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THE PREVENTION OF MALARIA IN THE FEDERATED MALAY STATES

BY

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WITH A PREFACE

BY

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CONTENTS

APPENDIX

REFERENCES

ILLUSTRATIONS

APPENDIX

PREFACE

Towards the end of last year I asked Dr. Malcolm Watson to contribute an article to my book on the Prevention of Malaria regarding his work in the Federated Malay States. Unfortunately, the article which he sent to me, though interesting from beginning to end, was too long to be inserted with the contributions furnished by nineteen other workers in various parts of the world; and I therefore determined to try to publish his paper as a separate book. We are greatly indebted to Sir Frank Swettenham, G.C.M.G., the distinguished organiser of Federal Administration in the Protected Malay States, for the assistance which he gave us in this respect. Mr. H. J. Read, C.M.G., of the Colonial Office, was kind enough to approach him on my behalf regarding the matter; and the result was that the various Companies mentioned on a previous page generously provided the necessary funds. Not only Dr. Watson and myself owe our thanks to Sir Frank Swettenham and to these Companies for the help given to us, but I think that the Governments and peoples of many malarious countries will be not less grateful.

The time is one of change and advancement in our ideas of colonial development. We are passing away from the older period of incessant wars and of great military or civil dictatorships into one of more minute and scientific administration in which the question always held before us is: What can best be done for increasing the prosperity of the people? Sanitation is almost the first word in the answer. Prosperity is impossible in the face of widespread disease, and perhaps the very first effort which must be made in new countries is to render them reasonably safe, not only from human enemies, but from those small or invisible ones which in the end are so much more injurious. As one example of this new theorem I can quote that of Panama, where the Americans began their great work by laborious sanitary preparations. Another example will be found in this book.

The author describes the origin of the Federated Malay States and the great sanitary problem which remained when that Federation was completed. It is a picture of a great work and of a great difficulty beyond it. Political adjustments are not everything, and for additional successes the statesman must be followed by the man

of science and the scientific administrator. Possessed of great natural riches, of an intelligent population and of neighbouring sources of intelligent labour, the States appeared from the first to have been designed for wealth and success. Within them, however, there lived a relentless enemy—a disease which hampers all human work, especially that of the pioneer and the planter, to a degree which will scarcely be believed in this country; and the task before the Government was to subdue this enemy if possible. I have said elsewhere that the Panama Canal is being dug with a microscope, and I believe that the same instrument will double the wealth of the Federated Malay States.

Technically, Dr. Watson's book is of the utmost value to all workers against malaria. He has laboured at his campaign for eight years; has studied the disease from every point of view, and its prevention by every method. He has attacked it in towns, in villages and in plantations; and has thrown into the work a degree of energy and enthusiasm which has not been exceeded in any anti-malaria campaign which has been carried out since we learned the manner in which it is carried from man to man. This book contains the details of his methods and the lessons which he has to teach. I may, perhaps, be allowed the privilege of considering it to be a part of my own work mentioned above.

More than ten years have now elapsed since we learned how the disease is carried. This has been a period of probation, during which many methods of prevention have been tentatively investigated. We have had great examples of success by various methods in the Panama Canal Zone, in Italy, in Ismailia, and in many other places; but I trust that this book, which describes the no less brilliant campaign of the Federated Malay States, will furnish the Governments, the health departments, and the planters of every malarious country with detailed information which they can always use for similar work; and we may now hope that progress will become still more rapid and complete in the future.

RONALD ROSS.

University of Liverpool.
1st December, 1910.

THE PREVENTION OF MALARIA IN THE FEDERATED MALAY STATES

INTRODUCTION

British Administration in the Federated Malay States. Only a generation ago a small band of Britons were sent to Malaya. Utterly insignificant in number, backed by no armed force to give weight to their words, they had strict orders only to advise the native chiefs and not to rule. Civil war raged in the land. To take one step from the beaten track was to be lost in a forest which had held men in check from the beginning of time. And they were expected to create order from jungle, and turn strife to peace.

A hopeless task it might appear, but they brought with them those qualities which have spread the power and influence of Britain throughout the world. In the work of these men will be found the highest examples of the tact, of the scrupulous dealing with native rulers, and of the sound administration, which have built up the British Empire. And the progress they made is almost too great to grasp. They found it a land deep in the gloom of an evergreen forest, whose darkness covered even darker deeds; for man fought with man, and almost every man's hand was against his fellows. In the space of one generation thousands of acres have been wrested from the jungle; thousands of people now live in peace and plenty; a railway stretches from end to end of the land; roads, second to none, bear motors of every kind; while chiefs who had never entered each other's country except with sword in hand, met in harmony in conference with the Man whose genius had made federation possible.

In Swettenham's History of British Malaya will be found the record of this marvellous change, and with scientific instinct the author contrasts the condition of the Federated States under British control, with that of the other Malay States which were still under Siam and their native rulers. These form a 'control' to the British experiment. To the Federated Malay States, British Administration has brought wealth and prosperity to which can be found no parallel.

And with the wealth has come health. From hundreds of square miles, malaria, which formerly exacted a heavy toll from Malay and foreigner alike, has been driven out.

Day by day it is being pushed back. Strong as its position now is in the hills, that too is being undermined, and it is my object to record the victories of the past and indicate the line of attack in the future.

Position and Climate. The following observations have been made in portions of the Malay Peninsula lying between the 2nd and 6th degrees of North latitude. The Peninsula itself lies between the 100th and 107th degrees of East longitude. The climate is therefore to be described as equatorial; that is, it is equable, hot, moist and without extreme either of heat or cold. Than such a climate none could be conceived more suitable for the propagation of the mosquito, and both in number of species and number of individuals the Culicidae are well represented.

'The rainfall is large, and is, on the whole, fairly evenly 'distributed throughout the year. In those parts of the States 'where a difference is noticeable the wettest period of the year is 'from September to March. The rainfall is always considerably 'heavier in localities near the hills than on flat land near the coast.

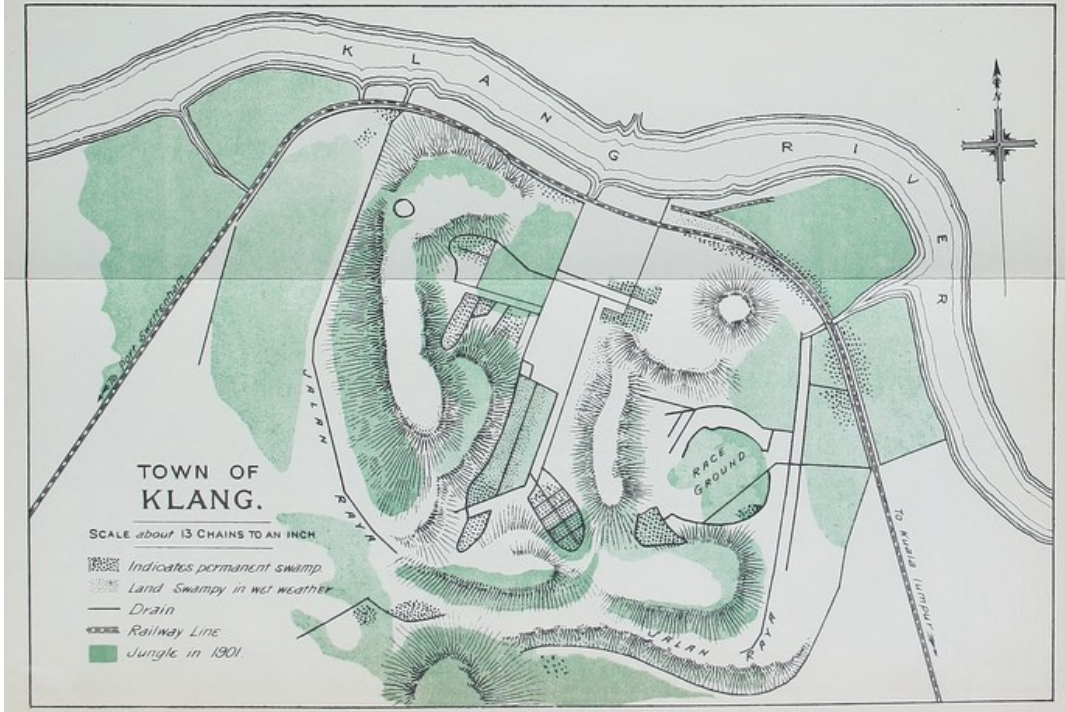
'The average rainfall in the hilly inland districts varies between '100 and 200 inches, while in the drier parts of the States it is 'usually recorded at from 70 to 100 inches per annum.'[1]

The general meteorological condition is as represented by the official return given in the Medical Report of Selangor for the year 1908.

Meteorological Return of Kuala Lumpur for the year 1908.

	Temperature						Rainfall		Winds	
	Solar Maximum	Minimum on Grass	Shade Maximum	Shade Minimum	Range	Mean	Amount in Inches	Degree of Humidity	General Direction	Average Force
January ...	147·2	53·1	90·5	71·1	19·4	80·9	7·71	79	N.W.	Not recorded
February...	149·6	52·5	90·1	70·6	19·5	80·8	14·01	77	Calm	
March ...	143·9	52·6	89·8	70·8	19·0	80·2	10·10	79	S.W.	
April	144·2	52·3	91·2	73·1	18·1	81·1	7·25	75	S.W.	
May.....	147·7	51·9	90·5	72·1	18·4	80·8	6·42	78	S.W.	
June.....	146·4	52·4	90·4	71·9	18·4	80·9	6·76	78	S.W.	
July	146·4	52·6	89·6	71·2	18·4	80·5	3·28	80	S.W.	
August ...	147·8	51·6	89·7	71·4	18·3	80·2	2·98	79	S.W.	
September	142·8	52·8	88·3	72·0	16·3	79·3	10·17	81	S.W.	
October ...	142·5	52·9	88·7	72·1	16·6	80·2	8·73	80	S.W.	
November	140·5	53·2	88·9	72·2	16·7	79·7	7·71	81	S.E.	
December	147·7	52·8	89·6	72·2	17·4	80·2	4·17	78	Calm	
Mean..	145·5	52·5	89·7	71·7	18·0	80·4	7·44	78	S.W.	

Total Rainfall 89·29 inches.


K L A N G R I V E R
TOWN OF
KLANG.
SCALE about 13 CHAINS TO AN INCH
Indicates permanent swamp
Land Swampy in wet weather
Drain
Railway Line
Jungle in 1901
JALAN RAJA
RACE GROUND
TO KUALA LUMPUR

Under such conditions it is not surprising that malaria should, in certain places, be a veritable scourge. And it is and has been so.

The former Residency of the British Resident of the State of Perak, built on one of the finest sites in the capital, had to be abandoned on account of malaria, and when recently I visited it the fine drive up the hill was so overgrown that I was unable to force my way to the top. Proposals for the abandonment of the town of Jugra were at one time made. Orders were actually given by telegraph by the High Commissioner to close Port Swettenham, within two months of its being opened, on account of the disease. A coffee estate was abandoned a few years ago on account of the impossibility of living on it, and at the present moment on many estates this disease is the cause of the gravest anxiety.

Since the disease is essentially a local one, it will be preferable if I first deal with my observations of various localities, and afterwards deal with their relationship to each other and their bearing on malaria in other countries.

PART I

MALARIA IN TOWNS

I.—Town of Klang. This town, the headquarters of the district of the same name, is situated on the Klang River some twelve miles from its mouth by river, and five miles as the crow flies. In 1901 the census of the population showed there were 3,576 inhabitants, occupying 293 houses. Since then the town has greatly increased in density of population as well as area. Within the old town limits of 1901 the number of houses has increased from 293 to 468, which would give an estimated population of 5,745. This, I believe, will be found to be less than the actual increase of the population. In all subsequent statistics when comparison is made between the figures of different years it is to be understood that these figures refer only to the population within the town limits of 1901, and not to those of the present town limits. The old town limit was practically the Jalan Raya except where for three-quarters of a mile this road ran parallel with the river and the river was the boundary.

The area of the town was in 1901 approximately 290 acres. Of this 22 acres was swamp, 25 acres virgin jungle, and 80 acres dense secondary growth in many places 30 to 40 feet high. The distribution of these undesirable portions will be seen from the map. The whole town was permeated with their influence, and it is hardly surprising that malaria was a scourge.

Assuming duty early in January, 1901, as Government Surgeon of the Districts of Klang, Kuala Selangor and Kuala Langat of the State of Selangor, one of the Federated Malay States, I found the hospital at Klang full of malaria. It appeared to me that my duty consisted in doing more than remaining in hospital all day treating patients, since to this there could be no end if no steps were taken to prevent infection of the population. At this time, Ross's brilliant discovery[2] had been fully confirmed by the Italians and others. Manson's dramatic proof at Ostia[3] and at London left no doubt of what could be done under certain conditions. Ross[4] himself had favoured mosquito reduction, and was actively engaged in West Africa in putting this method to the test.[5] The Italians were rather in favour of mechanical prophylaxis by mosquito netting, and by the use of quinine, and Koch[6] had already reported a success in a small community by the regular use of this drug.

At this time nothing was known about the species of Anophelines, and the valuable reports of the Commissioners[41] of the Malaria Committee of the Royal Society bearing on the importance of species were not published until the year after the works at Klang had been begun.

Choice of Anti-Malaria Method. At Klang the work of eradicating malaria seemed well nigh hopeless. No hot or cold season even temporarily stopped the mosquito pest, and every well, ditch and swamp teemed with larvae. The active co-operation of the native community could not be expected, and active resistance, especially from the Chinese, was certain if any attempt were made to enforce the use of quinine. An enforcement of mosquito nets was, of course, impossible, since this would have meant constant house visitation at night. Compulsory screening of the whole of all

the houses was impossible for financial reasons. The large acreage of swamp, the heavy rainfall and the amount of supervision required, apart altogether from its cost and temporary efficacy, prohibited the use of petroleum.

Again, with an area so extensive, sub-soil water so high as to form permanent swamps, and aquatic vegetation so dense, sweeping out or dealing with the individual collections of water in any continuous manner, was impossible. As Surgeon of a district fully 100 miles long, I felt that the time I could devote to any anti-malarial measures would be limited, and I also felt that no other member of the community was at all likely, either to be willing or able, to give more time than myself to the supervision of measures which would only keep down mosquitos as long as they were constantly applied. And to be quite candid, knowing that the burden would fall on myself, I did not quite appreciate the idea of having constantly to stand in the sun supervising coolies and insisting on that thoroughness on which alone success would depend.

Considering all these elements of the problem, I rejected as impossible Koch's quinine method, and the Italian mechanical prophylaxis, and decided to recommend Ross's method of mosquito reduction. To suit the local conditions I determined that any expenditure should be on works of a permanent nature. By draining and filling there would be a large and permanent reduction of the breeding places of mosquitos, and presumably malaria would be correspondingly reduced.

Finally I must confess that I by no means expected the success which as a fact followed the works. I had the feeling that perhaps a 20 per cent. or 30 per cent. reduction might be obtained in the hospital returns. Although I can afford to laugh at it now, one portion of the railway line between Klang and Port Swettenham always recalls to my mind the feeling of despair which came over me at that point one day, in the height of the outbreak of 1901. Indeed, I was prepared for a total failure of the works, and had my answer already prepared should I be called to account by Government. It was that Ross had proved Anophelines did carry malaria; that to remain doing nothing was to remain to die; and that it was at least worth spending money

to try whether such a scourge could be removed or even reduced. I record these feelings that they may encourage others who may be disinclined by the apparent magnitude of the task from attempting to combat this disease.

Preliminary Steps. Although the extreme prevalence of the disease was apparent to me from seeing so much of it in the hospital, some definite statistics were required if Government were to be justified in spending money. And as a business transaction it was also necessary to obtain some knowledge of the condition of the town for comparison with periods after the works should have been undertaken, to determine whether the results were worth the expenditure.

Unfortunately, although there were many cases of malaria in the hospital (they had in fact formed 24·9 per cent. of the total admissions for the previous year), there was no record of the residence of the patients beyond the district in which they lived. And although there had been much sickness among the Government officers no record existed of the disease from which they had suffered, although numerous prescriptions for quinine supplied a very significant hint.

From the Death Register little help could be obtained since the only qualified practitioner in the district was the Government Surgeon, and only such deaths as were certified by him could be advanced as being assigned to their true cause.

My first care was, therefore, to put the record on a more satisfactory footing. The exact residence of every case of malaria admitted to hospital was carefully and personally inquired into by myself. This was very essential, since the patients, if casually asked where they lived generally answered Klang, although in fact they might live miles beyond the town limits. But for these precautions the returns would have exaggerated considerably the actual amount of malaria in the town. To widen the basis of the statistics I had a new return made showing the number of out-patients treated for malaria. The disease for which an officer obtained sick leave was recorded, and for some months I personally kept a register of the houses within the town which were infected with malaria, at the same time recording the number of cases which occurred in each as they came to my knowledge.

These precautions I maintained until I went on leave early in 1908. Subsequent changes in the staff led to these being overlooked, and only recently I discovered that it was so. The record has again been put on a satisfactory basis, but unfortunately the returns for the years 1908 and 1909 are thus not available for comparison with the previous years. Fortunately the blood and spleen census of the children is a record of the condition of the town not affected by hospital statistics.

Anopheline Breeding Places. These were found everywhere within the town, and a plan was prepared showing their distribution. In the very centre of the town a swamp existed, with houses close up to it. People have told me they shot snipe on it from the Rest House. As will be seen from the map the town is situated within, upon and around a somewhat semi-circular group of small hills. At the foot of the hills, especially where they bend to form small valleys, the ground water was so high as to form permanent swamp. In the absence of a town water supply, wells innumerable were found mostly teeming with Anopheline larvae.

The exact species were not determined for some time after the works had been started, but even then some of the original swamps had not been completely drained. In December, 1903, and January, 1904, Dr. G. F. Leicester investigated the Anophelines of Klang and reported as follows in his 'Culicidae of Malaya'[7]:—

'Caught in houses:

Myzomyia rossii,
Cellia kochii,
Nyssorhynchus karwari.

Caught in jungle:

Myzorhynchus umbrosus,
Myzorhynchus sinensis.

The larvae of the following mosquitos were taken:—

(*a*) In mud holes, i.e., small holes made by the foot of a heavy animal or a waggon rut in a road.

Myzomyia rossii,
Cellia kochii

(*b*) In stagnant shallow water supplied by rain and liable to dry up.

Cellia kochii

(*c*) In swamps.

Myzorhynchus barbirostris,
Myzorhynchus sinensis,
Myzorhynchus umbrosus,
Cellia kochii

(*d*) In marshy ground fed by a stream.

Cellia kochii
Nyssorhynchus nivipes.

'The jungle on the hill range running parallel with the Langat 'Road was entered at several points to ascertain what mosquitos 'were common there. On the first occasion *Myzorhynchus* '(*Anopheles*) *barbirostris* and *Mansonia annulipes* were obtained in 'very large numbers during the day, but on the hill marked M in 'the map, no Anopheles were obtained in the evening though they 'were abundant in the day. Later on the jungle was visited on two 'other occasions, and the number of Anopheles present had 'considerably diminished.

'There is evidence that great seasonal variation of the number 'of Anopheles in the jungle occurs, as on an unknown date last 'year Mr. E. V. Carey observed Anopheles in great numbers in 'the jungle at the third mile; on a later occasion he, with Dr. 'Watson,* visited this jungle and they were unable to find a single 'Anopheles.

'The disappearance of the mosquitos does not seem to have any 'relation to the rainfall, nor should I expect this as the swamps 'at the foot of these hills where larvae were found are permanent, 'and therefore the breeding places would not dry up during the 'dry season.'

I think there is a possible mistake with regard to the *Myzorhynchus* which was found by Dr. Leicester on the hill. My recollection is that he called it at the time '*umbrosus*.' In his 'Culicidae' he calls it '*barbirostris*.' I think the explanation is to

* Dr. H. E. Durham was also with Mr. Carey and Dr. Watson.

be found in the existence of another Myzorhynchus so closely allied to *umbrosus* that it may possibly be only a variety. It differs from *M. umbrosus* in having two costal spots, the basal of which is very small. I think, therefore, that Dr. Leicester, when he came to go over his specimens in Kuala Lumpur rejected it as *umbrosus* on account of the two costal spots, and so called it *barbirostris*. I call this variety in the meantime *Myzorhynchus umbrosus* x. I am the more disposed to think this is the true explanation of the change of name, as *Myzorhynchus umbrosus* x. is the commonest jungle mosquito, and I have found it universally in jungle here. Not only so, but I have found it in enormous numbers. On the occasion when Dr. Leicester visited the hill, the mosquito was in such numbers that simply by slipping a test tube from one part of our clothes to another six or seven mosquitos could be obtained in perhaps about two minutes. Dr. Leicester, myself, and an attendant caught something like 200 Anophelines in a quarter of an hour, and could not stand the biting further. I may mention that *Mansonia annulipes*, *Desvoidea jugraensis*, and *Verallina butleri* were present in considerably greater numbers than the Anopheline, so it can be imagined a quarter of an hour in that jungle was unpleasant.

It is of sufficient interest to record, that although *Myzorhynchus umbrosus* x. was swarming in the jungle and attacking during the day, in a rubber estate separated only by a 20 foot road, but of course free from undergrowth, we were entirely free from attack, and no adults could be seen.

The point of the presence of this Anopheline is important, as I have found it to be a natural malaria carrier.

Of ten adults taken from cooly lines on Estate 'T,' one was found with numerous zygotes and sporozoites.

The Anophelines found in Klang Town in 1909 have been:

Pseudo-myzomyia rossii ? var. *indefinita*,
Cellia kochii,
Myzorhynchus barbirostris,
Myzorhynchus sinensis,
Myzorhynchus separatus.

The last of the breeding places where *N. nivipes* and *N. karwari* were found was destroyed about 1904, and except for

the renewal of a small piece of one of the swamps in 1908 through a brick drain being put in at too high a level, there is now in Klang no breeding place suitable for these mosquitos. It is still impossible to say exactly what mosquitos were carrying malaria in 1901, but I think *Myzorhyncus umbrosus* x. was probably the most important one.

Only two miles from the centre of Klang there is now a spot in which this mosquito abounds, and in which 50 to 100 per cent. of the children suffer from enlargement of the spleen according to the distance they actually live from the mosquito's breeding place.

In the earth drains and such wells as remain there has been a great reduction in the number of larvae. The number of adults, which can be caught, varies very greatly. In the month of August, 1909, during a period when the weather was dry, not an adult could be caught, although the most careful search was made. Yet two months later specimens of the above-mentioned species, particularly of *M. separatus* were caught with great facility, and in fact for about a week rarely a night passed without my being attacked as I sat reading.

Proposals made to Government for Drainage Scheme. Having made definite observations which convinced me of the necessity of striking at the disease, I laid the facts before the Klang Sanitary Board in May, 1901, with proposals for a drainage scheme. The proposals were accepted by the Board and were included in the proposed estimates submitted to the Government by the Board for 1902. This was entirely due to the strong support given to them by the Chairman, Mr. H. B. Ellerton, and I wish to record my grateful thanks to him not only for his support but for many valuable suggestions in connection with the proposals. When it is borne in mind that I personally had no experience of either the tropics or the methods of presenting proposals to the Government, those who have had experience of both will realise how much Klang owes to Mr. Ellerton.

