. M., and KRISHNASWAMI, A. K.

L

LOMAX, P. H. Paludrine treatment enquiry in Assam 389

M

MENON, M. K. *See* AFRIDI, M. K., RAMAKRISHNAN, S. P., GOSWAMI, A., and MENON, M. K.

MULLIGAN, H. W., and SOMMERVILLE, T. Malaria in the Malabar squirrel 329

PAGE

N

NAGENDRA, S. Further observations on dry leaf packing for the control of mosquito breeding 67

P

PAREKH, J. G., and BOGHANI, B. P. Report on the use of paludrine tablets 383

PETTMAN, W. E. C. Flushing streams as an antimalaria measure under field service conditions 395

PHILIP, M. I. *See* RAO, V. V., and PHILIP, M. I.

PURI, I. M. The practical application of DDT for malaria control in rural and urban areas in India 211

PURI, I. M., and BHATIA, M. L. Studies on some insecticides against anopheline adults and larvæ. Part III 183

PURI, I. M., and KRISHNASWAMI, A. K. Studies on some insecticides against anopheline adults and larvæ. Part II 159

PURI, I. M., and KRISHNASWAMI, A. K. Studies on some insecticides against anopheline adults and larvæ. Part IV 193

PURI, I. M., and RAJINDAR PAL. Studies on some insecticides against anopheline adults and larvæ. Part I 133

R

RAJINDAR PAL. *See* PURI, I. M., and RAJINDAR PAL.

RAMACHANDRA RAO, T. *See* VISWANATHAN, D. K., and RAMACHANDRA RAO, T.

RAMAKRISHNA, V. *See* RAO, V. V., and RAMAKRISHNA, V.

RAMAKRISHNA, V. *See* SENIOR WHITE, R., RAMAKRISHNA, V., and RAO, V. V.

RAMAKRISHNAN, S. P. *See* AFRIDI, M. K., RAMAKRISHNAN, S. P., GOSWAMI, A., and MENON, M. K.

RAO, V. V. *See* SENIOR WHITE, R., RAMAKRISHNA, V., and RAO, V. V.

RAO, V. V. On gonotrophic discordance among certain Indian Anopheles 43

RAO, V. V., and PHILIP, M. I. The relationship between the breeding of *A. fluviatilis* and distance from human dwellings 37

RAO, V. V., and RAMAKRISHNA, V. De-weeding tanks and ponds in anti-malaria operations 51

PAGE

RAO, V. V., and RAMAKRISHNA, V. Control of breeding of *A. sundaicus* by *Eichhornia*-cover 419

Report of a committee convened for the co-ordination of policy regarding the prevention of malarial conditions produced during the construction of roads and railways 253

S

SATYA SWAROOP. *See* YACOB, M., and SATYA SWAROOP.

SENIOR WHITE, R. On the anthropophilic indices of some Anopheles found in East Central India 111

SENIOR WHITE, R., RAMAKRISHNA, V., and RAO, V. V. Malaria on the North Madras coast 81

SOMMERVILLE, T. *See* MULLIGAN, H. W., and SOMMERVILLE, T.

SRIVASTAVA, R. S. Final report on the field trials of 'paludrine' in selected hyperendemic malarious areas of Naini Tal Tarai in the United Provinces (11th September to 31st December, 1946) 361

V

VISWANATHAN, D. K., and BAILY, J. D. Experiments with paludrine in the chemotherapy of malaria 307

VISWANATHAN, D. K., and RAMACHANDRA RAO, T. Control of rural malaria with D.D.T. indoor residual spraying in Kanara and Dharwar Districts, Bombay Province. First year's results 503

Y

YACOB, M., and SATYA SWAROOP. Malaria and spleen rate in the Punjab 469

YACOB, M., and SATYA SWAROOP. Preliminary forecasts of the incidence of malaria in the Punjab 491

INDEX OF SUBJECTS

ANOPHELES, *fluviatilis*, breeding and distance from human dwellings, 37; winter variations, 417; gonotrophic discordance, 43; anthropophilic indices, 111; *stephensi*, malarial oöcysts, 129; *sundaicus*, control in breeding, 419.

BIONOMICS, *see* Anopheles, 37, 43; *stephensi*, see Anopheles, 129; *fluviatilis*, see Anopheles, 417.

BALUCHISTAN, D.D.T. control in Quetta, 279; malaria in Fort Sandeman, 413.

BENGAL, incidence of malaria, 441.

CENTRAL INDIA, indices of some, *see* Anopheles, 111.

CONTROL, de-weeding in antimalaria operations, 51; dry leaf packing, 67; studies on some insecticides, 133, 159, 183, 193, 211; D.D.T. indoor residual spraying in Bombay Province, 503.

D.D.T., practical application, 211; *see* control, 503.

DRUGS, antimalarial drugs, 231; suppressive mepacrine treatment, 337; enquiry on certain aspects of paludrine, 221; therapeutic trials on paludrine, 347; field trials with paludrine, 361, 365; treatment of malaria with paludrine, 369, 373; use of paludrine tablets, 383; paludrine treatment enquiry in Assam, 389.

ENGINEERING, flushing streams, 395.

FLUVIATILIS, see Anopheles, 37, 417.

INSECTICIDES, *see* control, 133, 159, 183, 193, 211; malaria control with D.D.T., 503.

MADRAS, malaria on the North Madras coast, 81.

MALARIA, bats, clover, water lettuce and, 243; investigation on the Madras-Orissa border, 289; Malaria Institute of India, 1938–47, 1; malaria in the Malabar squirrel, 329; control in Delhi Province, 423; and spleen rate in the Punjab, 469; incidence of, in the Punjab, 491; malaria in Fort Sandeman, 413; *see* Madras, 81; co-ordination of policy for the prevention of malarial conditions during the construction of roads and railways, 253.

PARASITES, distribution of gametocytes in certain strains, 123.

PALUDRINE, *see* drugs, enquiry on certain aspects of paludrine, 221; therapeutic trials, 347; field trials, 361, 365; treatment with, 369, 373; use of, 383; treatment enquiry, 389.

PUNJAB, *see* malaria, 469

STATISTICS, measurements of malaria, 301.