The support of the State Surgeon of Selangor, Mr. E. A. O Travers was then sought, and in July, 1901, I forwarded a report to him asking for support for the Board's proposal. In it I pointed out that:—

(*a*) while the total number of cases treated at the hospital

during the first half of 1901 showed an increase of 3·25 per cent. over the corresponding period of 1900, the increase in the number of malaria cases amounted to no less than 69 per cent.; (*b*) of these malaria cases 55 per cent. came from the town, while the estates, which were better drained, sent in only 11 per cent.; (*c*) to my personal knowledge 60 houses out of 293 within the town boundary had been infected within the previous three and a half months; (*d*) the prevailing type of parasite was the tropical or malignant form; (*e*) a water supply was shortly to be introduced, and it would be unwise to bring increased moisture into a town already suffering from malaria without previously providing proper drainage; and (*f*) since in the returns from 1896 onwards 'Malaria has been more prevalent in the latter part of the year, the marked increase of fever in the first six months of 1901 is a matter for serious consideration, and some action in the way of drainage is clearly indicated.' This report was accompanied by a plan of the town showing the general distribution of the swamps, the breeding places of Anopheles, and the houses infected by malaria.

The proposals received from Dr. Travers the strongest support, and the Government not only indicated that the proposal would be favourably considered, but ultimately *doubled the sum asked for by the Board*.

The Outbreak of 1901. It was soon evident that the end of the year was to make good our worst fears. The outbreak reached terrible proportions. The inhabitants of house after house went down before the disease in the months of September, October, November and December, which incidently I may mention coincided with a marked rise in the level of the ground water of the town. It is difficult to convey any proper conception of such an outbreak and the misery it involves, but the following extracts from my notebook will show how much Government Officers and their families suffered.

'In the new clerks' quarters there were eleven cases, with one death; old clerks' quarters, four cases; clerk of works' quarters, seven cases; adjoining quarters, two cases; post office, two cases; railway quarters, sixteen cases; rest house, five cases; inspector of police's quarters, six cases; police constables, twenty-one cases; in the district officer's quarters the servants were attacked; in

the surveyor's quarters all the Europeans were attacked, the family consisting of the husband, wife and two children. In my own household all my servants were attacked (three in number). My wife and I escaped, I believe because the servants were sent to hospital at once and were kept there until their blood was found to be free from parasites, and they were dosed with quinine on their return to work. In addition we used Citronella oil lavishly on our persons and clothing in the evenings, and our mosquito curtains were thoroughly searched and cleared of Anophelines by me each night.

'In addition to those occupying Government quarters, many Government Officers were attacked who did not live in Government quarters, and I think two clerks' quarters and the dresser's quarters at the hospital were the only ones to escape. I may mention these had been attacked in the earlier part of the year.

'In the lower lying town, the condition was more terrible. Hardly a house escaped. In many houses I found five and six persons attacked, and the observations I then made have left an indelible impression on my mind. Night after night I would be called to see the sick in houses, and found men in all stages of the disease. Many and many a time I was called only to find the patient in the last stage of collapse or in burning fever. The whole population was demoralised, and when in November the death rate rose to the rate of 300 per mille, the Chinese suspended business entirely for three days, and devoted their energies to elaborate processions and other rites calculated to drive away the evil spirit.

Work done in Klang. Although the money voted by Government did not become available until 1st January, 1902, the Board was by no means idle. All the available Sanitary Board staff was occupied in felling jungle, clearing undergrowth, and doing some minor draining. Owners of private land were under one of the Board's laws compelled to drain and clear their land. The section reads as follows, and had been in force since 1890, although its powers had been little invoked in Klang:—

'When any private tank or low marshy ground or any waste
'or stagnant water being within any private enclosure appears to
'the Board to be injurious to health or to be offensive to the
'neighbourhood, the Board shall by notice in writing require

the owner of the said premises to cleanse or fill up such tank 'or marshy ground or to drain off or remove such marshy water' (Section 45 Conservancy of Towns and Villages Enactment, 1890).

This section gave the fullest powers to the Board, and it was freely used.

During 1902 the sums seen below were expended by the Board on draining and filling. The work was not, however, finished all at once and even in 1904 some small swamps were still in existence.

It was not until Mr. E. V. Carey pointed out that the only way of draining the swamps effectively was by contour drains at the foot of the hills, the method universally employed by planters. that these were really dry.

The actual expenditure was as follows.*

1901.	Extension of Brick Drains	750·17
1902.	,, ,, ,, ...	1925·44
	Filling in swamps	8579·26
	Main Sewer	3856·29
1903.	Extension of existing Drains	368·00
	Extension of Brick Drains	2340·00
	Filling in swamps	1303·00
	Main Sewer	6142·00
1904.	Rebuilding another Main Sewer	4000·00
	Extension of Brick Drains	2500·00
	Lowering Railway Culverts	1500·00
1905.	Brick Drains	2554·15

This work included the drainage of swamps just outside the old town limits, some 16 acres in extent.

I am indebted to Government for information regarding the actual expenditure. This expenditure may appear to be very great, but local circumstances are responsible for much of it.

Our Mistakes. In the first place most of the houses of the town were situated close to the river, and connecting them with the river were several brick drains, or more correctly open sewers. In order

* The value of the dollar was fixed at two shillings and fourpence of British money on January 29, 1906. Before that it fluctuated with, and was of equal value to, the Mexican dollar.

to drain the swamps of the town, which were further from the river than the houses, as will be seen from the plan, it was necessary to bring the water down these sewers. Unfortunately these sewers were at much too high a level to allow of this, and consequently had to be pulled up and rebuilt before the swamps could be effectually drained. In some places efforts were made to avoid this, but in reviewing the result I am convinced that had the original drains been entirely disregarded better results would have been obtained for the money spent. The drainage system of the town is bricked practically only where house sewage flows in it, and nine-tenths of the system is open earth drain. As will be seen from the sections relating to rural anti-malarial sanitation, an open earth drainage system is sufficient in land such as Klang. Consequently, in estimating the cost of the anti-malarial works at Klang, it must be remembered that brick drains (the most expensive part of the works) were, as far as malaria was concerned, unnecessary, and that they should properly be debited to ordinary sanitation.

Much money was spent on 'filling' which could have been avoided had the town not been burdened by the legacy of its old brick drains. In some places where no fall could be obtained because a brick drain was too high, the land was raised by filling. This was very expensive work, and work to which I should be strongly opposed now.

Until Mr. Carey pointed out the mistake, much money was spent on filling in at the foot of the hill where the drains cut were ineffectual.

I speak plainly of our mistakes, in order that others may benefit, and avoid similar errors and extravagances. But for the necessity of constructing part of the system as a sewer system, and had much unnecessary and expensive 'filling' been avoided, there is no reason why the works at Klang should have cost more than the cost of draining the land, i.e., about £2 st. per acre, or, in other words, about £800 instead of £3,000. Thousands of acres have been cleared of malaria in the neighbourhood at this cost, and I can see no reason why Klang could not have been similarly dealt with at a similar cost.

Results. These can be more conveniently dealt with when we come to consider the results of the works at Port Swettenham.

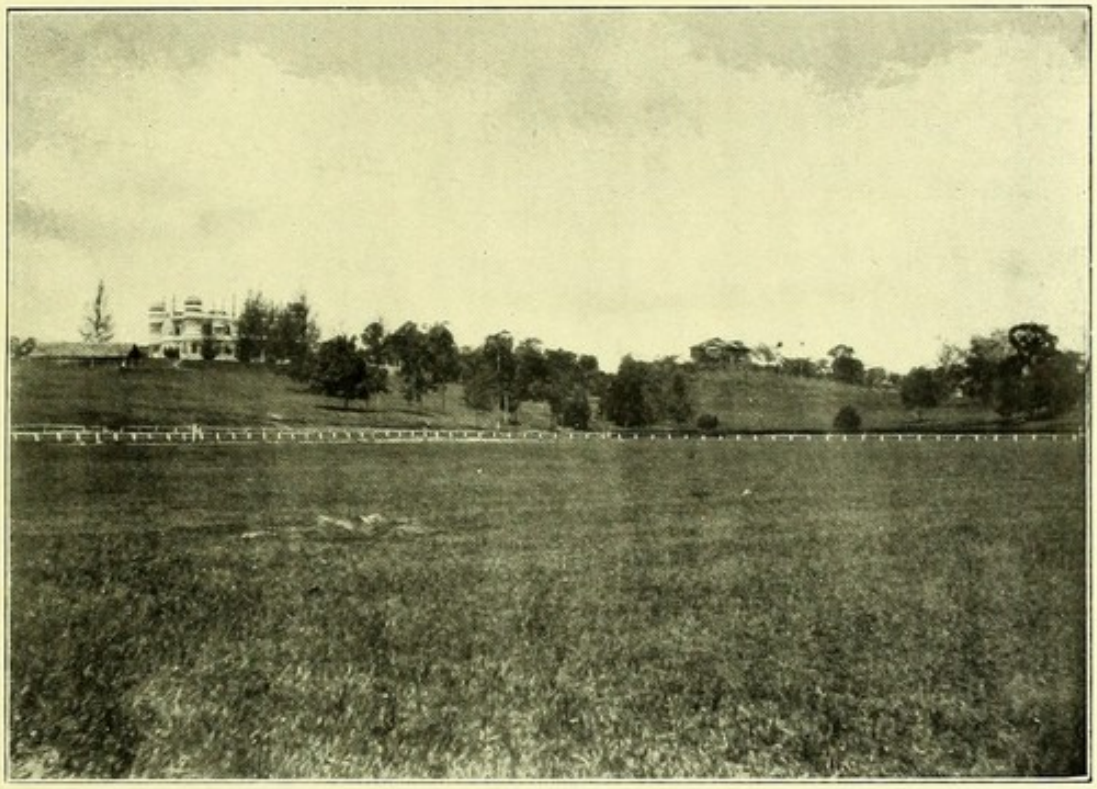


FIG. 1. SMALL HILLS OF TOWN OF KLANG.

The swamps were situated at the foot of the hills, especially where they bend to form concavities.

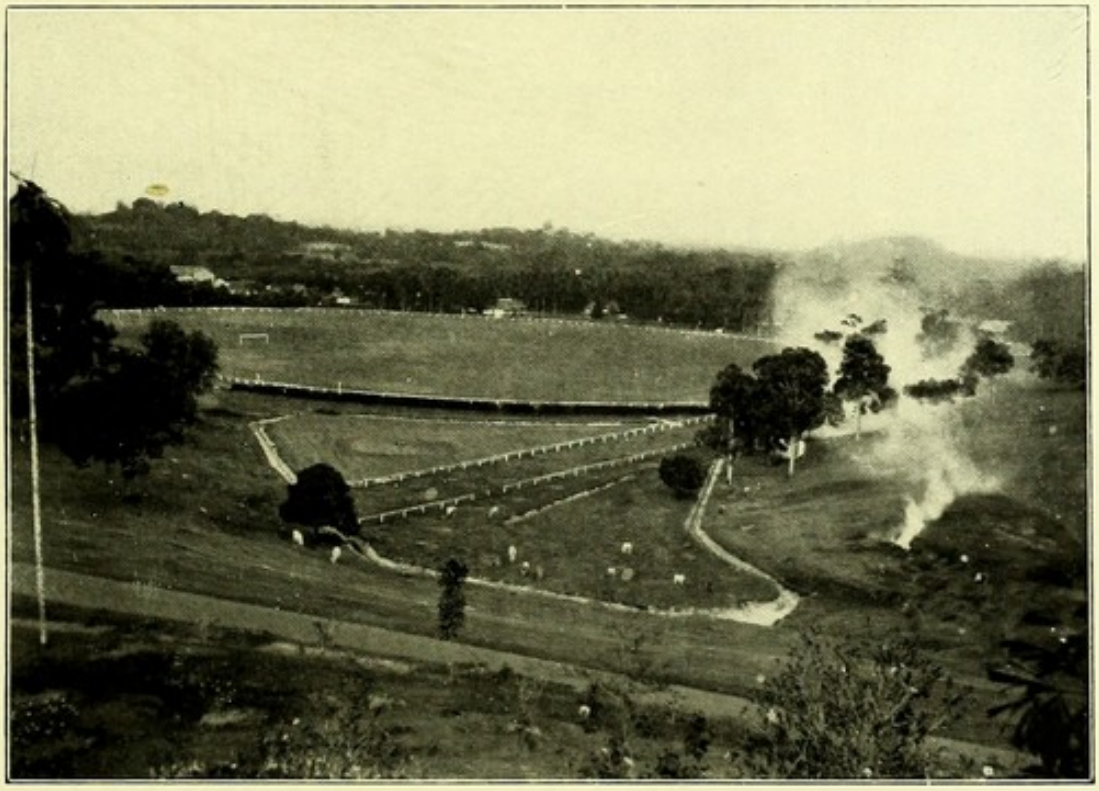


FIG. 2. HILL-FOOT DRAIN, TOWN OF KLANG.

Hill-foot drain encircling what was formerly a swamp with water knee-deep in places. The drains have rendered this so dry that part of it is used for the race course, and part for a golf green. No 'filling' was used to attain this result. In other swamps in Klang of exactly the same nature much money was spent in 'filling' with absolutely no result, as the springs from the hills poured water out over the new surface.

II.—Port Swettenham. The origin of this Port was the necessity of having a Port for the State to which ocean going steamers could come. It was impossible for large steamers to come up the winding Klang River in which, at spring tides, a current of 5 or 6 knots runs. It was therefore decided to make a port at the mouth of the river, and work was begun on 1st January, 1900.

The land at the spot chosen was very low lying mangrove swamp, which was covered at all spring tides to a depth of two or three feet by the sea. In the higher tides, especially at the September equinox, the tide floods the land for a distance of a mile inland.

The railway was carried along the fore-shore on an embankment, and wharfs were built connected with the embankment. No attempt was made to reclaim the land, and the workmen during the construction lived in huts raised above the land in the Malay fashion.

Port Swettenham in 1901. When I assumed duty at Klang in January 1901, the wharfs were practically completed, and only the finishing touches were being given to the station buildings. There were few inhabitants in the place, and there were few cases of malaria. But I observed that new arrivals quickly became affected. I also heard there had been a considerable amount of malaria among the workmen formerly employed there. The place was practically a mangrove swamp, in which about 15 acres had been cleared. No attempt had been made to reclaim or drain it, and it was full of Anopheline breeding places.

It was obvious enough what should be done, and at the suggestion of the Klang Sanitary Board, the Resident Engineer began in February 1901 to clear the land, fill in holes, and generally improve the land as far as his votes permitted. There was, however, no money available for a proper scheme.

On the 20th April, 1901, at the request of the Acting State Surgeon, Dr. Lucy, I forwarded a report with recommendations. These included, in addition to ordinary sanitary measures—

(1) clearing and levelling the Government reserve, and putting it under grass;

(2) the filling in of abandoned drains;

(3) a complete scheme of drainage;
(4) the notification and, if considered necessary, the removal to hospital of cases of malaria;
(5) experiments with mosquito netting and quinine on certain sections of the population.

In urging these recommendations, I expressed the opinion that the 'Government staff shortly to be stationed there will be seriously affected and their services much impaired.'

That much was necessary was obvious, and the Government put $10,000 on the Estimates for 1902.

Opening of the Port. On 15th September, 1901, the port was opened, and the Government population and the coolies connected with the shipping were transferred to Port Swettenham.

Fearing an outbreak of malaria, and desiring to have a record if such occurred, I had a register started of the Government population, showing for each person, name, age, previous history of malaria, date of arrival at Port Swettenham, date of attack, date seen, nature of parasite, if sent to hospital or not, date of return to duty, remarks. Each house had a separate page. This was completed within a few days of the opening of the port by Mr. R. W. B. Lazaroo, the Deputy Health Officer, and in order that I might have as complete a record as possible, this officer visited each of the Government quarters. This was continued for some years, and it had the further advantage that cases were properly treated from the beginning and were removed if necessary to hospital. As far as possible all officers were sent to hospital, and to remove one of their objections to this, Government allowed at my request the officer to recover his travelling expenses on the certificate of the Medical Officer. The result of these precautions had the happiest results in the saving of lives, as will be shown hereafter.

The Outbreak. Immediately after the port was opened malaria assumed an epidemic character. In less than a month the 180 loading coolies were so decimated by disease that the remnant refused to live any longer at the port, and returned to Klang. Two other batches (about 70 each) were imported on the 10th and 20th October, respectively, and were lodged in separate houses in Klang. But Klang, however, was in the throes of the epidemic foreshadowed

by the great sickness in the early part of the year, and these coolies also suffered so much that the majority left within a month. The loading contractor had then to employ Tamil coolies from a coffee estate. The Government population also suffered severely, and out of 176 persons, including the crews of the Government yachts and launches, no less than 118 were attacked between 10th September and 31st December.

Table showing the number of persons living in Government quarters prior to October 31st, 1901, attacked by malaria within certain periods after arrival:—

Days after arrival	9-18	19-28	29-38	39-48	49-58	59-68	69-78	79-88
No. of persons attacked	13	12	20	20	16	20	8	1

Two months after the Port was opened I visited the native houses which had been run up, and of the 127 inhabitants 78 were said to have been attacked, and 25 of the 27 houses infected.

The results of the disease on the business of the Port was very serious. Ships came in and could not discharge their cargoes. Those on fixed runs had to overcarry their cargoes. The crews contracted malaria, and after a month or so it was impossible to obtain a crew willing to trade to the Port. The Harbour and Railway Departments were so crippled that they could only imperfectly do their duties, and so utterly demoralised did the Port become, that the High Commissioner ordered the closure of the Port until it could be made more sanitary. It was, however, useless to return to Klang, and Government advised the trial of the recommendations of a Commission, consisting of the Director of the Institute for Medical Research (H. Wright), the State Surgeon (E. A. O. Travers), the District Surgeon, Klang (M. Watson), the General Manager for Railways (C. E. Spooner), the State Engineer (B. P. McGlashan), and the Resident Engineer for Railways (A. J. Watkins and, later, D. J. Highet), which in the meantime had been appointed.

The Commission advised the measures which I had recommended in the previous April, and within six weeks the work of the Port was proceeding without great difficulty.

An area of about 100 acres was bunded, drained, and freed from jungle. Quinine was systematically given to all who would take it, and most did. The outbreak had so much diminished by the time information about wire gauze was received, that none was ever required.

Cost of the Works at Port Swettenham.

1901. 1902.	Jungle clearing, drain cutting, forming bunds, filling in, tide flaps	$2,000·00 27,999·99
1903.	Felling and clearing jungle	2,563·96
	Brick Drains	1,180·00
1904.	Felling jungle, filling in, &c.....	12,311·69
	Brick Drains	1,541·88
1905.	Clearing scrub, &c.	1,469·52
	Brick Drains	1,022·17
	Concrete Drains	2,275·00
	Total	$52,364·21

III.—Results of Drainage of Klang Town and Port Swettenham.

Two definite experiments were thus carried out on a considerable scale. The experiments were in places of quite different physical characters: the one being a mangrove swamp which was reclaimed from the sea by bunds, and the other on and about low hills with swampy ground at the hill foot. Further, the two places were five miles apart. In 1901 they were probably the most malarious places in the district.

It was not until December, 1902, that a water supply was laid on to the towns, so this factor cannot have influenced the state of the public health. That the improvement was not due to any general improvement is clearly shown by the continuance of malaria in the surrounding district, which thus acts as a 'control.' The final proof, an undesirable one, is to be found in the recurrence of malaria, after a considerable period of freedom from the disease, in one of the places when its drainage suffered interference and its inhabitants spread beyond the drained area; while in the other place where the drainage was efficiently upkept no such recurrence has occurred.

Malaria treated at the Klang Hospital.—From 1901 to 1904 the number of cases treated was greatly diminished. There was a subsequent increase from the increasing rural population.

Table showing the number of cases of malaria treated at the Klang Hospital, and their percentage to the number treated for all diseases:—

Year	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904
Outdoor	172	479	730	554	694	668	737	965	364	245	240
Indoor.....	91	112	158	128	163	251	467	807	403	219	298
Total	263	591	888	682	857	919	1,204	1,772	767	464	538
Percentage	20·4	28·9	25·0	19·7	25·2	20·2	24·9	38·8	20·4	12·1	11·11

The decrease shown is striking, and the following table enables one to appreciate its cause.

Table showing the number of cases of malaria admitted to the Klang Hospital from Klang Town and Port Swettenham, as compared with the number of cases admitted from other parts of the district:—

Residence	1901	1902	1903	1904	1905
Klang	334	129	48	28	12
*Klang and Port Swettenham	88	—	—	—	—
Port Swettenham	188	70	21	4	11
Other parts of District.....	197	204	150	266	353
Total	807	403	219	298	376

Situated in a malarious country as Klang and Port Swettenham are, their inhabitants are liable to infection should they spend a night away from home in the neighbourhood, and, on the other hand, imported cases of malaria are frequent in both towns. A difficulty arises in connection with the classification of the

* Certain persons lived some nights in Klang and some in Port Swettenham.

residence of new arrivals, who, giving a history of malaria shortly before coming to Klang or Port Swettenham, develop symptoms again after they have been in the town more than eight days, which is generally regarded as the minimum incubation period of naturally acquired malaria. Such attacks are probably relapses, yet they might be the result of fresh infection acquired after arrival. Consequently, in order not to underestimate the number of cases contracted in Klang and Port Swettenham, and thus to overestimate the benefits derived from the anti-malaria works in the foregoing table, a residence of eight days free from symptoms within the town brings the case under the heading 'Klang and Port Swettenham.' In the light of these remarks, it is not uninteresting to note that of the thirty-two cases recorded from the two towns in 1904, eight were probably imported cases having definite histories of malaria before arrival, three* were Klang residents, who nine to twelve days before admission had slept out of the town, and eight were rickshaw pullers who frequently sleep away from home after a long journey, instead of returning to town.

In 1905 similar deductions have to be made.

Reduction in Number of Deaths Registered. The reduction in the number of cases of malaria from Klang and Port Swettenham was accompanied by a remarkable fall in the number of deaths registered in the same places, while there was no similar reduction in the number in the surrounding and not specially drained District.

The following tables show the Deaths in Klang and Port Swettenham corrected for Deaths occurring in Hospital:—

Year	1900	1901	1902	1903	1904	1905
Fever.....	259	368	59	46	48	45
Other Diseases	215	214	85	69	74	68
Total	474	582	144	115	122	113

* One was my boy. On October 28th, 1904, I found the man in charge of the Resthouse at Jugra, had malignant malaria, a severe crescent infection. Despite a warning, my boy slept in the man's room. From November 6th to the 9th the boy had headache; on the 10th and 11th his temperatures were 103·8 and 104 F. respectively, and on the 12th malignant parasites were found in his blood.

It will be noted that the remarkable improvement in the health of the inhabitants occurred in 1902, immediately after the anti-malarial works had been undertaken.

Table showing the number of Deaths in Klang District, excluding those occurring in Klang Town and Port Swettenham.

Year	1900	1901	1902	1903	1904	1905
Fever.....	173	266	227	230	286	351
Other Diseases	133	150	176	198	204	271
Total	306	416	403	428	490	622

The above tables bring out in a convincing fashion that subsequent to the anti-malaria works there has been a great reduction in the number of deaths recorded in Klang and Port Swettenham, while in the district outside of the towns the number of deaths still increases. And it is evident, too, from the first table that the improvement is due mainly to the great reduction in the prevalence of malaria. Striking as this appears from the tables, the actual reduction has been, I believe, still greater, for among the deaths recorded as due to 'other diseases' many were doubtless due to malaria, for in a malarious country the native informant is prone to report deaths really due to malaria as due to diarrhoea, dysentery, convulsions in children, or other terminal complications of malaria. Indeed, natives so frequently fail to recognise that their illnesses are connected with malaria that it has been found necessary to examine microscopically for malaria parasites the blood of all cases of diarrhoea, dysentery, anaemia, cardiac and renal diseases admitted to Klang Hospital, quite irrespective of whether the patient says he has had fever or not. That the native informant of death should make a mistake can, therefore, easily be understood. At the same time, the removal of malaria to such extent as has occurred has undoubtedly improved the general health of its inhabitants, and those who in former years would have succumbed to 'other diseases,' simply because they were in a low state of health consequent on malaria, are now able to resist the

attacks of such 'other diseases,' or if attacked to overcome them and recover.

Although a good water supply was brought into the towns in December, 1902, and greater attention is being paid to general sanitation, I cannot help feeling that the improvement has been due mainly to the diminution of malaria. As all deaths, with the exception of those certified by myself (up to 1907 the only qualified practitioner within twenty miles of Klang) are registered in accordance with the report of the friends, I regard the above tables as an 'unsolicited testimonial' unconsciously given by the native community to the efficacy of the anti-malaria works in Klang and Port Swettenham.

The following table shows how much Government and its Officers have benefited:—

Table showing Number of Sick Certificates and Number of Days' Leave Granted on account of Malaria.

	1901	1902	1903	1904y	1905
Certificates	236	40	23	14	4
Days of Leave	1,026	198	73	71	30

From 12th July, 1904, until December, 1906, no officer in Port Swettenham suffered from Malaria.

The anti-malaria measures also resulted in financial loss to me from diminution of my private practice, from patients suffering from malaria contracted in Klang or Port Swettenham. In 1901 this amounted to $734. In 1904 it was nil, and it remained at this cipher until 1909 when cases were seen from Port Swettenham.

Children infected with malaria, Klang. Unfortunately in 1901 no examination of the children was made in order to ascertain the percentage affected. I had, however, abundant evidence, both in my official and private practice, that they suffered severely. The disease frequently ran through a household. As an example, I may mention that on one occasion (15th April, 1901) when called to the Astana to see a child with malaria, I asked if there were any others, and found no less than 15 suffering from malaria.

From 1904 I have made a series of examinations, at first of the blood and latterly of the spleen and of blood of children* under the age of ten, differentiating according to the age. For the sake of simplicity I give only the totals. The examinations were made in the months of November, December and January, but mainly in November and December. In Klang the children were examined both in the centre of the town and at its periphery.

Table showing the number of children in Klang Town giving evidence of malaria on blood and spleen examination:—

Year	1904	1905	1906	1907	1908
Blood.					
No. examined	173	119	91	—	—
No. with Malaria	1	1	1	—	—
Percentage with Malaria	0·5	0·8	1·0	—	—
Spleen.					
No. examined	—	—	142	71	455
No. with Malaria	—	—	1	3	13
Percentage with Malaria	—	—	0·7	4·2	2·8

Convincing as these figures are of the absence of malaria in Klang Town, further enquiry showed that those with evidence of malaria had only recently come to the town, and had contracted the disease previously to coming. For example, in 1904 the child with malaria belonged to a company of travelling players, and had had malaria in Kuala Lumpur; in 1905 the child with malaria was an inhabitant of Klang who, two months previously had gone to Malacca for a month, and, when there, contracted malaria; in 1906 the child with malaria had arrived only three days previously from Port Dickson. In 1907 the examinations were made not by me personally as the others had been, but by a Dresser, and no history is recorded of those with enlargement of the spleen.

In 1909, desiring to have the fullest evidence possible of the condition of the town, *I personally went to every house in it, and also to all the schools, examining in all* 463 *children.* Of the 308 examined at their homes twelve had enlarged spleen; of the 155

* The children examined were under an estimated age of ten in all places, unless expressly stated otherwise.

examined in the schools five had enlarged spleen, giving a percentage of 3·8. Of those in the schools, four were not residents of Klang, but came to school daily; one from Kampong Quantan; one from 2nd mile, Langat Road; one from Padang Jawa (by train); one from $2\frac{1}{2}$ mile, Kapar Road.

Of the thirteen who were residents of the town, the following is their previous history:—Seven were in the Police barracks, four of whom had been transferred from Sepang, two from Jugra and one had just arrived from Malacca—all gave a history of malaria before coming to Klang; Jugra and Sepang are notoriously malarious: two were in Government Cooly lines, one having previously been in Batu Tiga, a very unhealthy place, and one had come from Kuala Lumpur where it had had malaria: two were children of an old watchman known to me for years; he told me he had gone to an estate for three months, and when there both he and his two children had contracted malaria; the estate he referred to has a spleen rate of about 50 per cent.: one child had come to Klang only ten days previously from $2\frac{3}{4}$ mile, Kapar Road; the mother informed me the child had had fever before coming to Klang: one child came from an estate twenty miles from Klang known to me to be malarious.

It is to be remembered that Klang is constantly receiving people who are capable of infecting others with malaria if the connecting link were present. In Klang Hospital in the years 1906, 1907, 1908, respectively, 789, 1,901 and 1,537 cases of malaria were treated without any special precautions to prevent the spread of infection.

One ward had been enclosed by wire netting, but when this decayed it was not replaced, as there was no evidence malaria was being spread by the Hospital; for four years I had used mosquito nets in the Hospital, but had given these up for Tamil patients as they would not use them unless compelled to do so: so that in 1907 when the maximum number of cases were treated there was the fullest opportunity for the infection spreading. No more severe test of the absence of malaria-carrying Anophelines could be devised.

That the whole child population of Klang, except those known to have contracted the disease outside, should be completely free

from all symptoms of it, is evidence of the value of drainage of the most irresistible character. And I would repeat that *not one single grain of quinine was given to any of the population except to those who were actually patients from malaria, in Hospital or in my official or private practice.*

Children at Port Swettenham. In 1901 there were thirteen children under the age of ten living in Government quarters. Of these nine contracted malaria within $3\frac{1}{2}$ months of their arrival.

Table showing the number of children with evidence of malaria at Port Swettenham :—

Year	1904	1905	1906	1907	1909
Blood Examination.					
No. examined	87	76	100	—	—
No. with parasites	1	0	5	—	—
Percentage with parasites	1·14	0	5	—	—
Spleen Examination.					
No. examined	—	—	100	41	109
No. with enlargement	—	—	2	9	9
Percentage with enlargement	—	—	2	21·9	8·9

In 1904 the child who showed infection was found in the Police Station, and had only recently been transferred from Cheras, where she had had fever. In 1906 I found the evidence in the children of the recrudescence of the disease, simultaneous with its reappearance among the adults, as I shall relate. In 1907 the examinations were made by a Dresser. In 1909 I made them myself, and visited, along with the present Medical Officer of Klang, Dr. Millard, every house up to the 4th mile on the Klang Road. Practically every child in the town was seen, and was examined by both of us.

Recrudescence of malaria at Port Swettenham. When in 1901 the Port was opened, in order to obtain exact information of the number of people who were attacked, I caused, as already mentioned, a daily visit to be made to each Government house. This was continued for several years. When it was discontinued, I caused the Deputy Health Officer to inform me when any Officer complained of fever, and no Officer received sick leave until he had come to Klang and his blood had been examined. Further, I issued instructions to the Deputy Health Officer, who was also in

charge of the Dispensary, that no person living in Government quarters was to be supplied with quinine except on my orders. I had thus a very firm grasp on the Government population at Port Swettenham. Seeing those who, complaining of sickness, sought sick leave, and making blood examinations if there was any complaint of temperature, I am in a position to state that no Officer suffered from malaria contracted in Port Swettenham from 12th July, 1904, until December, 1906. In that month three Officers were found to have malaria which had evidently been contracted in the Port.

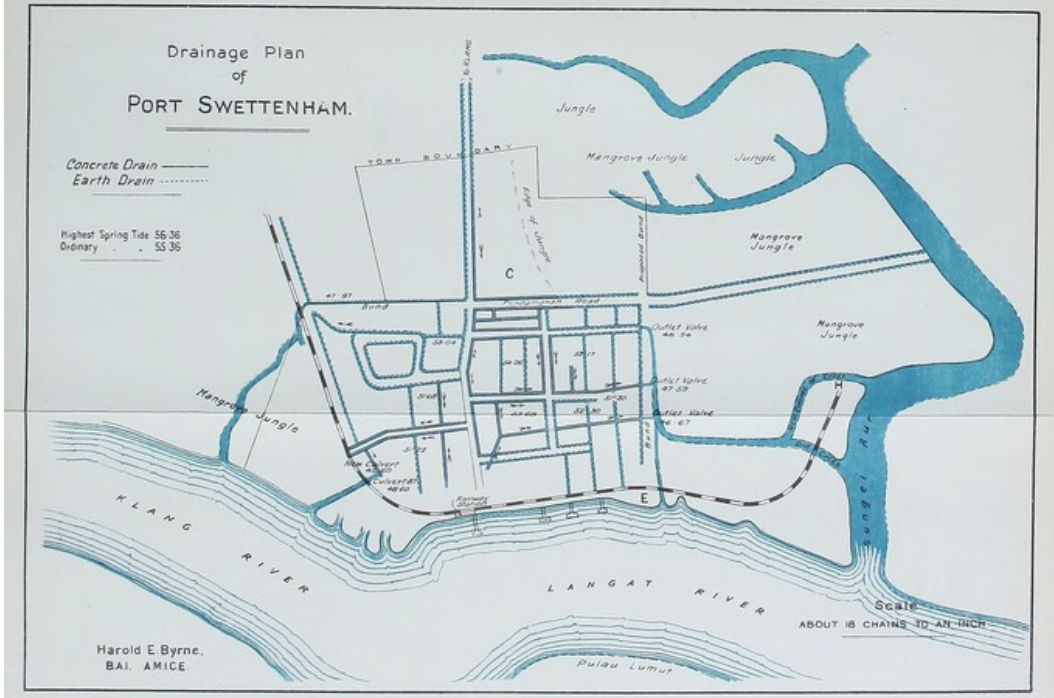
The matter was at once reported to the Chairman of the Sanitary Board, Mr. J. Scott Mason, now Adviser to His Highness the Sultan of Kelantan, and accompanied by the Executive Engineer we made a careful survey of the drainage conditions of the Port.

It was, I think, more than a coincidence that at the very moment of the recrudescence cement inverts had been put into the road drains at such a level that they effectually blocked all the lateral drains which previously opened into them. The whole of the area marked C. on the plan was therefore much less efficiently drained than previously, in fact, was now entirely without any drainage.

We also recognised the fact that a larger population than formerly were living entirely outside of the bunded area. In 1904 it numbered 548, whereas in 1901 only 127 lived beyond the bunds, and these were housed along the Klang Road on the edge of a deep drain, and on land fairly well drained before the new concrete inverts had been put in.

We also recognised that the drainage system within the bunds was not so efficient as previously, since in some places filling had sunk, and in other places drains had been diverted and lateral drains obstructed by cementing the mains.

The Board decided to spend the balance of a vote in 1907 in cutting outlets for Area C., but owing to the great competition for labour at the time it was absolutely impossible to obtain it. In 1907 I formally brought these matters to the knowledge of the Government.


Drainage Plan
of
PORT SWETTENHAM.
Concrete Drain
Earth Drain
Highest Spring Tide 56·36
Ordinary 55·36
Jungle
Mangrove Jungle
Jungle
Mangrove Jungle
Mangrove Jungle
Mangrove Jungle
Outlet Valve 46·54
Outlet Valve 47·59
Outlet Valve 46·67
Mangrove Jungle
Mangrove Jungle
KLANG RIVER
LANGAT RIVER
Jungei Ru
Pulau Lumut
Scale
ABOUT 16 CHAINS TO AN INCH
Harold E. Byrne,
B.A.I. A.M.I.C.E.

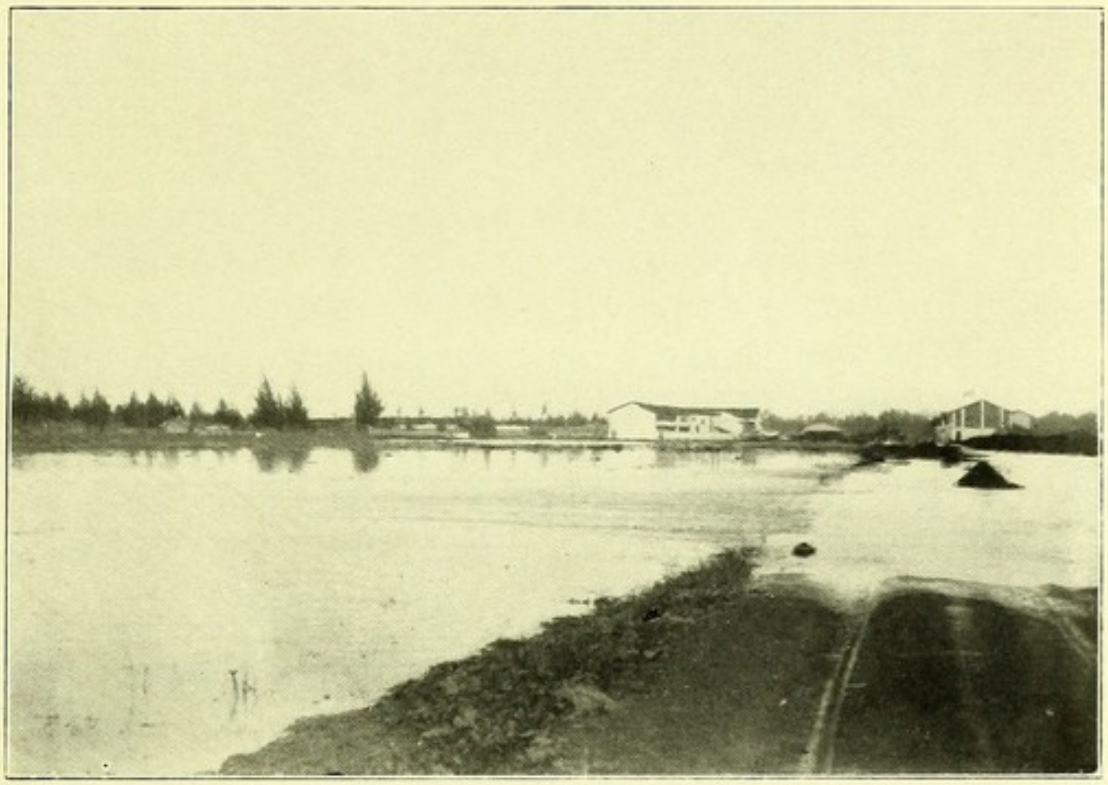


FIG. 3. FLOODING OF PORT SWETTENHAM IN OCTOBER, 1909.

In October, 1909, exceptional high tides overflowed the bunds and flooded the town to a depth of three to four feet, for the first time since 1901. The bunds were about one foot above the ordinary spring tides. But for the bunds the town would be flooded every fortnight by the spring tides.

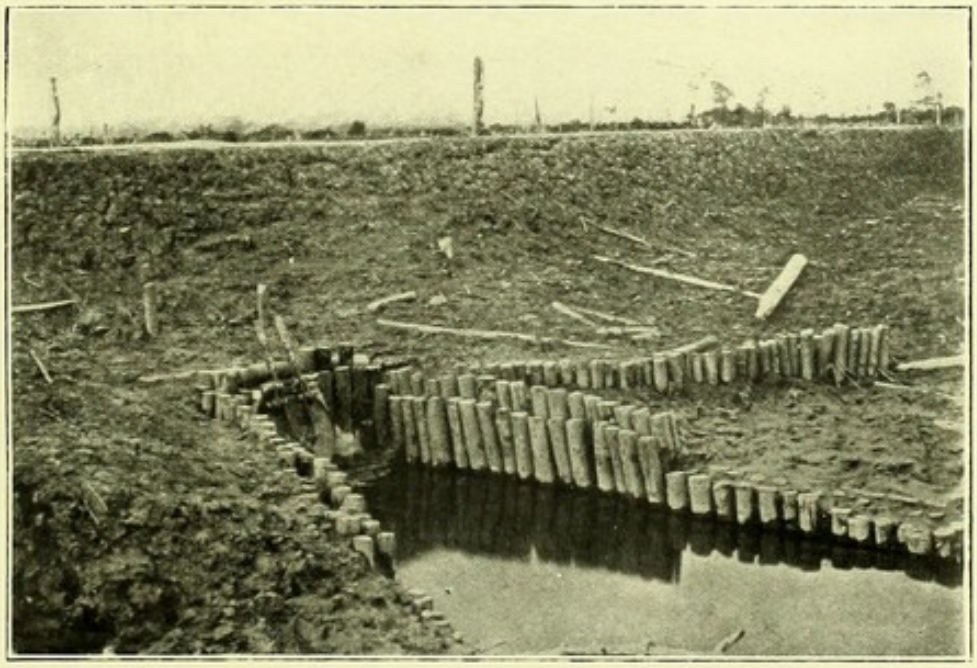


FIG. 4. TIDAL VALVE IN BUND 'B' AT PORT SWETTENHAM.

The photograph shows the original tide valve which opens outwards only. Recently both ends of the valves have been protected from floating wood, etc., by expanded metal screens set into abutments.

In 1908, when I was in England on leave, the condition was still further aggravated by the extension of the railway embankment from the point marked E. to the point marked H. in order to provide further wharf accommodation. This, of course, completely blocked the outlet of the whole of the drainage of Area A. on the plan. I am informed that malaria increased rapidly then, but an outlet was soon made for the water beyond the end of the railway, and, as the figures show, the amount of malaria now in Port Swettenham is not very serious. Government, however, appointed a Commission to make recommendation in 1908, and a sum of $27,000 is being spent in improving the automatic outlet valves, improving and increasing the bunds, and in improving an open sewer system for many of the houses.

I am of the opinion, however, that malaria will not entirely disappear from Port Swettenham until it is recognised that a large population is now outside the protected area. The bunded area should be increased to include these.

Criticism of the Original Drainage Scheme at Port Swettenham. In 1901 our chief fear was that mosquitos would breed in the drains within the bunds. We considered it essential the drains should have such a fall that they would dry during every tide, or at least would have such a current as was calculated would prevent the insect from breeding within them. Accordingly the level of the outlets made in 1901 was that of about half tide. At such a high outfall level, and with a grade to provide a good current, in many places the drains soon ran out practically on to the surface of the soil, especially at the top of the system. Places where water stood when the drains had been completed were therefore filled in at great expense. Since then filling has been continued to provide sites for buildings, &c. It must be clearly understood that expense was not allowed to stand in the way of success, as the whole existence of the Port was at stake.

Experience has shown that our fears were groundless, and that the danger from open drains in flat land is nil, if they are kept moderately free from weeds. Any further works will therefore be immensely cheaper, since the outlets of new drains can be put at

the level of low water neap tides.* Deepening of the drains is more satisfactory than filling, and while the cost is a mere fraction, this cannot be too strongly insisted upon.

I make these criticisms in order that others may benefit by the mistakes made in our pioneer work.

I am indebted to Government for the figures below and the levels on the plan, which show that the general level of Port Swettenham is 2 to 3 feet below that of spring tides.

The levels on the plan range from 50·24 to 54·26, and the highest known tide was 56·36.

The following are the official levels:—

H.M.S. 'Waterwitch' Bench Mark.

The surface is 14 feet 4 inches above the datum used for the reduction of the sounding.

Low-water spring tide	39·13	
Bench Mark above datum... ...	14·33	
High-water spring tide	55·36	
Low-water spring tide	39·13	
High-water ordinary tide... ...	51·37	
Low-water ordinary tide	42·35	
High-water neap tide	46·65	
Low-water neap tide	45·46	
High water on 30/10/09	56·36	highest known tide.
Invert of culvert 87	48·60	
Invert of flap valves in South Bund	48·54, 47·59, 46·67	
Invert of flap valve in North Bund.	48·86	

The level of the outlet is most important, and when a sea is tidal, bunding gives enormous powers of drainage. I need only mention how the English Fens have been drained by bunding, and incidentally malaria has disappeared. I think that is more than a coincidence.

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* Culvert No. 87 is now being lowered to 48·60, a gain of three feet to the whole area. The present executive engineers are now carrying out a low level drainage system such as I recently advised.

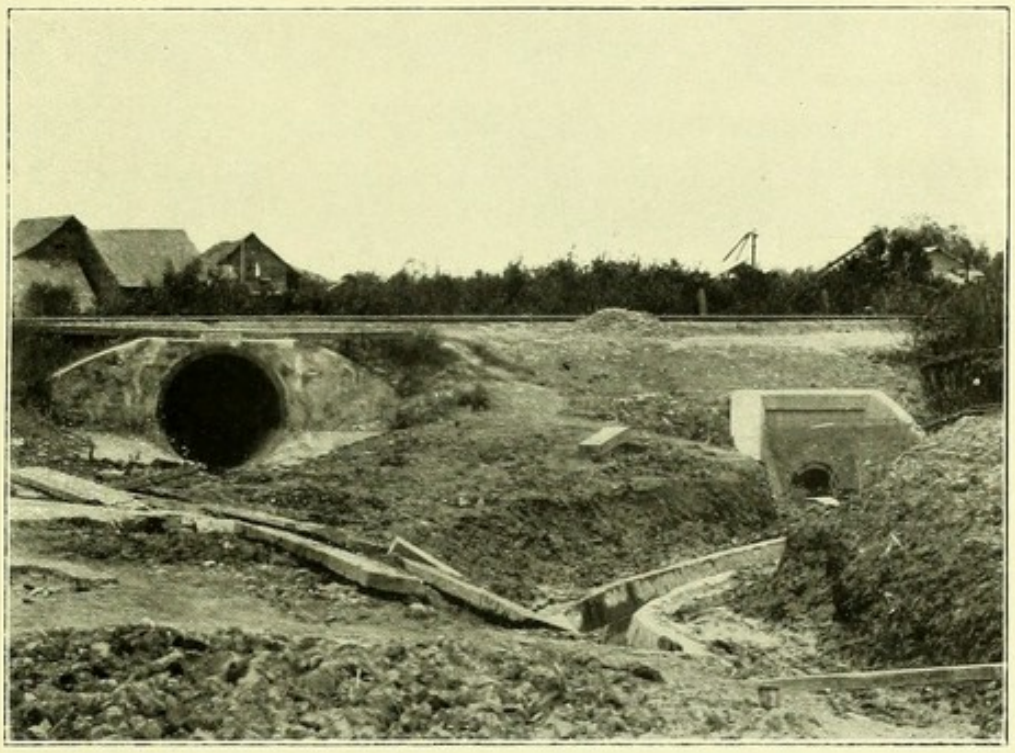


FIG. 5. CULVERT 87 AT PORT SWETTENHAM.

The photograph shows the old culvert on the left. The small culvert on the right is the low-level culvert put in by Mr. Byrne. It is three feet lower than the old culvert, and has enormously improved the drainage of the town.

The high tide of October, 1909, came over the railway at this point.

FIG. 6. KAPAR DRAINAGE SCHEME.

One of the main drains, with rubber trees on both sides.

Part II

MALARIA IN RURAL DISTRICTS

IV.—Malaria in the District of Kuala Selangor. North of the district of Klang lies that of Kuala Selangor. It stretches away towards the N.N.W. for about sixty miles and is, like Klang district, flat for some miles inland from the sea.

When I assumed duty as District Surgeon of Kuala Selangor district in addition to that of Klang, I found malaria was very severe. Desiring to obtain as much information as possible about it, in 1902 I went through the hospital registers for the previous years, and obtained the following figures as far as then possible:—

Year	1895	18 6	1897	1898	1 99	1900	1901	1902	1903
Total treated	433	524	782	836	1837	2115	2061	2279	1880
No. with malaria	103	136	222	336	1086	1007	512	528	268
Percentage with Malaria ...	23·7	25·9	28·3	40·1	59·0	50·1	33·4	23·0	14·1
No. of Deaths in District ...	170	193	163	168	78	317	290	287	248

These figures could be no mere statistical vagary. A definite rise in the percentage of the malaria treated at the hospitals during a series of years, followed by a gradual fall during another series of years, appeared to me to represent the existence of some definite fact —a phenomenon, the investigation of which was of urgent importance.

The Census had shown an increase of 30·7 per cent. in the population of the district, and while the increasing population might have accounted for the rise in the malarial wave, it could hardly account for the remarkable subsequent fall. I had no idea to what to attribute the phenomenon, but thought some explanation might be found in the history of the district. I accordingly read up all the annual reports of the District Officer, and also those of the State Engineer for the previous ten years. The explanation was soon forthcoming. In order to open up the country to which access hitherto had been only by rivers and creeks from the sea, Government had constructed a road and bridle tract for a distance of some sixty miles from Klang to Sabak Bernam on the Perak

boundary. The road passes through the villages and mukims (sub-districts) of Kapar (10th mile), Jeram (20th mile), and Kuala Selangor (28th mile).

Before the construction of the road the inhabitants had opened up the land at certain places, and malaria, although present, was not so to a serious extent. The road interfered with drainage, as there is abundant evidence to show, and it was followed by the outbreak of malaria. The road was put through in the early years of the nineties, and complaints were soon found in the reports of the District Officers, who in no uncertain terms accused it of doing serious damage. Mr. A. Hale, in his annual report for 1897, says :—'Javanese, who took 'up land on the Bukit Rotan Road and planted it with coffee which was 'destroyed by flood water, the drain having been dammed by the 'Public Works Department to use as a canal for transport of metal, 'have now most of them planted cocoanuts, as also have many others 'who hold land on the inland side of the Coast Road, which, as my 'predecessor pointed out, acts like a long dam from Sabak to Kapar, 'as if built purposely to prevent the water getting to the sea.' Stronger evidence could hardly be obtained, but if it were required it is to be found in an annual report of the then State Engineer. Referring to the Klang end of the Klang-Kuala Selangor Road, he congratulated the Government on the low cost of the construction of the road due to the drain on the inland side of the road having been used as a canal. There is thus evidence that from end to end the road had acted as a serious obstruction to drainage of land on its landward side, and coincident with this there appeared the remarkable increase in the malaria of the district.

Now, about the middle of the nineties we find in the reports proposals for a great irrigation scheme for the cultivation of rice in the same district. The first step in irrigation is the provision of drains to carry off water, so that the amount of water on the land may be properly regulated. In 1898 a start was made with the Jeram drainage scheme, but before it was completed all idea of rice cultivation had been given up by the natives in favour of the more remunerative dry cultivation of cocoanuts and coffee, made possible by the drainage. More and more land came under this cultivation, and the drainage begun in 1898 has steadily proceeded. European cultivation of rubber has spread over the district, and with it the

district has become populated by the Tamil cooly, a non-immune to malaria. Yet the public health has improved steadily. Malaria in serious amount is only to be found in the Hilly Land as in the Klang district. On the same Bukit Rotan Road (where Mr. Hale said the Javanese coffee was destroyed by flood) a large population is now living practically free from malaria. Dr. J. Lang Niven, who is in charge of the estates there, kindly informs me that of sixty-five children whom he examined only 4, or 6·1 per cent., had splenic enlargement, and three of the four children had been on estates in Southern India before coming to Kuala Selangor.

The parts of this district which are drained are now as healthy as any to be found in the country. While the parts still undrained and the hilly land where *N. wilmori* is still present are unhealthy. I think, therefore, we may reasonably conclude that the rise of the malaria epidemic which coincided with the obstruction of the land drainage by the road, and the fall in the epidemic which coincided with the more efficient drainage of the land, were respectively due to obstruction and to drainage.

V.—Kapar Drainage Scheme. In my first report on the anti-malaria measures of Klang [1903] I referred to the gradual improvement in the health of Kuala Selangor district as the result of draining large areas, in contrast with the more rapid improvement which had occurred in Klang and Port Swettenham as the result of measures carried out in a shorter period. These facts came to the notice of Mr. W. W. Bailey, who wrote to Government, complaining that the Klang end of the road still obstructed the drainage of the land, and made it impossible to drain the estates efficiently; and attributing the malaria which then existed on the estates to the road. In support of his proposals he quoted my investigations in Kuala Selangor, and referred the Government to me for further information.

On 29th April, 1904, I forwarded, at the request of Government, a report from which the following are extracts:—

> 'Roads and other public works, by producing breeding 'places for mosquitos, are important agents in spreading 'malaria and filaria. Roads in flat country, especially when 'parallel to the coast, are injurious in two ways: (1) During

'their construction borrow pits are formed, and these remain 'afterwards as mosquito breeding places; (2) when completed, 'roads may interfere with drainage of land on the inland side 'of the road.'

I quoted such figures as were available, which showed that from 55 to 65 per cent. of the deaths registered among residents on the Kapar Road were attributed to fever, and up to 35 per cent. of the admissions to hospital were from malaria, and said: 'Without 'straining these figures, there is little doubt that malaria is an 'important cause of sickness and death among the people living 'along the road.'

Not being a Civil Engineer I declined to say that the drains were insufficient to drain the land, or that the openings through the road were insufficient to allow the water to find its way to the sea, although in wet weather the whole inland side of the road was flooded and the water came to within a short distance of the level of the road. I wrote, 'It would be going beyond my province to 'express an opinion as to whether or not the Klang-Kuala Selangor 'road is still preventing the drainage of the estates and the land 'on the inland side, but the unanimity of the planters on the point, 'and the sight of water standing often many feet higher on the 'landward than seaward side of the road, seem evidence sufficient to 'justify a thorough enquiry . . . When it can be proved that a 'road interferes with the drainage of land on which any considerable 'population lives (such as on the Klang-Kuala Selangor Road) then 'expenditure on drainage is advisable from every point of view.' I then made some remarks on the construction of drains from the point of view of anti-malaria sanitation, and the necessity of engineers remembering that 'work which without excuse leaves a 'trail of malaria behind it is bad engineering. . . Finally, I would 'express the opinion that the stamping out of malaria, or at least 'reducing it to a negligible quantity is a much more hopeful affair 'than has hitherto been anticipated. . . . The experience of Klang 'and Port Swettenham, taken with the knowledge that malaria has died out of the Fen Country in England, while Anophelines still 'flourish in considerable numbers, all point in the same direction. I 'would, therefore, urge upon Government that to abolish malaria it 'is not necessary to abolish mosquitos completely, and that

'measures intelligently directed against the disease may at once cost 'little and be strikingly effective.'

As a result of the representations made, the Resident-General, Sir W. Hood Treacher, K.C.M.G., the Acting British Resident, Mr. Douglas Campbell, the Director of the Institute of Medical Research, Dr. C. W. Daniels, the Government Engineers, Mr. W. W. Bailey and other planters, visited the Kapar sub-district and held an enquiry into the condition of the road and land. The necessity of improved drainage was recognised, and a scheme involving the expenditure of $110,000 approved. The outlets through the road were enlarged, necessitating in some places bridges double the length of the previous ones; and the scheme provided 37 miles of main drains, sufficient for the drainage of 24,000 acres, upon which the estates now pay drainage assessment. Some of the drains constructed are 20 feet wide (fig. 6, p. 38). The effect of this drainage will be shown further on.

VI.—Malarial Survey of Klang and Kuala Langat Districts. During 1902 and 1903 I devoted considerable time to microscopic work on the blood of patients admitted to hospital, and to the clinical aspects of malaria. It soon became evident that a very large number of patients, who were admitted complaining of symptoms other than pyrexia, were really suffering from malaria. Some of these observations were published [1905] in a paper entitled, 'Some Clinical aspects of Quartan Malaria.'[8] In it I showed that in 18·18 per cent. of the cases pyrexia was absent for periods averaging 6·4 days, and in 18·18 per cent. of the cases the rise in temperature was at so much longer intervals as to lead to little, if any, importance being attached to it by the patient. A considerable experience of labour convinces me that 1 or 2 per cent. of coolies working on malarious estates have pyrexia of which they are unconscious and which they deny, even when the thermometer shows a temperature of 102° F. The same will often be seen in hospital. I was led to the conclusion that while there might be much pyrexia and few if any parasites be found in the peripheral blood during the first few days of the illness, the later stages might show large numbers of parasites and no pyrexia, as immunity was becoming established. It appeared to me that sufferers from malaria might be divided into

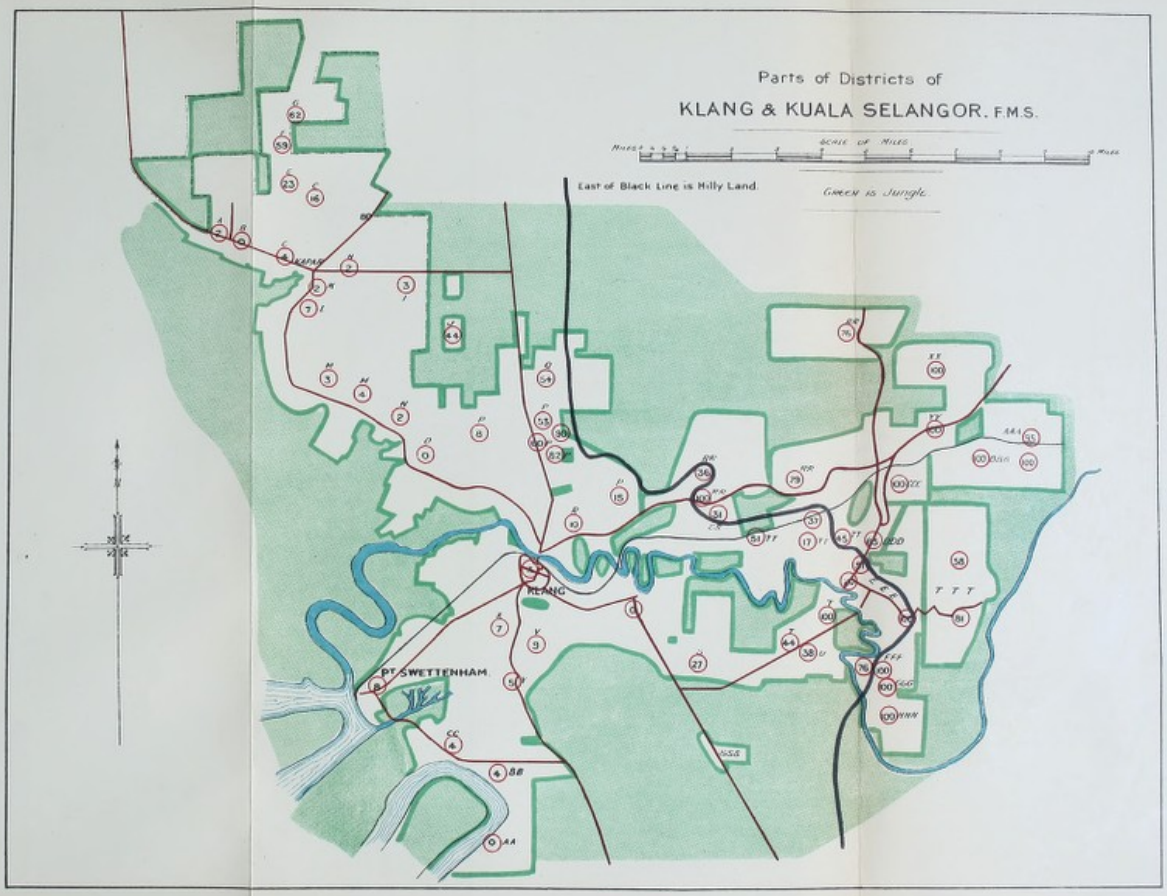
those with pyrexia and those without it, the latter class being not the less either in number or importance. And the more I have seen of malaria the more I find in support of this conclusion. It supplied an explanation of the extraordinary fall in the number of deaths registered in Klang in 1902 as due to diseases other than malaria; and the observations on coolies on large doses of quinine and apparently in good health, referred to on page 88, further bears it out.

It is sometimes said that the native registers everything as malarial fever, and that the returns grossly exaggerate the amount of the disease. This may be so where there is little malaria. I am convinced however that where there is any considerable amount of malaria the error is entirely the other way, and that many deaths from malaria are recorded as due to their complications instead of the disease to which they are really due. In confirmation of this view there is the great fall in the number of deaths recorded as due to diseases other than malaria when malaria was reduced in Klang, as shown in the table on page 30.

The result of my microscopic work in hospital was to convince me of the enormous amount of malaria on the estates of the district, and I determined in 1904 to carry out as complete a survey as my official work would permit.

Choosing the most unhealthy months of the year, November and December, I visited a number of estates in different parts of the district, and made examinations of the fresh blood of the children. The work was laborious, but the specimens were taken by an assistant, and I examined about eight to ten an hour. Out of 298 children under the age of ten examined in 1904 no less than 101, or 33·89 per cent., were infected. During the same months, 1905, 1906, and 1907, either blood or spleen examinations were made, and in 1909 and the early part of January, 1910, examinations of the children on every estate of Klang and Kuala Langat districts were made by either Dr. Macaulay or myself, and blood examinations were also made by Dr. Macaulay on some estates. The species and breeding places of the Anopheline have also been determined.

VII. Disappearance of Malaria from certain Rural Areas. The sum of these observations is that malaria in certain portions of the district, namely the flat land, is exclusively carried by


Parts of Districts of
KLANG & KUALA SELANGOR. F.M.S.
SCALE OF MILES.
East of Black Line is Hilly Land.
Green is Jungle.
KLANG
PT. SWETTENHAM.

Part of

KUALA LANGAT DISTRICT.

SCALE: THREE MILES TO AN INCH.

Myzorhyncus umbrosus x., which breeds in pools in undrained jungle; that when the jungle is felled and the pools drained this mosquito is exterminated completely; and that with its extermination, malaria disappears. It has been found too that the spleen rate in the children bears a definite relationship to the distance they live from the breeding place of the mosquito, and that the death-rate of an estate is in relation to the spleen rate. Finally, these facts have enabled me to estimate with considerable accuracy the probable health or unhealthiness of a proposed site for coolie lines, and to give advice which has already borne fruit. A theory which will provide a sound working rule is one of considerable value.

In order to make good these statements, I must now refer to the individual estates, the position of which will be seen from the maps. In these are seen the parts under cultivation and the parts which are still undrained jungle. Coolie-lines or houses are shown by the number, which is the spleen rate for the lines or group of lines at that part of the estate.

Estate A. This was opened in 1906, and the coolies were housed within 100 yards of the jungle. In 1907 malaria was very prevalent among them and it became necessary to administer quinine daily. Rapid progress was however made in opening up the land, and within a year there was an extraordinary improvement in the health of the estate. The most striking evidence is to be found in the reports of the Indian Immigration Department from which the following figures are taken:—

	No. on 1st Jan.	Additions to labour	Died	Deserted	Discharged	Sent to India	Total. Deductions	No. on 31st Dec.	Average Population	Deaths per mille
1907	132	261	12	34	125	12	183	78	120	100
1908	60	173	2	7	19	—	28	100	101	20

These figures exhibit the economic importance of malaria. The whole success and, in fact, the very existence of tropical agriculture depends on a healthy and contented labour force. The severe prevalence of malaria in 1907 not only led to a high death rate, but it led to the unnecessary loss in other ways of about 150

coolies. Coolies will not remain on an unhealthy estate; and, therefore 34 deserted and 125 gave the legal month's notice and left. Instead of having a fine labour force of close on 300 coolies, the estate had to begin the year with considerably less than it had the previous year.

In 1907 the manager, and a friend who lived with him for some time, both suffered severely from malaria. On 23rd July, 1907, only 167 out of 245 coolies were working, and of those not at work ten had high temperatures. Three months later, after much loss of labour, I found on one occasion 8 per cent. of the labour force with 'fever,' with oedematous feet, and the other sequelae of malaria.

The present manager has been on the estate for nearly two years. He has been off work only for one day and that not from malaria, a disease from which he has not suffered. On 10th January, 1910, I examined all* the children on the estate, and out of the 51 found one with an enlarged spleen, who on enquiry was discovered to have come from an estate in another district, the death-rate of which in 1908 was 108 per 1,000, and which I know suffers severely from malaria. The child had malaria when it came to Estate 'A.'

I regret I have no figures referring to the children in 1907, but I consider that the figures I have given exhibit in the most striking way how malaria has disappeared with the draining and opening up of the land. Undrained jungle is now about half a mile distant from the lines.

Estate 'B.' I examined this estate first in 1904, when all the nine children on it were found free from parasites. There was only a small labour force on it, about sixty in all, and only occasionally one got fever. The jungle was comparatively near; but the land immediately behind the coolie lines was drained. I find, however, that a small labour force often escapes when a larger one is seriously affected. This estate has continued to enjoy good health throughout, and on 10th January, 1910, none of the thirty children on the estate had enlargement of the spleen, and the conductor who

* It is to be understood that practically every child on the Estates was examined: and that where a spleen rate is given it is based on the examination of the whole child population, and not merely calculated from an examination of a proportion of the children.

has been there for one and a half years tells me he has not had fever.

The death-rates have been, during 1906, 1907 and 1908, 22, 28 and 9 per mille respectively.

This estate thus shows continued good health from the time I came to know it, even while in 1907 its neighbour only half a mile away was suffering severely from malaria.

Estate 'C.' This estate began operations in 1904, when its labour force was placed on land already opened a year or two before by Malays. They were thus placed on drained land from the beginning and accordingly were healthy. Its death-rate shows this, and was as follows:—

Year	1904	1905	1906	1907	1908
D. R.	26	—	34	37	13

An experiment, from my point of view, was carried out on this estate in 1906 and 1907, which bears out the extraordinary limitation of the flight of the mosquito, the relation of malaria to undrained jungle, the value of selecting the site for the housing of a labour force, and the certainty with which one can predict the health or otherwise of a site on the flat land.

It is an estate of about 3,000 acres, and, with the healthy labour force it possessed, such rapid progress was made that within three years of starting 1,000 acres were already opened, and it was proposed to open still more. In 1906 much of the work of the coolies was one to two miles distant from their lines, and it was obviously an economy, both to the estate and the coolie, to house him nearer to his work. I was informed in 1906 that it was proposed to remove most of the force up to what would ultimately be the centre of the estate, and which at that time was still on the edge of undrained jungle. Knowing from experience that the site would probably be very unhealthy, I strongly advised that only a small body should be removed to begin with until the land had been further opened up. However, four sets of lines were built, three about twenty-five chains, i.e., quarter of a mile from jungle, and the other about 100 yards. The removal took place in October, 1906; and on 22nd November there were 120 coolies in the lines marked 16 and 80 in a set of lines near to the jungle at a

quarter of a mile from the place marked 80*. The result was disastrous. The coolies were overwhelmed with malaria and soon had to be removed. I am indebted to the present manager for the following:—

'Re Abandoning Lines: You ask me my reason for 'abandoning four sets of coolie lines in March, 1907. They 'are as follows: I found that amongst the coolies living near 'E.E. drain (place marked 16, about twenty-five chains from 'the jungle) I had 28 per cent. down ill with fever every day, 'and amongst those living near to my bungalow, marked 80, 'about ten chains from . . . . jungle, the rate was 33 per 'cent. daily. On that account I removed that portion of my 'labour force to the South-western end of the estate, which 'had previously been healthy, and I abandoned the top lines 'altogether; but about the beginning of 1909 I put a portion 'of my labour force back again near E.E. drain, the jungle 'being then forty chains away, and I am glad to say the fever 'rate has been very small, and of very little consequence.'—Sd. E. H. King Harman.

On 22nd November, 1906, there were fifteen children in the lines marked 16 of whom only one had enlargement of the spleen. On 17th February, 1907, there were twelve children, of whom seven or 58 per cent. had enlarged spleen.

As these were the same children it shows how malarious the place had become. On 4th January, 1909, there were fifteen children living on the same spot, of whom three had enlargement (very small in the case of two), equal to 20 per cent.; but a portion of the force had only recently been removed to the place, marked 13 on the edge of drained jungle, so that the real figures should have been thirty children with five with enlarged spleens, or 16 per cent.

Now on the South-western portion of the estate, that is the portion of the estate first occupied in 1904, I examined, on 5th January, 1910, the children, in all 109. Of these, four children had enlarged spleen, giving a spleen rate of 3·6. They were recent

* The place marked 80 on Estate 'C' does not represent a spleen rate, but only the number of coolies there in 1906. Coolies no longer live on this spot as it was so unhealthy, and the lines were destroyed.

arrivals. I recognised two sisters as being the only two children who had been found with enlargement on an estate in the neighbourhood; one other had come two months previously from an estate in another district, and one had come from an estate where the spleen rate is 100. The corrected spleen rate should therefore be nil.

The bungalow to which the manager refers is still in occupation and malaria is far from unknown to its occupants, while the bungalow on the South-western division has never been infected with malaria.

The medical history of this estate has been practically that of a series of experiments of the most convincing character. If any doubt remained a glance at the map showing the condition of the estates marked 'E,' 'F,' and 'G,' the coolie lines of which at the present moment vary in distance from jungle which has been drained only for about one year. The lines marked 23 had undrained jungle to within 200 yards about a year ago. Jungle is now distant about 500 yards, and it has been drained for about four months. The lines marked 59 on Estate 'F' are opposite and within fifty yards of jungle which, however, has been drained for some months. The percentage of children with abnormal spleens was fifty-nine, based on the examination of thirty-two children. Of the thirteen with no enlargement, one had been one and a half years on the estate, three had been only fourteen days, while the others had been less than six months. It is interesting that the jungle opposite had been drained for about the same period, and this probably accounts for these children having escaped. Dr. T. S. Macaulay kindly examined the blood of twenty children on this estate and found parasites in seven, or 31·9 per cent. These children get about five grains of quinine daily.

On 6th December, 1906, I examined three children on this estate, and of these two had considerable enlargement of the spleen.

The death-rate of the estate in 1908 was 41 per 1,000.

Estate 'G' has been unhealthy since it was opened, as undrained jungle has always been within less than 100 yards of all the coolie lines.

On 5th January, 1910, I examined twenty-four children on this

estate, and of these fifteen had enlarged spleen, equal to 62 per cent. Of the nine with no enlargement, two had been only fourteen days on it; and one had a high temperature at the time of my examination.

Dr. Macaulay examined the blood of eleven of the children on this estate, but did not find parasites. All are on quinine—about five grains daily.

On 6th December, 1906, I examined eight children on this estate and found three or 37 per cent. with enlarged spleen.

The death-rate given in the Indian Immigration Return is 69, but this does not represent the exact death-rate, since Estate 'M,' which belongs to the same Company had an estate hospital, to which the sick from this estate were sent. Those who died there were not accredited to 'G,' but swell the death-rate of Estate 'M' to an unnatural degree. I draw attention to this later.

From these figures it is evident that the opening up of the Estates 'F' and 'G' has not led to any improvement in their health, and the reason is obviously that the lines are still as near to jungle as when the estates were first opened. This is in marked contrast to the improvement to be seen where the opening of the estates pushes the jungle away from the lines.

Estate 'H.' The medical history of this estate can be found from the sub-joined table.

Year	1904	1905	1906	1907	1908	1909
Blood Examination.						
No. examined	25	13	27	—	—	26
Percentage infected	28	48	0	—	—	0
Spleen examination.						
No. examined...	—	—	27	—	—	58
Percentage enlarged	—	—	0	—	—	1·6
Death-rate	—	—	30	30	22	—

Now from these figures it is obvious that a marked improvement occurred in the health of this estate in 1906. I give in the manager's own words the explanation:—

'In answer to your enquiry with regard to the health of 'this estate. In 1904 only 160 acres were opened and jungle

'came comparatively close to the lines. There was so much 'fever that coolies had to be dosed with quinine daily at 'muster. Little opening was done during 1905 and the state 'of health among coolies remained much the same; in 1906 'jungle was carried back by opening to a distance of one and 'a quarter miles on one side and about half a mile on the other, 'and from that date there has been practically no fever on the 'estate, and the out-turn of coolies daily has improved to a 'marked extent.' Dated 5.1.10, sd. N. C. S. Bosanquet.

Comment on this is hardly necessary, but I might mention that the lines were distant from the jungle in 1904 about a quarter of a mile. The extra quarter of a mile made all the difference. Being a quarter of a mile away to begin with the estate was not suffering so severely from malaria as would have been the case had they been closer, but I think the lesson can hardly be missed.

Estate 'I.' Opened in 1904 this estate suffered very severely from malaria, more so than the percentage of children infected in 1905 would lead one to suppose. It was so severe that not a child below the age of one year was to be found on the estate, although the adult labour force was then about 250. The manager suffered so severely from the disease that he had to be sent on three months' leave of absence. On December, 1905, I saw no less than seventeen coolies, or 6·8 per cent. of the whole labour force, ill with malaria fever, while diarrhoea and dysentery, the common terminal sequelae of malaria, were far from uncommon. Then, in 1906, opening up having been continued, improvement took place. The present manager has been on the estate for over three years and he has not had malaria.

Table giving Particulars of Estate 'I.'

Year	1905	1906	1907	1908	1909
Blood.					
No. examined	15	16	—	—	59
Percentage infected	26	0	—	—	1·6
Spleen.					
No. examined	—	—	—	—	58
Percentage enlarged	—	—	—	—	3·4
Death-rate	—	68	—	54	—

The jungle is now rather less than half a mile from the lines.

We have thus seen that on the same road on two different estates the lines which were near to the undrained jungle were unhealthy and that when the jungle was pushed back the lines became healthy. Yet there has been no general change in the whole country, for we find that, at the present date, we have only to go to the lines still on the jungle edge to find malaria. Immediately inland from Estate 'I' we come to *Estate 'J,'* and here of the nine children four or 44 per cent. have enlarged spleens. Quinine was given systematically on the estate, and doubtless this keeps the death-rate comparatively low. It was 34 per mille in 1908, and 120 in 1907.

The story of how malaria has disappeared from estates on the flat land as the jungle has been pushed back to about half a mile, little short of miraculous as it is, becomes monotonous as we trace it North up to Kuala Selangor, and down South through Klang to Kuala Langat over a distance of some fifty miles. The maps indeed tell the tale. I would gladly leave it at that, but the subject is of such economic importance that I must make the proof of the improvement as full as possible. For miraculous as the disappearance of malaria has been with the opening up of the flat land, just as striking has been the total failure of similar opening to affect malaria on the hilly land. The explanation of the difference is to be found in the mosquito theorem, and it alone can explain it. On the flat land the carrier of malaria is the mosquito *Myzorhyncus umbrosus* x., which, breeding in pools in the jungle, is exterminated when these pools are drained even by open drains. While on the hill land the chief carrier is *Nyssorhyncus willmori*, a mosquito which cannot be exterminated in the ravines by open drainage, however quick the current, since its proper breeding place is the running water of springs and hill streams.

My object, therefore, even at the risk of being tedious, is to show that on the flat land, the manager of an estate can put his coolie lines in almost every instance beyond the reach of the malaria carrier, and so save his labour from malaria; and I would insist that since over thousands of acres of flat land malaria has been abolished by exterminating the mosquito which carries the disease, so the manager of the hill estate can also abolish the disease if he abolishes the breeding places of the hill carrier by putting the water of the ravines underground.

Estate 'K' is small and I have few figures referring to it. Its coolie lines have always been at a distance from jungle, and has always been healthy. I am indebted to Dr. Macaulay for examining the fourteen children on this estate. Of the fourteen he found one with an enlarged spleen, equal to 7 per cent. This child, however, came from an estate on which the spleen rate is twenty-three, and had suffered from fever before coming to Estate 'K.' The death-rate of this estate was 18 per mille in 1908.

Estates 'L,' 'M,' 'N,' 'O,' 'P,' 'Q' are seen on the map to illustrate at the present moment that those away from the jungle are healthy, while those close to it are more unhealthy, and that even on the same estate there are marked differences of health depending also on the proximity or otherwise of the lines to the jungle. Estates 'L,' 'M,' 'N,' 'O' are all at some distance from the jungle and all are healthy. Estate 'P' has some lines near to the jungle and these are very unhealthy, while others away from it are healthy. Estate 'Q,' on the other hand, had all its lines close to jungle until recently, and some remain so, and its spleen rate is high.

Dealing with these estates in detail we find that during the course of the past few years some of those which are now healthy were unhealthy when the lines were closer to jungle.

Estate 'L.' This estate, begun in 1902, had already a considerable area opened and drained by November, 1904, when I first made an examination of the children.

TABLE SHEWING THE RESULT OF BLOOD AND SPLEEN EXAMINATION OF CHILDREN AND THE DEATH-RATE OF ESTATE 'L.'

Year	1904	1905	1906	1907	1908	1909
Blood.						
No. examined...	10	16	18	—	—	—
Percentage infected	33	6	0	—	—	—
Spleen.						
No. examined...	—	—	18	—	—	39
Percentage enlarged	—	—	0	—	—	2·5
Death-rate	—	—	—	20	21	—

Dr. Macaulay, to whom I am indebted for the examinations in 1909, says that of the thirty-nine children, only one with

enlargement of the spleen was a child eight months old, born on the estate. The enlargement was so slight that he could hardly call it pathological.

Here again we see the improvement which has followed the abolition of the malaria carrier, for *M. umbrosus* x. can no longer be found on this estate.

Estate 'M' was first opened in 1898, and I cannot recall the time since I came to the district in 1901 when it was unhealthy. Such figures as I have show this.

Year	1903	1904	1905	1906	1907	1908	1909
Blood.							
No. examined	—	—	26	25	—	—	—
Percentage infected ...	—	—	3	4	—	—	—
Spleen.							
No. examined	—	—	—	25	—	—	202
Percentage enlarged ...	—	—	—	4	—	—	3·4
Death-rate	—	—	—	—	15	26	35

The death-rate of this estate is shown as larger than it should be since coolies sent from Estate 'G,' who died in the estate hospital on 'M,' have been counted into this death-rate.

That the estate is free from malaria is shown by the fact that no European has contracted malaria on it since I came to the district, and there is now, and has been for several years, a European staff of six.

Estates 'N' and 'O.' The lines of both of these estates are now a considerable distance from the jungle, the nearest being the mangrove which is 600 to 1,000 yards off.

I have few figures concerning these estates. I remember on one occasion in 1905 visiting a set of lines on 'N' and found many cases of fever. It was then within 100 yards of the jungle.

I cannot, unfortunately, find my notes of this.

The following figures show that the estates are not by any means unhealthy. The labour force is small on each, being only 280 on 'N,' and 120 on 'O.'

	Death Rates			Spleen Rate 1909	
	1906	1907	1908	No. examined	Percentage enlarged
Estate 'N' ...	8	20	43	29	0
,, 'O' ...	44	18	34	45	2·2

Estate 'P' is one of the largest in the country, and stretches over several square miles. Within its boundaries are to be found lines at varying distances from undrained jungle. These show in the most distinct manner what has been evident in all the other estates to which I have previously referred.

It will be seen from a reference to the map, that the lines 82 are close to the jungle. They contained seventeen children, of whom fourteen had enlarged spleens. Further along the edge of the same jungle are lines containing eleven children, of whom ten have spleens abnormal in size, giving a rate of 90·9.

Two hundred yards from these the lines containing fifteen children showed a spleen rate of 53·3, while at a distance of 300 yards from the lines marked 82 the spleen rate of twenty-two children was 59·9.

In marked contrast to these are the 109 children who live at a greater distance from the jungle and whose spleen rate is 8·2. That it should be so high as this is due to some of the lines being near to a small belt of jungle once drained, but whose drains are not upkept. When the lines were put there in 1906 I have notes showing there were considerable numbers of cases of malaria on the estate, and I recollect these were unhealthy, but I have unfortunately not recorded the exact number of cases found in each of the different sets of lines. There is no doubt, however, that the lines next the belt of jungle have improved in health to a very considerable extent. In tabular form these facts become more evident.

Distance from Undrained Jungle

	Within 100 yards	200 to 300 yards	Beyond 600 yards
No. of children examined	28	37	109
No. with enlarged spleen	24	17	9
Percentage with enlarged spleen	85·7	45·9	8·9

Estate 'Q.' The lines on this estate also vary in distance from one hundred yards to a quarter of a mile from the jungle. I found however, that the coolies had been moving from the lines nearest to the jungle to others further away. I, therefore, cannot determine with accuracy the spleen rate of the different lines. The lines a quarter of mile from jungle have a spleen rate of 28, while that of those within 100 yards is 59·3.

The other rates are 55·5, 42·9 and 60, and that for the whole estate is 53·6.

The death-rate was 60 per 1,000 in 1908.

Estate 'R.' Within 150 yards of the lines on this estate is a small swamp about half an acre in extent. There is no other swamp within half a mile.

Of nineteen children examined in 1910, 10·5 per cent. had enlarged spleen. The death-rate of the estate has been 40, 56 and 45 in the years 1906, 1907 and 1908 respectively.

Passing South across the Klang River we come to Estate 'S,' which has been opened for some years. Although extensive in area the opening has not been such as to decrease the distance of the lines from the nearest jungle. The following table gives the facts.

Distance of the Various Lines from Jungle

	200 yds.	300 yds.	350 yds.	300 yds.	200 yds.
No. examined	4	7	13	8	20
Spleen rate	50	28·5	23·0	37·5	20

There has been a great improvement in the health of this estate during 1909 due to the extensive use of quinine. It is an example of how quinine may appear of greater value in a place where malaria is not very severe than where the disease is intense.

The estate has always been unhealthy, but not intensely malarious, the spleen rate of the whole estate being only 23; still, the disease has caused considerable trouble. There are no official figures for 1907, but in that year the Manager was invalided to Europe on account of malaria. In the same year a large gang of coolies also left on account of the disease. In 1908 there was great sickness, and I saw many severe cases of chronic and acute malaria on the estate. In the months of November and December no less than sixteen coolies died from malaria or its complications. The whole labour force was then put on to quinine, ten grains daily, and the death-rate at once came down. Of the six deaths in 1909 none were due to malaria either directly or indirectly. The figures are interesting:—

	Average Population	Deaths	Desertions	Discharges	Total Loss
1908.....	362	42	137	230	409
1909.....	373	6	46	172	224

This is the only estate whose spleen rate is below 40 on which quinine is given systematically. I refer to the subject of the dose of quinine in relation to the intensity of the disease on page 94.

The next two estates, 'T' and 'U,' I deal with together, as they form practically one clearing in the middle of the jungle.

On *Estate 'T'* one set of lines is close to jungle, about fifty feet from it, and of three children all have enlarged spleens, while in the set of lines one hundred yards from jungle nine out of ten have enlargement. The spleen rate of these two sets of lines is therefore 92·3.

The other lines on the two estates are close to each other, and about one-third of a mile from jungle. Of the fifty-four children twenty-one suffer from enlargement, giving a spleen rate of 38·8.

The rate of the whole sixty-seven children on the two estates in 1909 is thus 49·2. On the 16th January, 1907, I examined

forty-four children on these same estates and found twenty-six with enlarged spleens, giving a rate of 59. It will thus be seen that here again the lines near to the jungle are the more unhealthy, and that during the last three years because the nearest jungle is still at the same distance from the lines, there has been practically no improvement in the health. The death-rate bears this out.

Year	1906	1907	1908
Estate 'T'	72	33	107
,, 'U"	37	64	75

Estate 'SSS,' a small clearing in the jungle follows the usual rule. No coolies can be kept on it, *as it is so unhealthy.*

Turning back towards the coast we come to the Estates 'V,' 'X,' 'Y,' 'AA,' 'BB,' 'CC,' which are among the oldest in the district, and have large areas opened. In all, with one exception, the lines are at a distance from jungle, and the health of all is good. It was not however always so, and I remember when District Surgeon that cases of malaria were not unfrequently admitted from Estate 'V,' while in the first half of 1906 I find from my notes that malaria was constantly seen in the lines of Estate 'X,' which are marked and which were then on the edge of the jungle. I have however no figures referring to the children.

The following table shows their present condition.

Estates	'V'	'X'	'Y'	'AA'	'BB'	'CC'
No. examined	32	85	145	26	25	82
Spleen rate	9·6	7·0	4·8	0	4	3·6
Death rate 1908...	11	30	29	22	22	9
,, ,, 1907...	6	25	35	—	20	30
,, ,, 1906...	0	67	23	38	20	30

It is hardly necessary to comment on these figures. But on Estate 'V' of the three coolies with enlarged spleens one came from a set of lines on another estate whose spleen rate is over 50. In April, 1909, Dr. Stanton, of the Institute for Medical Research, examined

160 unselected coolies on this estate, and found only two, or 1·3 per cent., with malaria parasites in the blood.

Although the estate is classed among those of the flat land, it is not entirely flat. Part of it is hilly. The absence of malaria is due to the valleys between the hills being of such a formation that no proper hill streams are formed, and *N. willmori* cannot be found either in the drains or in the lines of the estate. Klang Town is also hilly, but here again there are no hill streams such as *N. willmori* breeds in. Hence open drains sufficed to eradicate malaria. An idea existed among medical men at one time that malaria was due to disturbance of hill soil, the exposure and excavation of red earth, and the quarrying of laterite.

The absence of malaria from estate 'V' where red earth and laterite are abundant, and from the town of Klang where the constant quarrying of laterite and the excavation of red earth have gone on for years from the midst of the town and at the hospital, show that malaria is not due to the presence or disturbance of these soils. The one constant condition which I have found associated with malaria is the presence of certain species of Anopheline. It is true that in some of the most malarious places it is said by the layman there are no mosquitos. On one such place, an estate where the spleen rate is 100 and the death-rate in 1908 was 300 per mille, the Manager, a man of more than ordinary intelligence, assured me that mosquitos were never seen except on a wet night, and then only in small numbers. My experience was that whereas the man who helps me to catch mosquitos usually earns 20 or 30 cents in a couple of hours, being paid at the rate of 3 cents for each Anopheline, on this estate he earned $3 and twelve cents in the same time and at the same rate, having thus caught 104 Anophelines. When I went to the lines, I found the mosquitos, mostly *N. willmori*, in great abundance. *N. willmori* is a small mosquito; it makes little noise, and causes little if any pain when it bites. This is different from *M. umbrosus* x., which gives a painful bite something like a sharp hot needle.

Of the six children on Estate 'X' with enlarged spleen three had been on the estate only fourteen days, having come from India. The presumption is these children had had malaria before their arrival on the estate. The high death-rate of this estate in 1908 was due to the return to the estate of a gang of coolies in number, who

had gone to an estate whose spleen rate is 100. They suffered so severely from malaria there that they returned at the end of six weeks.

The manager of Estate 'X' was afraid these coolies might infect the others, but this did not occur since there was no Anopheline to act as carrier.

On *Estate 'Y'* several of the lines are close to jungle, which although with drains on two sides of the part which is close to the lines could not be called properly drained. I was, however, unable to get Anophelines in it on one occasion three years ago. Of the ninety children in these lines 5·2 per cent. have enlarged spleen, while in another set of lines close to drained jungle twenty-two children showed a spleen rate of 8·3. The spleen rate of the remaining thirty-three children who are housed about half a mile from jungle was nil.

This is the only estate which even appears to be an exception to the rule that lines within 200 yards of the jungle should have a spleen rate of about 50, but the presence of a large 15-foot drain along one side of the jungle and a 6-foot drain along the other side, probably explains the freedom from sickness.

Continuing to the Langat district we come to *Estate 'EE'* on an island. This estate commenced operations at the end of 1906. The labour was at first housed on land originally opened by natives, and drains were at once put through a considerable area by Javanese. So that when the Tamil labour was introduced later it was on open land. The Tamils have accordingly never suffered from malaria, and now one of the finest labour forces in the country is there, consisting in all of about 2,000 coolies of whom 1,200 are Tamils.

The death-rate of the estate was 22 per mille in 1908 and in 1909 was only 11.

Owing to the good health of the labour force over 4,000 acres are now drained and opened, and no set of coolie lines is closer than half a mile to the jungle. On 29 December, 1909, I examined 246 children on this estate, and found only one with an enlarged spleen (it was just palpable), giving a percentage of 0·4. The boy was in perfect health, and no history of malaria was obtainable. The presumption is, therefore that he had had malaria when in India.

This estate shows that it is not necessarily the oldest estate which is the healthiest, but that old or new the state of the health is in relation to the proximity or otherwise of the jungle.

Passing on to the mainland again, we come to a small *Estate* '*III*,' the lines of which are a little over a quarter of a mile from jungle. The spleen rate of the twenty-one children is 14. The death-rate of 1908 was 19 per 1,000.

The next estate is '*FF*,' and in the lines next jungle the rate is 33, while in the more distant lines it is nil. For the whole estate it is 23·7, and the death-rate of 1908 was 53 per mille.

Further on *Estate* '*GG*' has a spleen rate of 22 (fifty-nine children examined) although the lines are a quarter of a mile from jungle and separated from it by a river. On this estate were eighteen children of whom ten had enlarged spleen. These came from an estate whose rate is about 50. Deducting these children the corrected rate of the estate would be 7·3.

The death-rate of the estate in 1908 was 31. It has been healthy from the beginning as it began on opened land.

In marked contrast to this is the next *Estate* '*HH*,' only half a mile further on, where all the lines are within hundred yards of jungle. Of forty-six children 54·3 per cent. had enlargement of the spleen, and the death-rate of the estate was in 1908 correspondingly high, namely 60 per 1,000.

Estate '*TT*' has a spleen rate of only 13 in the fifteen children examined. The lines are about 200 yards from jungle, but are separated from it by a river. Its death-rate in 1908 was 47.

The following three estates again corroborate the evidence which we have been so steadily accumulating. *Estate* '*JJ*' has lines within a quarter of a mile of jungle and the spleen rate of fifty-three children is 26·3. Its death-rate was 39. The figures tell their own tale.

	Distance lines are from jungle	Spleen Examination		Death-rate 1908
		No. examined	Percentage enlarged	
Estate 'JJ' ...	400 yards	53	26·3	39
,, 'KK' ...	Over 1,000 yds.	48	0·0	12
,, 'LL' ...	,, ,, ,,	70	1·4	17

The only child found on *Estate 'LL'* with enlarged spleen had come from an estate whose spleen rate is between 30 and 40.

Adjoining Estate 'KK' are two estates illustrating the same rule. *Estate 'PP'* is a small one, but the manager and his coolies suffer considerably from fever. The two children on it had enlarged spleen. All live within a hundred yards of jungle.

Estate 'OO' has lines in two places. One lot of lines is now half a mile from jungle, but until recently the jungle was only a quarter of a mile away. The other lot of lines are, and have been, half a mile from jungle for about two years. The result is very striking, for whereas in the lines which were until recently a quarter of a mile from jungle, 60 per cent. of the twenty-eight children examined suffered from splenic enlargement, of the seventeen in the other lines the spleen rate was nil.

Until recently the lines on *Estate 'NN'* were one-third of a mile from jungle. The spleen rate of the thirty-five children is 11·4, while the lines of Estate 'MM' are over 1,000 yards from jungle and none of the twelve children had abnormality of the spleen.

The carrier of malaria on the estates mentioned as being malarious is *M. umbrosus* x., as it is on all the flat land estates of the coast. But in Langat district Jugra Hill rises to a height of 915 feet, isolated from all other hills by some twenty miles of flat land. It is not uninteresting, as Dr. Leicester remarks, that the mosquitos of the hill are not those of the surrounding flat land but that of hill land.

And among the hill mosquitos is *N. willmori*, the stream breeder. As a result of its presence, all around Jugra Hill has been extremely malarious, while only a short distance from it people have enjoyed good health.

What amounts to an experiment took place a few years ago, when a set of lines belonging to the Public Works Department was removed from the base of the hill to a spot a mile from it. The result was an immediate and marked improvement in the health of the coolies, which has ever since been maintained. The condition of the coolies in 1901 and 1902 can be seen from the following extract from a report dated 15 January, 1902, made by me to the Government on the prevalence of malaria in Jugra:

'But I would like to draw attention to some observations 'made at the P.W.D. coolie lines at Permatim Pasir which 'show that the malaria is not confined merely to the town, but 'extends round the foot of the hill, and which also explains 'the absolute refusal of many of the coolies to remain after 'the term of their agreement had expired, although they were 'willing to work at Klang.

'On February 5, 1901, out of nine persons in the lines one 'alone was healthy. Two men and one child had malarial 'fever; two children, two men and one woman had enlarged 'spleens, the result of repeated attacks of malaria. I was 'informed that about fifteen coolies were living there at the 'time.

'On July 10, 1901, I found of these P.W.D. coolies:—In 'the lines, two women one man and three children with malarial 'fever; in the hospital, seven with fever, three with enlarged 'spleens and ulcers. At this time there were about thirty-four 'persons living in the lines.

'On January 7, 1902, there were eleven children under ten 'years present at my visit. All, without exception, had 'enlarged spleen. Two women had fever.

'The overseer volunteered the statement that fifteen 'children had died within the past six months, which is not 'improbable as malaria often affects children severely.'

As the result of the representations made, the lines were removed in 1903 from the immediate foot of the hill, and, taking no risk, I advised they should be put one mile from the hill.

The result has been successful in the highest degree. From 1903 onwards I have often gone to the lines, and I have never once happened to find a coolie in them suffering from fever, although doubtless a coolie may occasionally do so.

On 18 January, 1910, I examined fourteen children in the lines. Two of them had splenic enlargement, and the overseer told me both had come to the place about a year before from other P.W.D. lines, and that they had not suffered from malaria since their arrival.

The overseer said he had been two years in the lines, and had not suffered from fever. No children had died since he had been

in charge; the only death had been that of a coolie who was ill when he arrived from India, and had died shortly after his arrival. No adult or child had fever on the day of my examination.

That no improvement has taken place in the health condition at the foot of the hill is to be seen from an examination of thirty-five Malay children in the Permatim Pasir School, made on 16th May, 1909. Of the thirty-five, eleven or 35 per cent. had enlargement of the spleen. This is in marked contrast to the P.W.D. coolies only one mile from the hill, and from the freedom from malaria on the Estates 'KK' and 'LL,' distant one and a half miles and two miles respectively.

An example of the selection of a thoroughly bad site is to be seen in the one I selected for coolie lines on the Government reserve near to the number 82 on Estate 'P.'

Bearing in mind the teaching of the books—'As high ground as 'possible is a golden rule for a camp. Against the vertical uprising 'of malaria, elevation however small, affords some protecton'—the lines were placed on a small hill. They were built about 1903, and were soon found so unhealthy that they had to be abandoned. They stand abandoned to this day, and the estate lines near to them show a spleen rate of 82, because to this day the jungle remains undisturbed close to the lines.

Had these lines been put on the flat land only half a mile away they would have been quite healthy.

I shall, later on, discuss the origin of the idea that hills are healthy, and show what may be a golden rule in one country may be disastrous in another.

It is sometimes argued that malaria is never as severe on the flat land as it is on the hilly land. This is generally so, for the conditions from the first are different. On the hill land, the coolies are housed on the side of a ravine so that water may be conveniently to hand. They are, therefore, placed as close as possible to the breeding place of the malaria carrier, that is, on the most unhealthy spots on an estate, and there they remain. No further opening of the estate alters the distance they are from the breeding place.

In the case of the flat land estates, the conditions are entirely different. Before a Tamil coolie is brought on to an estate, at least fifty acres are felled, drained and burned by Javanese, people who are, as we shall see, generally immune to malaria.

The Tamil on the flat, therefore, starts with the breeding place of the malaria carrier at a distance of some hundreds of yards, and every few months further openings put the breeding places further off. He starts, therefore, under better conditions as a rule, and the conditions improve with every additional opening.

That there is no essential difference is seen if a non-immune population be placed on undrained flat land. The conditions are then the same as on the hilly land, and the results are the same. It is not of course often that we see a population under such circumstances, but it occurred at Port Swettenham in 1901, and there malaria was as severe as it ever was on any hill estate.

We have seen, too, that lines close to the jungle have 90 to 100 per cent. of the children suffering from enlarged spleen, and the occurrence of a case of blackwater fever in a European who lived within hundred yards of the jungle on the flat land supplies a further proof, if the history of Port Swettenham has failed to convince.

VIII.—Summary of Examination of Children on Flat Land Estates. On the flat land estates altogether 2,295 children were examined.

Tabulating the results we find that the health of the lines bears a very definite relationship to their distance from the jungle, and the following is the table.

Table showing the spleen rates of children living at different distances from undrained jungle on flat lands.

Distance from jungle	Within 300 yds.	300 to 600 yds.	600 to 1000 yds.	Over 1000 yds.	Total
No. of children examined...	325	396	532	1042	2295
Spleen rate, per cent.	47	21·9	11	2·6	14·2

It is clear from these figures that malaria can be avoided on the flat land by housing coolies about 1,000 yards from the nearest undrained jungle, and that every yard the coolies are removed from jungle improves their health.

In a later table it will be seen that the death-rate of estates in Malaya is largely due to malaria, and that were malaria abolished the death-rate would be about 15 per 1,000 of the coolie population as at present constituted.

Over an area of the Selangor Coast, some fifty miles long, I have traced how malaria affecting a population of many thousands, has been driven back, year by year, as the land has been drained and opened by agricultural operations.

At the towns of Klang and Port Swettenham, deliberate attempts were made to deal with the disease, and they were successful in the highest degree.

But of infinitely more importance have been the results of the agricultural operations. Although malaria may affect a town, it is essentially a disease of the country. The capital of the peasant is his health, and if this be destroyed by malaria, poor indeed is he. The planters in Malaya have carried out, unconsciously it is true, what really form an extensive series of rural anti-malaria and anti-mosquito experiments. I have watched, over a number of years now, experiment after experiment, with control after control, which have proved that the pool-breeding Anopheline, which carries malaria on the coast of Malaya, can be exterminated by open drainage, at a very low cost. And that with the extermination of the Anopheline, malaria has disappeared. Anti-mosquito measures have therefore been proved on the coast of Malaya to be not only entirely suitable to rural districts, but have greatly improved the value of the land.

IX. Persistence of Malaria in certain Rural Areas. In the previous chapter I have shown how malaria has disappeared from certain portions of the coast districts of Malaya, as the land has been drained and the jungle felled. That this occurs is well known to all with tropical experience, and it is with the hope this will occur that the pioneer battles with his troubles. The hope is so strongly implanted that he takes it as a matter of course the health will improve as the land is opened up.

We often hear of what a terrible place some spot was or is. We rarely hear that a place was abandoned on account of its ill-health. But we never seem to hear that a place always remains

unhealthy, and never improves as time goes on. This is because, after a time, the population of an unhealthy place consists almost entirely of those who have acquired a certain amount of immunity. New people have practically ceased to come to it, and so the health seems to improve, and the local experience seems to fall into line with the general experience of the tropics. Yet it only wants new arrivals to come in numbers to start a severe outbreak of malaria. I have now, however, to record that in certain portions of the district there has not been the slightest improvement in the nine years during which they have been under my observation, nor have I any reason to suppose they will improve as long as the present conditions favouring the mosquito persist. The land to which I refer is the hilly land of the coast districts of Selangor, in the ravines of which run streams of water, often of very small size indeed.

In this hill land the mosquitos which are to be found are *M. umbrosus* x., (as in the flat land), *N. willmori* and *N. karwari*. Now the important point about these mosquitos is that if a ravine stream be kept free from grass and other weeds *N. karwari* and *M. umbrosus* x. no longer breed in it, while *N. willmori* will breed in streams which have been absolutely free from grass and weeds for three years to my knowledge. Extensive observation has shown that *it is not in all ravines that N. willmori can be found, nor is it always present in* the same ravine. It is possible there may be some seasonal variation, but of this I am not yet warranted in making any definite statement. I can say, however, that no amount of weeding or other care of a hill stream will abolish *N. willmori*, which I have found to be a natural carrier of malaria.

For some years malaria has formed a subject of anxiety to the managers of certain estates in the district, since their labour forces have been seriously crippled, apart from the fact that the Europeans have also suffered severely, and blackwater fever has occurred in one instance. It was always hoped that the general experience would hold good in these estates and that as they were more opened up the health would improve. In the meantime there appeared nothing to be done except to push on with the opening programme, and give quinine to the coolies systematically. This has been done, thereby reducing the death-rate and improving the general health of the coolies. The arrival of any considerable number of new

coolies was, however, always the signal for an outbreak of the disease, and the older coolies who were apparently becoming acclimatised appeared occasionally to suffer with the new ones.

In the middle of 1907, when my investigations on the estates had for certain reasons suffered interruption, the position was as follows. I had determined the percentage of infected children on many of the estates in the district. I had also determined the adult mosquito to be found in the coolie lines, and made certain observations on their breeding places. I had determined that the carrier of malaria on the hill land was *N. willmori* and that it was confined exclusively to the hill land. I had also observed on three estates that it was present when there was grass and other weeds in the drains, but not when these drains were clean. I attributed its absence to the freedom from weeds. I had also determined its absence from certain ravines altogether. I therefore concluded that when further opening had taken place, the health of the labour would improve on the hill land places as it had already done on the flat land to my knowledge. In 1908 I was on leave in England, and on my return to Malaya was for several months fully occupied in administrative details of the hospital system which I was organising for the estates. During this period I came to the conclusion from what I incidentally saw that despite the lapse of nearly two years, and despite the greater areas opened no improvement had taken place in the hill land estates.

I accordingly determined to investigate the matter *de novo*. I determined to examine every set of coolie lines in the district, and particularly those on the hill land, with the object of ascertaining the exact condition of each. I also decided to make a fuller enquiry into the breeding places and habits of the Anophelines. The result of this enquiry has been to show that *N. willmori* cannot be exterminated as long as there is water in the ravines in which it can breed, although it disappears from time to time; secondly, that malaria is as prevalent as before in the hill land; and thirdly, that quinine in practically therapeutic doses can hold in check, but cannot eradicate malaria.

It will be unnecessary to enter into details of each of the hill land estates, but the following figures will show the general condition.

Estate 'RR.' This is a large estate, work on which was begun

FIG. 7. STREAM IN THE HEAD OF A RAVINE.

This small stream coming down a ravine, despite its current of clear running water, swarms with the larvae of *N. willmori* at certain times. The water in this stream will in dry weather easily flow in a three-inch pipe.

FIG. 8. BREEDING PLACE OF *N. WILLMORI.*

Down the centre of this ravine *N. willmori* is found freely breeding. On one occasion it was found in a well two feet deep, with perpendicular sides and free from all trace of weeds or vegetation.

in 1906. From the first malaria has been prevalent. Quinine was begun in 1906 in doses of ten grains twice a week, but as this was apparently without effect, it was increased to ten grains daily, with double doses to those who did not work. The following table shows the condition :—

Year.	1906	1907	1908	1909
Blood Examination—				
Number examined	61	—	—	—
Percentage infected	73	—	—	—
Spleens—				
Number examined	61	43	—	174
Percentage enlarged	65	83	—	49·8
Death-rate	—	73	165	43

It should be mentioned that one set of the most unhealthy lines was abandoned in 1908. During 1908 the amount of quinine administered was much less than had been the case in 1907, as ankylostomiasis was said to be the real cause of death in many of the coolies that year. This led to the necessity for giving quinine being questioned, and on my return from leave I found an entirely insufficient quantity was being given. The dose was at once increased, and the result has been to reduce the sickness and the death-rate, as is seen in the above table.

From the tables on page 71 it will be seen that the death-rate in 1908 was generally higher than in the previous year. There was no special immigration in 1908; indeed, it was smaller than usual, and I attribute it to the idea spread about that ankylostomiasis was the chief cause of the death-rate. Quinine was consequently neglected on some estates. The coolies on Division I of estate 'RR' are housed in three places. The health of the different lines of these varies, at least the spleen rate varies, being 100 and 90·9 per cent. in one place, 76·6 in another, and 36·6 per cent. about a quarter-mile from the worst. The majority of the coolies are now living near the last of the three places—hence the lower spleen rate for 1909. It is possible the mosquitos infesting the place with the low spleen rate come from a ravine near to the place with the highest rate. The point is one of the greatest practical importance, but I have not yet finally determined it. In addition, there has been a considerable

influx of new coolies lately to this division, so the spleen rate is lower than it will be when the recent immigrants have had time to become infected.

The number examined on the other two divisions on this estate were as follow:—

	No. examined	Percentage with enlarged spleens
No. 2 Division ...	63	79·3
,, 3 Division ...	33	75·7

An idea of the amount of malaria present will be gathered from the fact that of thirteen children, on the estate only two and a half months, no less than eight had splenic enlargement.

The death-rate of this estate will be referred to later when I deal with the effect of quinine.

Estate 'SS.' This estate is on the border of the hilly land, and its cooly lines are situated on the end of a ridge. The number of children examined was thirteen, and the spleen rate 30·7. Five of these children had been only one month on the estate, so the corrected rate would be 50.

Estate 'TT.' This estate lies on the edge of the hills, with part on the hills and part on the flat. The lines at the west end are close to jungle now being opened and on the flat; the central lines are on the flat about half a mile from the nearest jungle; while the east lines are among the ravines, but ravines which are clean. Anopheline larvae were found only a quarter of a mile from these lines, in a clean ravine. No larvae were found in two ravines close to them. Sinniah's lines are about a quarter-mile from rather poorly drained native holdings.

The summary of this estate is then:—

	West Lines		Central Lines		East Lines		Sinniah's Lines	
	No. examined	Percentage spleen rate	No. examined	Percentage spleen rate	No. examined	Percentage spleen rate	No. examined	Percentage spleen rate
1906	14	64	28	32	5	57	17	35
1909	49	51	47	17	31	45	8	37

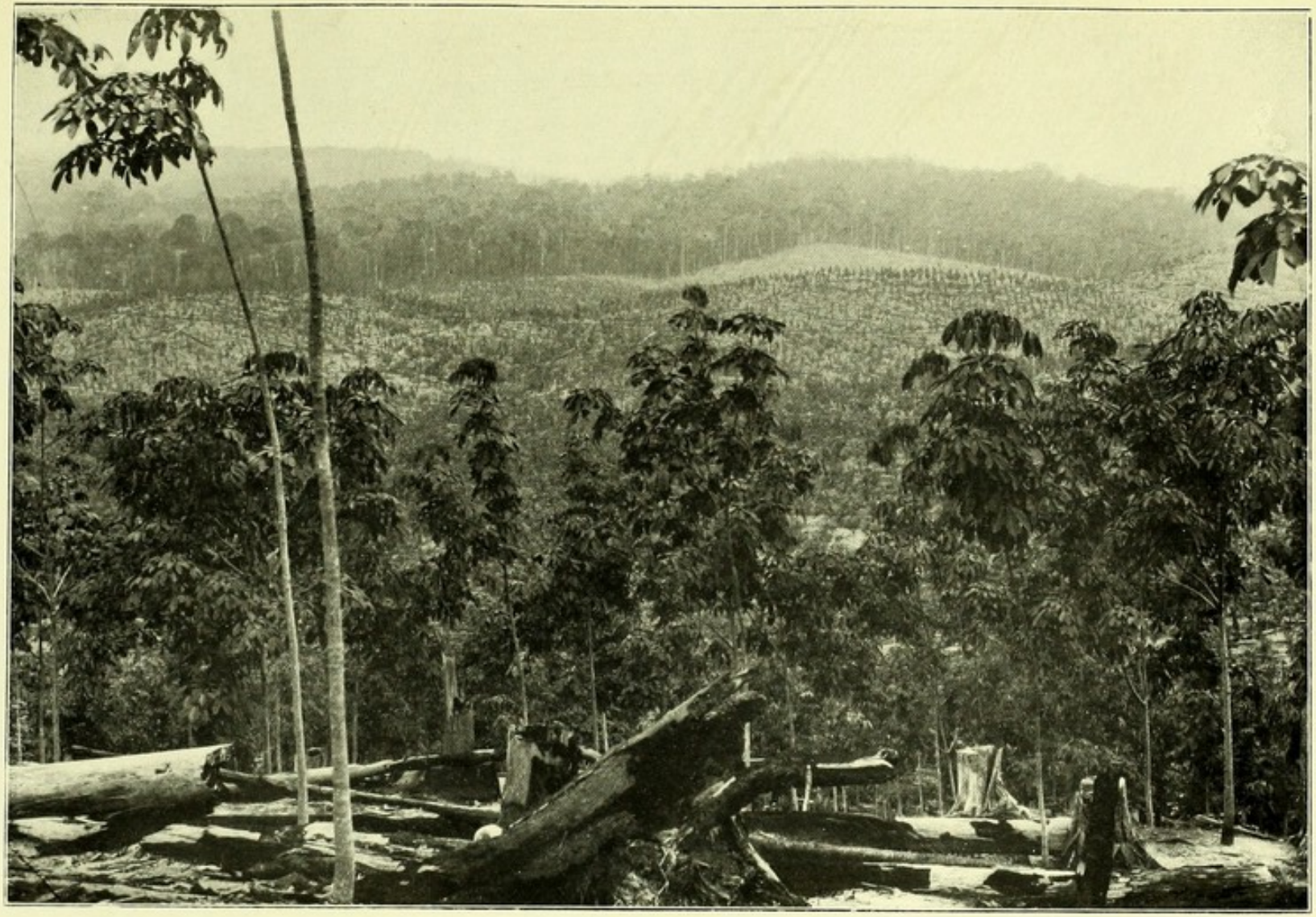


FIG. 9. GENERAL VIEW OF HILL LAND ESTATE.

The photograph is taken from an elevation of about 300 feet. The view shows a series of similar ridges of greater or less height planted with rubber. In the background is the jungle. Between each of the ridges is a stream such as is seen in the photograph, Fig. 10.

Estate	1904	1905	1906	1907	1908	1909
Blood.						
Number examined ...	41	40	—	—	—	—
Percentage infected ...	37·8	12·5	—	—	—	—
Spleen—						
Number	—	40	43	—	—	49
Percentage enlarged ...	—	17·5	30	—	—	55
Death-rate	—	—	95	138	176	—
Estate						
Blood—						
Number examined	6	17	18	—	—	—
Percentage infected ...	100	11·7	94	—	—	—
Spleen—						
Number	—	—	—	—	—	42
Percentage enlarged ...	—	—	—	—	—	83
Death-rate	—	—	—	200	—	—
Estate						
Blood—						
Number examined ...	6	17	26	—	—	—
Percentage infected ...	100	23	96	—	—	—
Spleen—						
Number	—	—	26	—	—	13
Percentage enlarged ...	—	—	80	—	—	100
Death-rate	—	—	300	178	—	—
Estate						
Spleen—						
Number	—	—	13	—	—	15
Percentage enlarged ...	—	—	100	—	—	100
Death-rate	—	—	150	56	223	—
Estate						
Spleen—						
Number	—	—	14	—	—	20
Percentage enlarged ...	—	—	71	—	—	95
Death-rate	—	—	—	60	90	—
Estate						
Spleen—						
Number	—	—	18	—	—	29
Percentage enlarged ...	—	—	100	—	—	100
Death-rate	—	—	—	6	58	—
Estate						
Spleen—						
Number	—	—	—	—	—	15
Percentage enlarged ...	—	—	—	—	—	100
Death-rate	—	—	260	93	250	—

FIG. 10. STREAM IN HILL LAND.

Streams such as these run between the ridges of the Hill Land. *N. willmori* are found in them. Large quantities of silt are deposited in these streams, and when cleaned out the silt is thrown on to the banks of the stream as will be seen from the photograph.

These figures show in the most unmistakable way that there has been no improvement in the health of these estates. They, indeed, only confirm what I had already observed from the hospitals, from visiting the estates, and from the health of the Europeans.

Effect of Malaria on the Europeans. During the years I have known this district, only two Europeans who have lived more than a few months in it have escaped the disease. They lived on a spot where the spleen rate is only 20. It is the place which is furthest from the breeding place of Anophelines, being on a point well away from any ravine or jungle. That such a spot should be found so near to very unhealthy places is of the most hopeful augury, showing that the flight of the hill land mosquito is by no means great.

There are at the present moment twenty-nine Europeans living on ten hilly land estates. Of these twenty-five have had malaria at some time or other on the estate. Of the four who have not had the disease, two have been less than one month on the estate; one, who had malaria before his arrival on the estate, takes 15 grains of quinine daily; one has been six months on the estate without getting the disease.

As I write, I have before me a record of the Europeans who have been on these estates during the past four years. It shows how practically all have had the disease, how from time to time they were invalided either to hospital or off on sea trips to recover their health, or to Europe on long leave. It shows how many have left the estates permanently, unable to withstand the disease. One man who had suffered severely from malaria had Blackwater Fever, but fortunately recovered. There is only one bright spot in the record, and it is, that no European has died from malaria.

So much sickness among the Europeans means that they cannot supervise the work properly, and if there be much sickness among the labour force at the same time, the absence of the controlling and directing force of the estate is indeed deplorable. Few native subordinates can be trusted to see that quinine is properly administered to a labour force, and one of the great difficulties is that if the manager from sickness cannot supervise it the subordinate is very liable to do this duty in a perfunctory way. The welfare,

not only of the estate, but of the labour force, depends therefore on the welfare of the manager.

Effect of Malaria on the Coolies. No less severely has malaria affected the coolies. In visiting estates, I have always noted all cases of sickness seen in the coolie lines. In addition I have noted on the opposite page of my book, any general observations which might seem of importance. I have, therefore, a fairly complete record for some years of the health of the estates which have been under my care. From this book I will give the substance of a few notes showing the effect of malaria.

On one estate 170 coolies were recruited. They refused to take quinine at first, and were a somewhat unruly gang. Within two months of their arrival I visited the estate and found that on the day of my visit 102 out of the 170 were unfit for work. Many of these were removed to hospital. A month later I note, 'of the 'gang of 170 only 57 remained on the estate, of these 29 working, 'and 28 off work.' Practically all these coolies were lost to the estate.

Of another estate 'have been having a bad time with malaria. '. . . .Turning out 170 out of 340 coolies.' The following month turning out 179 out of 250 coolies. The following months again, the note is '150 coolies.' In other words the coolies had either given notice and left or absconded. On this estate the labour force was reduced from 340 to 150 in three months. I need hardly say that weeds got a firm hold of it.

Another estate: 'Have been very bad with fever, practically 'every coolie had it, and about six deaths. Appear to be getting it 'in hand with quinine; 140 coolies working out of 350.' The following month 'turnout 150; coolies looking better.' A month later the manager remarked 'turnout somewhat better, but accounts 'not made up.' The manager had been very ill. He was taking infinite pains with quinine administration. He had every room in his lines numbered, and the name of every coolie who lived in each of these rooms in a special book. He tried to get each coolie twice daily, and ticked the name off in his book when the quinine had been given. Only those who know from visiting an estate how difficult it is to account for each coolie can estimate how much labour this involved.

Another estate: 'Nineteen cases of malarial dysentery. The 'manager had not given quinine when complaint was dysentery. 'Every one gave a history of fever five to ten days previously. 'Are getting a considerable amount of quinine; 75 out of 190 'working.' A month later I note, 'now only about 80 coolies on 'the estate. Others wish to leave, but —— and —— and —— 'persuaded them to stay for two months. Many have died in 'hospital.' I promised that if they would take quinine regularly and would report at once to the manager when ill they would not die. New lines were also built for them in another place. A month later I find less fever on the estate, and note 'old lines 'abandoned, coolies healthier.'

Among the children malaria is no less severe. On one occasion I was asked by a manager to advise him what should be done for the children, as fifteen children had died in the previous two months out of a total of thirty-three. He told me a native clerk was giving them quinine daily. I examined the blood of the remaining eighteen, and easily found parasites in seventeen of them. The manager then gave personal attention to the quinine administration of the children, and there were only two deaths in the next three months, these being children who were seriously ill before he took it in hand. The effect of this terrible death-rate on the coolies was such that even though they were living in good lines built less than three months, and on land opened for ten years, they declared the lines were haunted. The lines had to be pulled down and re-built elsewhere. Such a death-rate among the children affects the mothers, and leads to loss of labour, since coolies naturally refuse to live on such unhealthy estates.

I have been struck, too, with the very low birth-rate on malarious estates, including those on which quinine is given, and the health of the labour appears good. It has been said quinine may have some injurious effect. I am unable to express any opinion, but am making enquiries.

I am indebted to Mr. E. V. Carey for the following:—'Notes 'of fever experiences upon New Amherst Estate. Between the years '1892 and 1898 there were on an average over fifty Tamil women 'upon the check roll each year. Yet, in the whole period no living 'child was born. Several women became pregnant, but only in

'one case did the child become quick, and even in this case the 'woman eventually had a miscarriage. The estate was so riddled 'with malaria that the coolies were all miserably anaemic and 'lacking in strength. So anxious was the management that the 'stigma attached to the absence of child-birth should be removed 'that every possible care was taken of the women when they became 'pregnant; light, but regular work being provided for them, and 'a supply of milk, etc., being given them, but all with no result; 'although a big present was offered to the woman who first brought 'forth a living child, and the coolies were all most anxious 'themselves that this reproach should be removed.

'The supply of cooked rations to all coolies under the 'supervision of a high-caste cook worked wonders in improved 'health and general physique, but when the coolie insisted on 'returning to the system of feeding himself there was soon a 'relapse, and the estate had eventually to be abandoned. During 'the last two years at least, all coolies were given a five grain pill 'of quinine each morning at muster, together with a cup of hot 'coffee.'

This is very striking evidence of the effect of malaria on the birth-rate, of the practical inutility of small doses of quinine in intensely malarious spots, and of the difficulty, indeed impossibility, of carrying out the most beneficient measure in the face of native opposition and prejudice.

The effect of the introduction of any large number of new coolies* to estates of such an unhealthy character as those I am describing can be estimated from the following extract from my annual report for 1906, quoted in the Selangor Administration report for the same year:—

'The great increase in the death-rate has been due to the 'introduction of a very large body of Tamil coolies, and the 'spread among these of malaria, mostly of the malignant type. 'These coolies came mainly from famine districts in India, and

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* Next to the Anopheline the introduction of a large body of non-immune coolies is the important factor in the production of the severest outbreaks of malaria in the tropics. Captain Christophers and Dr. Bentley in a valuable paper on 'The Human Factor in Malaria'[15] have called the condition produced *hyper-endemicity*. This is truly so called since as there are a greater number of non-immune persons than ever occurs in a normal population, there is a greater amount of malaria.

'while of a fair average physique for recruits, naturally do not 'compare in their capacity of resistance to disease with coolies 'who have been well fed and well housed for a year on the estates 'here. Among these coolies malaria spreads with extraordinary 'rapidity, and the systematic doses of quinine which were 'sufficient to maintain the older coolies in health appeared to 'have little effect on these. Within two months, it is hardly an 'exaggeration to say that 90 per cent. of these coolies in the Batu 'Tiga district were infected with the disease, and the children 'suffered with equal or greater severity. From the new it spread 'to the old coolies, and also to the Chinese and others working on 'the estates draining and building lines. Among the Chinese, 'who will not take quinine, it was very fatal, and many of them 'were brought to the hospital in a moribund condition. The 'new coolies literally made no stand against the disease, and on 'some estates there was difficulty at first in inducing them to take 'quinine. Another fruitful cause of death was the bowel trouble 'which so frequently supervenes on an attack of malaria. In the 'hospital, in the month of December, out of forty-seven deaths 'due to malaria, no less than thirty-four were the result of bowel 'complications. These patients rarely complain of fever, and it 'is only by microscopic examination of the blood that the malaria 'element in the case is detected. At first the necessity of giving 'quinine in addition to other treatment was not recognised on 'estates, as the coolie made no complaint of fever, and the 'consequence was that many new coolies, with no stamina to 'spare, so to speak, were literally past hope in three or four days. 'As I had occasion to point out a year or two ago in a paper on 'Quartan malaria,[8] patients with dropsical swelling resulting from 'malaria are often unaware they have malaria, even when the 'thermometer shows they have a temperature of 102° F., and 'their blood is swarming with parasites. As if further to confuse 'the issue, many of the new coolies rapidly became anaemic and 'dropsical from the malaria, and attributed their illness to every- 'thing but the right thing. In some cases, malignant malaria was 'worthy its name, and struck dead those who forty hours before 'had been at work. It ultimately became obvious that the only 'way to save the coolies was by daily administration of quinine

'to every coolie on the estate. This is now being done on eight 'estates with an aggregate labour force of about 2,000 coolies, 'and fortunately there is some evidence that the coolies begin to 'appreciate the value of the drug, at least there is now no 'opposition to its administration.'

Variation of Death-rate with Spleen-rate. The important influence which malaria has on the health of an estate will be more easily realised from a study of the relationship existing between the spleen rate of the estates obtained from my examination of the children in 1909 and the death rates taken from the Indian Immigration Report for 1908.

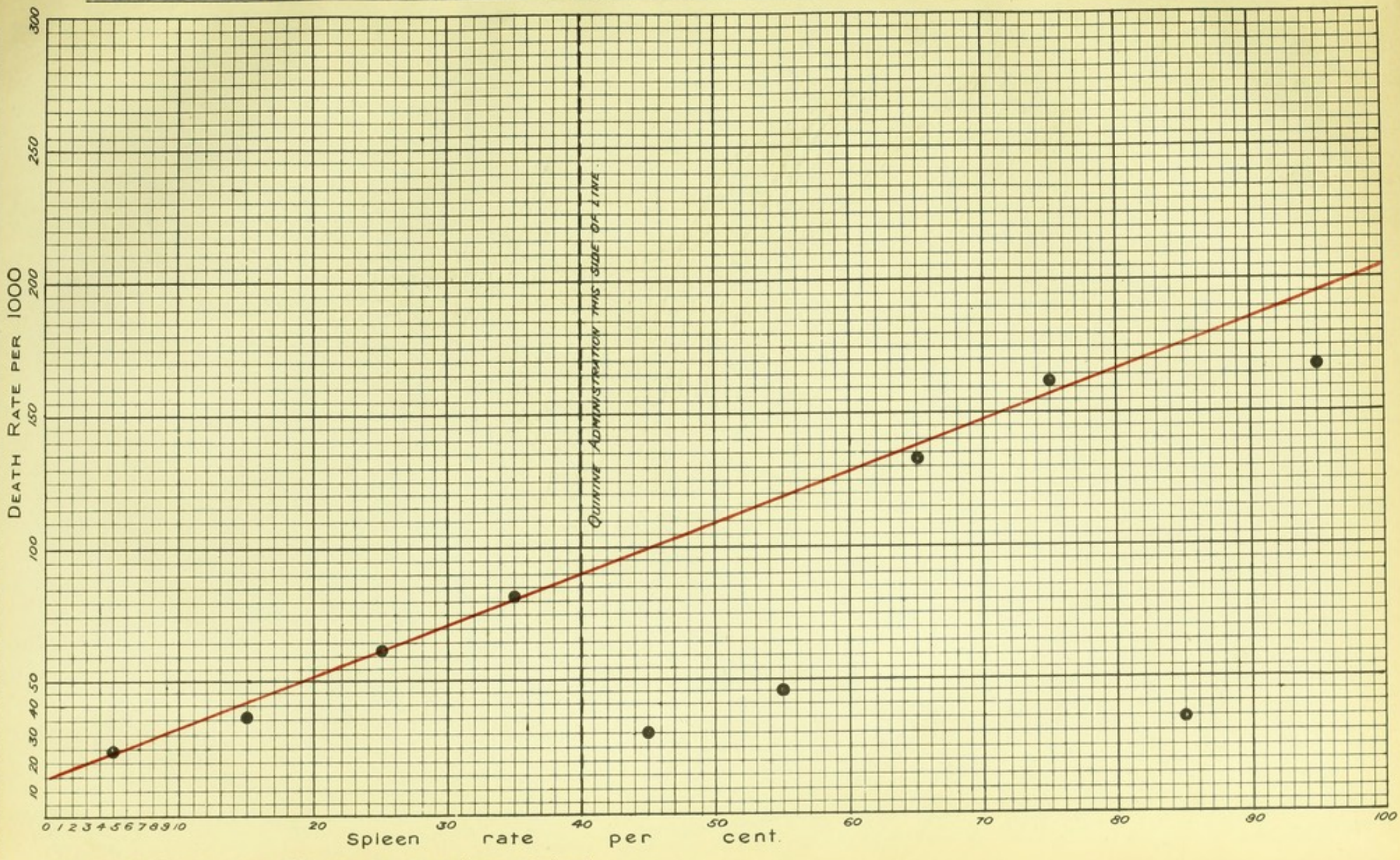
The following table shows the death-rates of the estates arranged in accordance with their spleen rates. It shows the total population living on estates where the spleen rates varied from 0 to 100 per cent. the total number of deaths in, and the death-rates of, these populations :—

Spleen Rate	Average population 1908	No. of deaths	Death rate per 1000
0 to 10	7106	175	24·6
10 ,, 20	492	18	36
20 ,, 30	2291	143	62·4
30 ,, 40	1121	90	82·0
40 ,, 50	65	2	30·0
50 ,, 60	767	35	45·6
60 ,, 70	1738	232	133·4
70 ,, 80	1165	189	162·2
80 ,, 90	180	6	34·0
90 ,, 100	973	163	167·5
Total	15898	1053	66·2

These figures exhibit the terrible effects of malaria, and I have exhibited them in graphic form in the annexed chart.

From 0 to 40 the influence of malaria is unaffected by systematic quinine administration, except in the case of one estate, 'S.' From 40 onwards quinine is given with varying degrees of thoroughness. I think it not improbable that, although it has been possible to plot the lower values as a straight line, that from the point at which quinine begins to influence them the values if influenced by the drug would

Chart showing variation of Death Rate of 1908 with Spleen Rate of 1909.



Number of Coolies on which results have been obtained.

| 7106 | 492 | 2291 | 1121 | 65 | 767 | 1738 | 1165 | 180 | 973 |

be represented by a curve rising to about 300 to 1,000. It is difficult to believe that the considerable doses of quinine given to a population of 1,165 on the estates in the group 70 to 80 should have had no effect. The death rate of several estates whose spleen rate is between 90 and 100 ranges between 200 and 300 per 1,000.

As will be seen from the Wastage Chart, the greater the amount of malaria the greater the wastage from all causes. To maintain a labour force on the more unhealthy estates at a constant strength larger proportions of the coolies would be new, the death-rate of these is higher than that of the older coolies. Among the more unhealthy estates there would thus be death-rates increasing at an ever accelerating rate. I do not think 300 per 1,000 would be the maximum in a locality of the most intense malaria, were the labour non-immune.

The values which are plotted below the straight line are known definitely to be the result of quinine to a great degree. Between forty and fifty the low death-rate is due to all the coolies (sixty-five in number) on one estate having been dosed daily with 10 grains of quinine, and once a week with castor oil. The low death-rate on the estates whose spleen rate was between 50 and 60 was due to two of the estates using quinine, one in the most thorough manner possible. The same applies to the low death-rate, with the spleen rate from 80 to 90.

The plotting of the death-rate values shows in a graphic manner not only how malaria is responsible for most of the deaths on the estates, but enables us by exterpolation to arrive at the conclusion that were malaria eliminated the death-rate of the Tamil population on an estate would be about 15 per 1,000. The line shows, too, how money can be spent with most profit and advantage in improving health on a malarious estate.

The sum of money which would be required to reduce the deaths from causes other than malaria by 3 per 1,000 would in all probability reduce the deaths from malaria by 100 per 1,000 if spent on anti-malaria works. It is absurd to talk of applying to malarious estates the sanitary measures which are required in an overcrowded town, and expect them to improve its health. Expenditure on such measures would only be an obstacle to expenditure on the special sanitation

required by the local conditions. As will be seen later, sanitary areas free from Anophelines should be established on malarious estates, and the coolies housed on these areas.

Wastage of a Labour Force. Although local factors have a powerful influence on the happiness and welfare of a labour force, it can easily be understood that where an estate is unhealthy, coolies will be less contented, and will be less inclined to stay. A month's notice frees a coolie on the estates of Selangor, and in many instances he leaves without giving even the legal notice. There is no Indentured Labour.

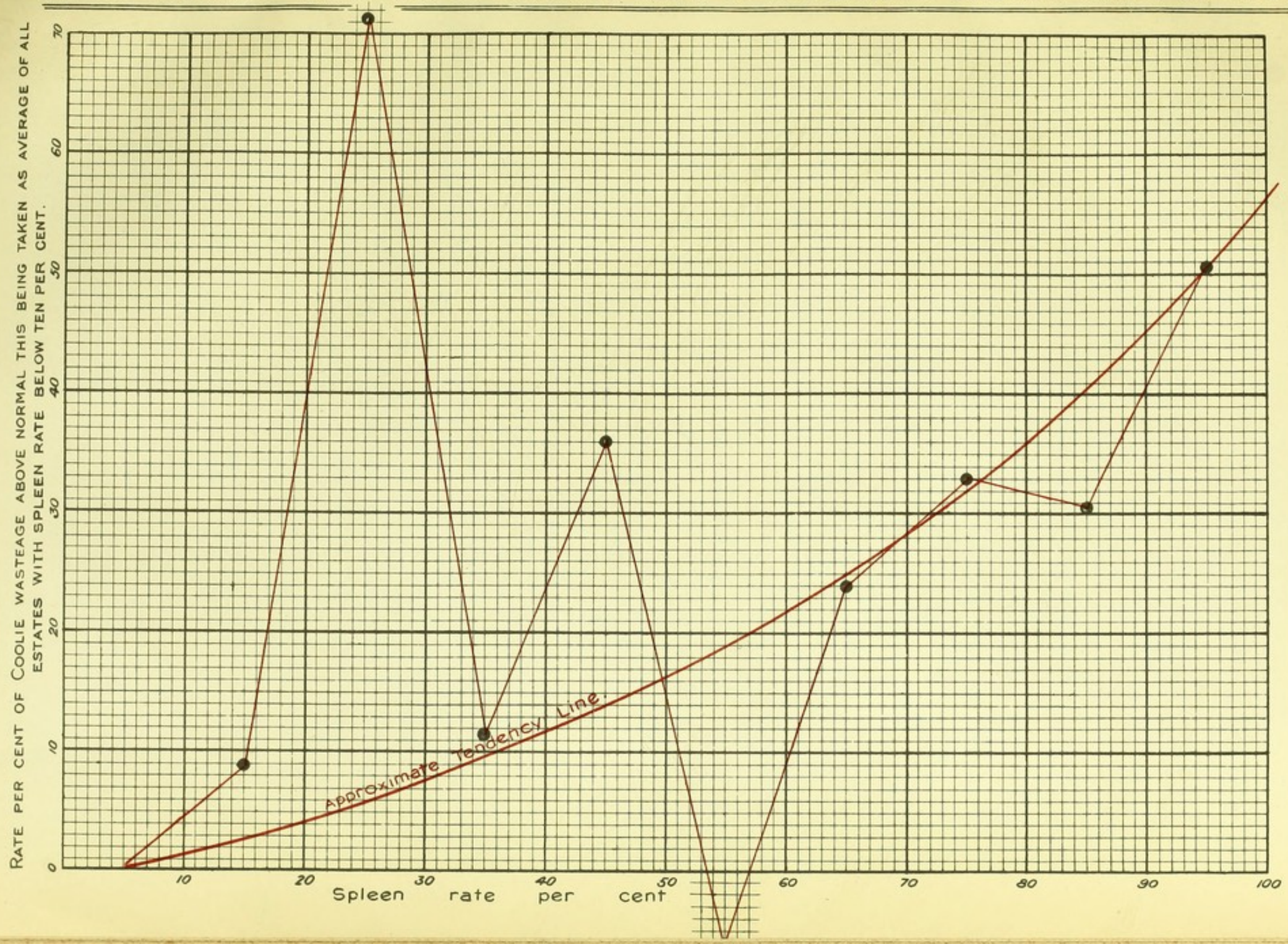
The following chart illustrates how in the estates under my care the wastage of labour from all causes has a very definite relationship to the health, as exhibited by the spleen rate.

I have taken as the base line the wastage on the estates having the lowest spleen rate, and the other wastages have been calculated as a percentage above or below this. The chart shows that the greater the spleen rate the greater the loss of labour. There are only two exceptions practically. The very great loss on estates whose spleen rate was from 20 to 30 was due to practically the whole of the coolies on one estate leaving owing to the conduct of some drunken mandors. The Government Immigration report deals with this. Great loss was due on another estate to differences between the coolies and the manager. These are exceptional circumstances, and this group of estates showed a wastage in 1907 quite in line with that of other estates.

In the groups of Estates whose spleen rate is 90 to 100 the actual loss was 507 per 1,000. In other words while the coolies remain on an average 3 years in the healthiest Estates they remain only 2 years on the most unhealthy Estates. The extra year means for the healthy Estates an increase of the labour force by 50 per cent., and more than 50 per cent. increase in the work done, for the coolie is by the end of his two years a skilled workman, especially where he is tapping. Malaria is, therefore, an economic factor of great importance.

Economic Effects of Malaria on the Estate. In the working of an estate, a certain number of coolies are required for each class of work, and the manager must estimate some months before how many he will require, so that the necessary number may be recruited from

Chart showing variation of Wastage Rate of 1908 with Spleen Rate of 1909.



India in time for the work. Any extension of the estate means more coolies are required. One of the most important works of an estate is the weeding. In a tropical country like this weeds grow with surprising rapidity, and in less than two months will in many places form a complete cover to the ground, and having seeded it will take months to eradicate them. In addition, a grass called lalang often takes root, as its seeds are blown to great distances by the wind. The roots of this grass grow several feet deep, and to eradicate it costs $50 an acre at least.

The most economical method of working an estate is to have a labour force of such strength that the whole estate can be weeded once in from two to three weeks. Not a weed has time to seed, and the cost of weeding falls to about 50 to 60 cents an acre a month.

If, then, there are too many coolies on an estate, the work will be insufficient for them, which will lead to dissatisfaction; while, if there are not sufficient coolies the work gets behind, and if this work be the weeding, then the whole land may be covered with lalang. As the cost of bringing an acre of rubber into bearing is generally estimated at about $250, it will be seen that the effect of an outbreak of malaria which seriously cripples a labour force even for only a few months may easily increase the original cost of an estate by 20 per cent., and on an estate of 1,000 acres will actually cost about £6,000 sterling.

X.—Value of Quinine Administration.* During these years it need not be imagined that nothing was being attempted to eradicate the disease. About 1902 I had arrived at the conclusion that once a man was infected with malaria he should take quinine after his apparent recovery daily, and not once a week, as was the custom. I made this observation first of all from one of my dressers in Klang Hospital, who, although he took quinine once a week with a tonic in the interval after the pyrexia had disappeared, had a return of the pyrexia about every ten days for many weeks, and got rid of it finally and at once by taking quinine daily.

In 1904, having determined that there was much malaria on certain

* By daily quinine administration I mean six days out of seven, namely on the working days.

estates, I advised the administration of quinine at first in weekly doses of ten grains, and later of bi-weekly doses.

The following tables show the result of giving quinine in the above-mentioned doses:—

Table showing the numbers of children infected with malaria in the months of November and December, on certain estates

1904				1905		
Quinine not given systematically				Quinine given systematically		
Estate	Number Examined	Numbe infected	Percentage infected	Number Examined	Number infected	Percentage infected
1	16	10	62·5	17	2	11·7
2	41	16	37·8	40	5	12·5
3	12	12	100·00	17	2	11·
4	—	—	—	17	4	23·5
	69	38	55·5	91	13	14·3

Table showing the number of children infected with malaria in November and December on estates on which quinine was not given systematically in either 1904 or 1905

1904				1905		
Estate	Number examined	Number infected	Percentage infected	Number examined	Number infected	Percentage infected
5	66	33	50·0	52	23	44·2
6	25	7	28·0	13	6	46·0
7	—	—	—	15	4	26·1
8	—	—	—	16	11	68·7
Total ...	91	40	43·9	96	44	45·8

Table showing the number of coolies not at work on account of malaria on the day of my monthly visit. November, 1905. A. Estates where quinine is given systematically B. where it is not given

A.—Quinine Given				B.—Quinine not Given			
Estate	Number of Coolies	Number with Malaria	Percentage with Malaria	Estate	Number of Coolies	Number with Malaria	Percentage with Malaria
1	70	0	0·0	5	800	33	4·1
2	320	2	0·6	6	170	12	7·0
3	120	1	0·8	7	250	13	5·2
4	80	5	6·2	8	212	27	12·6
	590	8	1·3		1,432	85	5·8

An estate bears the same number in all the tables. The administration of quinine is doubtful in estate No. 4. From it the manager was dismissed.

These figures appeared to me to be most encouraging, and I said of quinine administration in a presidential address before the Native States Division of the British Medical Association, in Ipoh, in 1906:—

'Although many without thinking consider it acts merely by 'curing the individual after he has been infected, and aborting 'threatened attacks, it is in reality much more than this. It is a 'real prophylaxis, for by cutting short attacks, it diminishes the 'chances of mosquitos becoming infected, and thus prevents other 'coolies from ever becoming infected. It is by no means a case of 'locking the stable door after the horse has been stolen, and there 'need be no hesitation in advocating its use.

'Nevertheless, it is not a method which commands very 'unqualified approval, for the single reason that it requires too 'much of the manager. He has other work to do, work which 'must be shown as done in his monthly report, or his directors 'will want to know why. Instead of spending perhaps the best 'and coolest time of the morning giving out quinine, he wishes to

'go out into the field. Again, the manager himself may fall ill, 'and there may be no one to see the coolies take their quinine. 'A new manager may come, and he has probably to learn by 'bitter experience that the hours spent in giving out quinine are 'not only well spent, but must be so spent, if the labour force is 'to be kept together. Again, it is not given to every manager to 'have the patience to see that every coolie, and especially every 'child gets its quinine ration, and with new coolies more or less 'undisciplined, there may be great difficulty in getting down the 'quinine, as the coolie has little faith in it. It is a great point 'when a "Kangany" realises the value of quinine, but, at the 'same time, no native can be trusted entirely with this, and it is a 'considerable call on the manager's time. Then, when the 'necessity appears to pass off, there will always be a tendency to 'slackness, as with all human efforts. Therefore, while I value 'the method, I consider the call it makes on the manager a very 'serious drawback.'

I hoped by giving quinine daily to those who had malaria, to prevent the formation of gametocytes which would infect mosquitos, and that if any new coolies should chance to become infected, quinine twice a week would destroy the parasites before they had time to develop to numbers sufficient to give fever to the host. As will be seen later, neither of these hopes was fulfilled, since it has been impossible to give the large doses which would be necessary to attain the object to people who are working. And, secondly, as I shall refer to later, what may be a sufficient dose when malaria is not intense, is quite insufficient when it is. My advice in 1906 was as follows:—

(1) That every coolie should get a cup of hot coffee before starting work in the morning. (2) That twice a week every coolie should get 10 grains of quinine, and every child five grains. (3) That every coolie who has fever should have a mark put against his name on the check roll when he resumes work, should not receive 'Name' for the day's work until he has taken a dose of quinine, in the manager's presence.

This advice was followed on one estate which was just being opened up, and the result was a total failure of the quinine even to hold the disease in check, so that on 6 November, 1906, every coolie

was put on 10 grains of quinine daily, and those who were not at work on 20 grains, it being assumed that if he did not work he might be unwell, and that the extra dose of quinine would do him good by preventing an attack of fever even if he had not pyrexia at the time. The effect of the daily dose was to reduce sickness to a marked extent, as the following table shows :—

Table showing the number of coolies who were unable to work from 'fever' and from 'other disease' during certain months of 1906 and 1907.

	1906			1907					
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apl.	May	June
Fever	136	152	50	38	19	14	14	5	8
Other diseases	147	195	83	81	41	54	54	14	10
Total	283	347	133	119	60	68	68	19	18
Number of Coolies on the Estate	220	245	243	247	248	234	255	322	228

It is interesting to observe that what we saw when malaria was reduced in Klang Town, namely, the reduction in diseases other than those recognised by the general population as malaria, was reduced on this estate also with the reduction of the amount of malaria.

The economic effect of the malaria and the effect of the quinine can also be observed from the following table.

Table showing the number of coolies on this estate, the number of days which it would have been possible for these coolies to work had they worked every working day of the month, the number of days they actually worked, and the percentage this forms of the possible working days.

Month	No. of Coolies	No. of possible working days	No. of days actually worked	Percentage of possible days worked
1906				
May	69	1241	1050	84·6
June	135	2499	2100	84·0
July	190	4914	3670	74·6
August	299	8073	5590	69·2
September	248	6200	4257	68·7
October	220	5380	3352	62·3
November	245	6366	4238	66·5
December	243	6318	4584	72·5
1907				
January	247	6175	4907	79·0
February	248	5952	4829	81·1
March	—	—	—	79·8
April	—	—	—	76·9
May	—	—	—	83·
June	—	—	—	84·
July	—	—	—	90·
August	—	—	—	90·
September	—	—	—	79·
October	—	—	—	76·
November	—	—	—	76·
December	—	—	—	77·6

The decrease in the out-turn of the labour of 1907 was due to unsatisfactory work of the dresser in charge, who had to be dismissed. It was found he was seriously neglecting his duties, as the coolies who did not turn out to work were not sought for and given the extra quinine. The unreliableness of native dressers will always be one of the great drawbacks to quinine administration. In this instance, the dresser who by his hard work had helped so materially to obtain such good results in 1906 and the early part of 1907 now became lazy and mischievous for no reason apparently, and ultimately was convicted and sent to prison for six months for attempting to cause riot by setting one class of coolie against another.

The best results I have obtained are shown in the following table:—

	1905	1906	1907	1908	1909
Average population	—	175	380	399	—
Blood, No. examined	16	9	—	—	—
Percentage infected	68·7	76	—	—	—
Spleen, No. examined	16	17	23	—	47
Percentage enlarged	56	88	39	—	62·5
Deaths per 1000 Division I	—	114	66	34	—
Division II	—	—	60	27	—

Writing in 1906 I described the condition of this estate in 1905 as follows:—'In November out of 212 coolies I found twenty-seven 'down with fever on one day (where) five children had died in one 'week (where) coolies were bolting daily, and the work of the estate 'was almost paralysed. This was followed by an outbreak of 'dysentery, and it was in the month of February before the malaria 'was got in hand.'

In 1906 or the beginning of 1907 it was discovered that the pills which were supposed to contain four grains of quinine contained much less than that amount, namely about one grain. The dose was then increased, with a steady improvement in the death-rate each year. It is interesting that the fall held good for each division of the estate. In 1905, in the month of October, 245 coolies worked 3,393 days, or 58 per cent. of the possible working days. In October 1906, 260 coolies worked 2,131 days or 70·9 per

cent. of the possible. In October 1909, 360 coolies worked 89·36 per cent. of the possible working days.

The economic effect of this quinine administration has been that the present small labour force now maintains in perfect order some 2,000 acres at a minimum cost. That it is not due to any improvement in the estate from other causes will be seen from the following paragraphs relating to the limitations of quinine.

The Limitations of Quinine. In 1908 and 1909 considerable attention was being paid to the presence of the Ankylostoma worm in coolies, and at the request of the Institute for Medical Research I arranged in April, 1909, for the examination of a large number of coolies. I choose for this purpose a healthy estate where no quinine was given, and the above-mentioned estate on which quinine was being administered with such satisfactory results* The result was to show that while Ankylostoma was present in large numbers on both estates, on the healthy one (Estate V) two out of 160, or 1·3 per cent. of the coolies had parasites in their peripheral blood, and on the other estate no less than 56 out of 215, or 26 per cent., showed the parasite. The examinations were made by Dr. A. T. Stanton, of the Institute, to whom I am indebted for the figures.

These results, in view of the splendid physique and work done by the labour force, appeared to warrant further enquiry, and on receiving the details I accordingly visited the estate and examined all the coolies on it, paying particular attention to those who had been shown to have had parasites in their peripheral blood. I separated the fifty-six as follows:—

Well developed, well nourished, and apparently in perfect health	42
Less well developed and nourished, but still apparently in good health and fit for work	5
Anaemic	1
In hospital	2
Died	1
Deserted	1
Paid off	4
	56

* I chose this estate in preference to one where quinine was less efficiently given, and where the parasite rate would presumably have been higher, on the ground, as I explained to Dr. Stanton at the time, that although the coolies appeared healthy, from clinical observation in hospital they appeared to me to have little resistant power to attacks of disease. (They were still on their quinine ration when in hospital.) Dr. Stanton's observations at once explain what I had observed clinically.

In other words, 75 per cent. of the coolies with parasites in their peripheral blood were apparently in the most perfect health apart from splenic enlargement, while 87·5 per cent. were in good health and fit for work. Of the 48 seen 30, or 62 per cent., had enlarged spleen, and of the whole labour force of 345 I found 174, or 50·4 per cent. with enlargement of that organ. On one division the coolies were getting six and on the other eight grains, with double doses when they were ill or off work, often quinine in solution. As at this time mosquitos were freely breeding on the estate in the ravines close to which the coolies were living, and adult *N. willmori* could be obtained in the lines at any time, this observation is of the greatest value in determining the effect of quinine. It clearly demonstrates that while keeping the malaria in check, so that the coolies could carry on their work, three years' administration of the drug had entirely failed to eradicate the disease. That the estate is really as unhealthy as ever is shown by the visitors to it, who contract malaria in about ten days, and even the head Cangany suffered severely from malaria on his return to the estate after a visit to India.

Finally, out of nineteen *N. willmori* captured in the lines four, or 21 per cent., had malaria, two with zygotes, one with sporozoits, and one with both zygotes and sporozoits.

Desiring to have further information on this important point, I took the blood of every man, woman, and child on an estate on which quinine was being given in the most thorough and systematic manner. The doses being given were 10 grains to each adult who worked, and 20 to those who did not work, the latter being given in solution. To the children 5 grains are given daily, and double doses also to those who did not work or were ill. Mr. R. W. B. Lazaroo, for seven years my chief assistant in Klang Hospital, kindly examined the slides for me, and reported as follows:—

Of the twenty-nine children, the results were as follow:—

Malignant parasites (subtertian) ...	5	17·27 %	27·58 %
Benign tertian	2	6·89 %	
Quartan	1	3·44 %	
No parasites seen	21		
	29		

Of the 125 adults the results were:—

Malignant (subtertian)	15	12·0%	18·4%
Benign Tertian	3	3·4%	
Benign Quartan	5	4·0%	
No parasites seen	102		
	125		

Of the whole 154 the percentage found with parasites in the peripheral blood was 20·12.

These figures agree very closely with the ones obtained by Dr. Stanton, and they at once supply the reason why no improvement has taken place in the hill land estates despite the use of quinine in what appear very large doses for constant administration.

Now this failure to eradicate malaria falls into line with our knowledge generally of quinine. I would indicate the following as the limitations of quinine.

(1) However thorough the dosing has been malaria is very liable to return to a patient although the possibility of re-infection is excluded. In other words quinine does not poison the parasite outright.

(2) When a person is attacked by malignant malaria (subtertian) for the first time, even with the most thorough administration of quinine in solution some four or five days elapse before the temperature falls, and Rogers has published figures which show that 60 grains daily have no advantage over 20 grains or less.

(3) Quinine has little if any effect on the sexual forms of the parasite in the peripheral blood. I have watched crescents in a man's blood for three weeks during which he was taking 20 grains of quinine solution daily, and after all pyrexia had gone.

(4) In bad epidemics I have watched cases of malaria admitted to hospital who have had no pyrexia, but rather who have been in the algid state; who, despite the administration of quinine by the mouth, by the rectum, and intramuscularly to the extent of 40 grains daily, have continued for four days in this algid condition, and then died. During this time the skin was in the condition of a cold, clammy sweat. No diminution appeared in the number of parasites in the blood. The patient apparently failed to react in any way.

(5) It is common experience that a patient, particularly if he be suffering from benign tertian malaria, must be put to bed before pyrexia will leave him, even when on full doses of quinine.

Finally, when we remember that thousands and thousands of people who do not take nor have the opportunity of taking quinine, recover from the disease yearly, it is evident that the human subject of the disease must depend on some power within himself to save him from death. Daniels,[9] in his presidential address to the Tropical Section of the British Medical Association, in 1909, in Belfast, appears to me to strike the right note when he insists that the protozoal group of diseases of which malaria is a member may persist for years without sexual regeneration, and despite any drugs which may be given, and that freedom from the disease can be acquired only by the development of resistant powers within the human host. It is when we consider malaria as an infection of the human host by a parasite which, in the majority of infections, lasts for at least three or four months, and in exceptional cases for years; in which the relationship of the parasite to its host is that of enemies at constant war; where, for a time, first one and then the other may be in the ascendant, and where victory in the end may be to either, that we can understand the apparently contradictory results of quinine.

When from any cause the health of the host is depressed, the parasite increases in numbers, and may be found in the peripheral blood.* As the struggle continues, and the life of the parasite is threatened, in harmony with the rule of nature, the parasite produces the sexual forms destined to continue its existence as a species. Thus from time to time the human host becomes dangerous to others, if anophelines which form a congenial breeding place for the sexual forms (i.e., capable of carrying malaria) are present.

When, on the other hand, the health of the host is improved from any cause, the parasites are reduced in numbers, and may disappear

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* Among the causes which predispose to a malaria relapse, menstruation is a powerful one. Menstruation frequently is followed by, and sometimes accompanied by a malaria attack. I have a record of a European who, when in England had six attacks of malaria following at once on six regular menstrual periods. On her return to the tropics and after an interval of many months she had a return of severe pyrexia within two days of a more than usually severe monthly period.

It acts either by attenuating the 'virus' within the host, or by increasing the reactive powers of the host, or perhaps both.

from the peripheral blood. The parasites may, in the end, die or be killed out by the host. It is not unlikely that two separate immunities are required by the host before the parasite is destroyed. It appears to me to be not uncommon for the host to become immune to the poison causing pyrexia long before it acquires powers to reduce the number of parasites, for cases with numerous parasites and without pyrexia, over considerable periods are not uncommon, indeed are recorded by every writer on malaria. The true action of quinine appears to be to assist the human host in working out for himself the resistant power which will ultimately free him from the disease. Without quinine in many cases, especially in very unhealthy spots, the human host would die before he had acquired his resistant powers. We thus see that if quinine in sufficient doses be given, the man will gradually overcome the parasites, and apparently suffer little from them; but, at the same time, we see that during this period he is capable of infecting others. The man is for a time a 'malaria carrier,' not unlike the typhoid carrier.

There must be an optimum dose of quinine, possibly it varies with the individual, and from time to time in the same individual, but whatever that dose be, it must bear a close resemblance to the ordinary therapeutic dose.

Finally, if, as has been shown, the immunity from malaria produced by quinine leaves the patient infective while he is acquiring the immunity, then it will be impossible in the presence of many Anophelines, and in the presence of many new arrivals (such as newly-born children) ever to eradicate malaria by quinine. It follows, too, that if drainage be an alternative even although much more expensive, drainage must be the method which should be adopted. Even if a community possesses no money for drainage, money might be borrowed with which to carry out the works, and at the end there would be an asset to show for the expenditure. Borrowing, however, would be impossible if the object were to buy quinine, since in the end nothing could be shown for the money except people still liable to malaria, and possibly some agriculture which could not be maintained without the continued use of the drug.

Time and Form of Quinine Administration. When I first began quinine administration systematically to large bodies of coolies, I advised quinine sulphate in solution, and in the morning. I advised

the solution because in solution its action is most certain, and it would thus be possible to use a smaller quantity of the drug; I advised the morning because the parasites usually sporulate in the forenoon, and consequently would then meet with the quinine in full strength.

In practice it was found that there were serious objections both to the time and the form of administration. In solution the action was so certain, that in ten grain doses cinchonism was so marked that the coolies could not work in the sun. In addition they were frequently sick after the dose; ultimately it was suspected that they deliberately vomited the dose to avoid the unpleasant after-effects.

Since then it has been given when work is finished for the day, that is about 2.30 p.m.

When I decided to abandon the solution I considered that the compressed forms as usually supplied were too much compressed, and coolies were taught to make quinine pills with bread. They became astonishingly expert at this. The pills were supposed to contain four grains of quinine, but after a time it was found they were putting in too large a proportion of bread, as the pills were thereby more easily made.

In order to standardise the dose, in 1907 I obtained machines from England, and hoped to make tablets, compressing the drug just enough to keep it in a mass.

The machines were not a success, as the rate at which the tablets could be turned out was far below that of the coolie making pills by hand, and quite insufficient to meet the demand. I therefore returned to the pills, but now have them made by mixing dry quinine sulphate with so much gum solution that when made the pills can be crushed easily between the finger and thumb. There are at the present moment just over 4,000 coolies taking ten grains daily, with double doses when off work. The efficiency with which the drug is administered is, however, dependent on the manager of the estate. Each year the drug is being given over larger areas and with greater efficiency, as its value is being better recognised. A change of manager is usually followed by less care being taken to give the drug, and this is a serious drawback.

Europeans tell me that it is impossible to continue the use of

quinine solution for any length of time. If taken in the morning, they cannot take food and cannot work in the sun. If taken at night, even dry quinine prevents sleep. I hoped at one time that if taken at night larger doses could be taken, the effects of which would pass off during sleep. But men are unanimous that, taken at this time, it prevents proper sleep, and the drug is now rarely taken at night.

Quinine sulphate in powder often fails to have any effect on an attack of malaria if there is gastric disturbance. This even when 20 or 30 grains are given in the course of 24 hours, and for a period of a week. In such cases I give quinine hydrochloride with a little morphia in solution. This effectively controls the sickness, and the temperature is usually down in 36 hours. I have often wished to try the old native remedy of opium with the quinine, but have never felt quite justified in doing so on a large enough scale to be of value.

Warburg's Tincture I have used both for pyrexial attacks and as a preventive. It appears to have no special advantage over a simple mixture of quinine hydrochloride and morphia. I have also given it over considerable periods combined with additional quinine to bring the dose of the latter up to 15 or 10 grains as the case might be. I cannot see that it has any special advantage.

Small children learn to swallow pills very quickly. For infants I find the easiest way to administer quinine is to give Euchinine (quinine ethyl carbonate) broken up in a little sweetened condensed milk.

On estates where quinine has been much used it is not uncommon to find coolies ask for solution in preference to pills when they have fever or suspect an attack is coming on. Kanganies are often found to carry pills in their pockets and give them out to any coolie who complains or asks for them during the day. On the other hand, I recently found the conductor on an estate where quinine has been given daily to the coolies for four years with the best results, who has suffered from malaria himself and taken quinine for it, would not give his wife quinine when she was almost dead with malaria until literally forced to do so. If such happens with a native who reads and writes English, who lives on an estate, where, if any place in the world, quinine has shown its power to control malaria, it is impossible to believe that native populations will ever be induced voluntarily to

take quinine in such doses as will effect any marked difference on the death-rate of the disease.

Although quinine sulphate may not be absorbed when there is gastric disturbance, there can be no question about its being absorbed in the majority of cases. For a week after a coolie or a European begins the daily consumption of quinine powder or pills, quite definite symptoms are felt in the head. After that period no unpleasantness is experienced, unless the dose be increased. Instinctively men have learned to take their total quantity broken up into two or three doses. And my object now on the most intensely malarious places is to have from 10 to 15 grains taken daily without producing symptoms. After an attack of malaria I advise 20 grains in solution daily for a week, and then reduce the dose to 10 grains in pill form, resuming 20 grains should the person feel unwell, and find his temperature 100° F. or more taken in the mouth. I prefer the sulphate for continuous use, because the more soluble forms are more apt to produce cinchonism. There is reason to believe the sulphate is absorbed not only from the stomach, but from the intestines. Its slower rate of absorption, therefore, leads to less violent fluctuation in the amount circulating in the blood, than where more soluble preparations are used. It has the advantage, too, that a dose will therefore have a more continuous action, and be present in the tissues and fluid for a longer period, than where there is more rapid absorption and presumably more rapid elimination or destruction. Nor is it an unimportant advantage where thousands of coolies are receiving comparatively large doses daily that the price of the sulphate is some 30 to 50 per cent. less than the other common preparations.

Relation of Dose to Intensity of Malaria. I think the same dose of quinine may be of more apparent value where the degree of malaria is less than where it is great. I have long been of the opinion too, that what is often supposed to be a relapse is in reality a new infection. It is impossible to decide with absolute certainty, but there is a certain amount of evidence beyond the cases where we find different parasites in different attacks.

For example, when in the service of Government, it was one of my duties to visit a place called Jugra at regular intervals. Jugra is intensely malarious, Government servants, their wives and families suffer severely from the disease. The place is consequently very

unpopular, and at each visit I was interviewed by one or more applicants for transfer on medical grounds. As long as Government decided to keep Jugra as a district centre so long must its servants remain, and so I refused to grant certificates on the ground of ill-health, if the complaint was merely of attacks of malaria. I advised daily quinine, and it was given to the police daily by a dresser from the hospital. Before I gave a certificate of transfer I had to be satisfied that there was danger of some serious damage to the person's health. I thus had an opportunity of watching people progressively deteriorate and when I considered there was any real danger I recommended transfer. This was, in the case of the police and clerks, often to Klang, and I was then still able to keep them under observation. It was interesting to observe the steady improvement, with but few relapses in most cases, after transfer to a non-malarious place. Had their almost constant attacks of fever when in Jugra been merely relapses these would certainly not have ceased so suddenly when the patient came to Klang, nor would the improvement in health have begun so soon, and been so marked: and this, when I am sure they were taking less quinine than when in Jugra, and often, I think, none at all.

What appears to bear out the same idea is the severity of the attacks of malaria in Europeans on intensely malarious estates. These patients are constantly going down with malaria even when on daily doses of ten grains of the sulphate. A short holiday usually permits them to recover, but attacks recur soon after their return to work, often in about the period necessary for new infections. Should they permanently leave the unhealthy place they rapidly recover, even when their new work and the climatic conditions under which they work are identical with that of the unhealthy place they have left.

An observation on estate 'RR' has some bearing on this point. This estate is in three divisions, and there is a European bungalow on each. Bungalow I is situated between the lines marked 100 and those marked 37. It is on a ravine in which I have not been able to find *N. willmori*, and which I think is probably unsuitable for them. Bungalow II and Bungalow III are near to ravines in which *N. willmori* swarm, and the spleen rate of the lines, if we exclude new arrivals, is practically 100. The history of the bungalows is that while I is malarious, II and III are intensely so.

In Bungalow I six Europeans who from time to time have lived there have had attacks, with one exception who took ten grains of quinine daily for the two years he was there. One of the five attacked had only two attacks, and these at intervals of a year. He also took ten grains daily. The others suffered more severely, but rapidly were free on taking the drug daily, while neglect just as certainly led to new attacks. Ten servants had malaria in 1907, and there was difficulty in keeping servants until they were compelled to take the drug under supervision. It will thus be seen that the bungalow was malarious, but not intensely so.

Bungalow II has been more malarious, and the three Europeans who have lived in it have been severely attacked time and again, and have frequently been compelled to go on periods of sick leave.

Now in 1909 it was necessary to re-arrange the work of the estate. A and B who had lived in Bungalow I (A never having had an attack, and B who had had only two attacks) were transferred to Bungalows III and II respectively, while C was transferred from II to I. A and B now suffered very severely from malaria, and both were invalided for a time, and this although they were taking the same amount of quinine as when in Bungalow I. C on the other hand ceased to have attacks, and gradually reduced his daily dose, until, when only taking about five grains a week, he had a sharp attack, which put him on to his full doses again. That there is no improvement in the health of Bungalow I is seen from D, who about the same time arrived on the estate, refused to take quinine daily or at all, and had so severe an attack that he had to be sent on leave for a month.

Now the work on all the Divisions is practically the same. It is impossible to believe that A and B were never infected in Bungalow I during the two years they lived there, and when the servants and other Europeans suffered frequently from the disease. The only explanation appears to me to be that the dose of quinine which kept them free from symptoms in Bungalow I was insufficient to do so when they had to overcome larger and more frequent infections.

Again we saw (page 89) that the quinine which appeared to keep the old coolies in health in 1906 failed to keep the new arrivals in health, but that ' from the new it (malaria) spread to the old,' and

the doses of all had to be increased. From this I concluded that the large number of new coolies had raised the percentage of infected mosquitos on the estates, and that by old coolies infecting new, and these again infecting the old, a vicious circle was established which could only be broken by the gradual establishment of immunity among both old and new.

The following is another instance of a large dose (the largest I have known taken continuously) giving protection where smaller doses have failed. The individual (close relative of my own) took 20 grains of quinine sulphate daily for three months. He had previously suffered so severely from malaria on an unhealthy estate, although he had been taking quinine in 10 grain doses, that he had to give up his post as manager. He had twice to go to a hill station to recover his health; ultimately he resigned his post. I anxiously considered the necessity of invaliding him home. He was so breathless he could only walk a few yards, and his weight had fallen to 136 pounds. He was, however, determined not to go to England, and took a post on another, but smaller, intensely malarious estate, one where each of his predecessors had left—a wreck. Its spleen rate has been 100 for years. He took 20 grains of quinine sulphate in gelatine capsules daily, taking five grains at a dose. In two months his weight had gone up from 136 to 164 pounds. He said he had an excellent appetite, and was soon playing in an Inter-State Rugby match. After three months he reduced the dose to 15 grains daily, and he has been on this dose for four months. I have kept a watch on him, and have critically examined him, not without some anxiety lest the drug should do harm. But I cannot recommend a reduction to less than 15 grains as long as he is well and when to take less might spell disaster. The fine bungalow in which he lives is at the top of a ravine, and has been so unhealthy in the past that its abandonment was suggested by the owners. *N. willmori* breeds freely in the ravine.

The marked contrast between this planter whose health improved when taking large doses and the progressive deterioration in his predecessors who were on smaller doses is so striking as to be a matter of general comment. And I think we are driven to the conclusion that in this extremely malarious place larger doses are required than are usually taken.

Each year has only strengthened my view that to keep a European

or a labour force in apparent health, the amount of quinine to be given bears a relation to the amount of malaria in the place at the time. The more the malaria the more frequently and in larger doses (within limits) must the drug be given.

This would explain the contradictory results obtained by various observers when quinine has been given as a prophylactic. Not only does it explain and bring these contradictory observations into line, but the observations recorded here help us to understand the cause of the variation of the intensity of malaria in different places and in the same place from time to time.

From the clinical observations recorded, I think we are justified in concluding that the very frequent attacks from which men suffer when in very malarious places as compared with the few attacks when removed to non-malarious places, are due to fresh infections, and not to relapses. If such an explanation of the more frequent attacks be accepted then the necessity for the administration of quinine in larger quantities and approaching ordinary therapeutic doses, in the more malarious places, and at times of the greater prevalence of the disease is easily understood. The human host has larger quantities of malarial parasites injected into him, and thus requires an increased protection by quinine.

Again, on the flat land we saw that the nearer we were to the breeding place of the Anopheline—that is the jungle—the greater the malaria: indeed, within the half-mile radius it bears a definite ratio. We are forced, therefore, to believe that the intensity of malaria bears a definite relation to the number of Anophelines in the air to the number of times a person is bitten, and to the number of infections he receives.

Similarly on the hilly land observations from all time have show that the head of a ravine is the most malarious; it is nearest to the chief breeding places of the Anopheline. The most malarious bungalows in the country are those situated at the head of or close to a ravine. The once notorious bungalow on Drummond's Hill, Taiping, had its servants' quarters over a ravine. Now it is obvious that the inhabitants of such a place must be bitten oftener and infected oftener than those living at a distance from the breeding places. They are infected time and again by their own parasites, after passage through a mosquito, in which, too, by the sexual

reproduction which occurs in the mosquito it is not improbable the parasites have acquired an exalted virulence.

Thus again we are forced to believe that the greater intensity and persistence of malaria in the hilly land is due to the greater number of Anophelines, and the greater number of infections which the persons in these regions receive.

Now if the foregoing be true, it would follow that malaria would be also intensified by increasing the percentage of the infected mosquitos without increasing the total number which bite, and we find it to be so in fact, as seen from the infection of old from new coolies. The introduction of many new non-immune coolies who almost simultaneously contracted malaria from the few still infectious old coolies, soon raised the percentage of persons on the estates with parasites in their peripheral blood and capable of infecting mosquitos to a higher rate than it was when there were only old coolies, most of whom had acquired a considerable amount of immunity and control over their parasites. A higher percentage of mosquitos soon became infected, and these in biting old and new coolies indiscriminately soon increased the infection of the former and led to their again suffering from attacks of the disease.

The intensity of malaria therefore depends, in my opinion, on the absolute number of infected mosquitos in a locality, and anything which increases the number of malaria-carrying Anophelines therefore increases the intensity of malaria.

Many of the factors which influenced the prevalence and intensity of malaria were well known to our fathers before us. Such were disturbance of soil, interference with drainage, seasonal variation in temperature and rainfall, etc., etc. It is extremely interesting to see that, although their deductions as to the cause of malaria were incorrect, their observations were marvellously correct. In childhood's language, they were 'very, very hot' in their search for one of Nature's most cunningly-hidden secrets, and I desire to pay my humble tribute of respect to their memories.

Finally, if these observations and deductions be correct, the Anopheline is *the factor* in the production of malaria which must be eliminated if any permanent improvement is to take place.

It was largely on these grounds that I opposed in 1907, and am still opposed to, the erection of hospitals on malarious estates.

Apart from the difficulty of keeping an efficient staff, constant re-infection of the patient would make cure a difficulty. The erection of a hospital in an intensely malarious locality would also have meant that the worst malarial cases would have remained in it. Infection on the estate would therefore have been intensified. Now it is just in the regions of most intense malaria that blackwater fever is to be found. Malaya has fortunately been singularly free from that disease, and it would be a profound folly to create conditions which would in any way tend towards its production. Finally, I think that the coolie, like the European, should be taken from a malarious estate to a non-malarious place if with the aid of quinine he cannot overcome the disease. Not only is his recovery more rapid, but he ceases to be a danger to others. (See non-infection of Klang Town from hospital, page 34.)

Ill-Effects of Quinine. It has not been without a due sense of responsibility and no little anxiety that I have found myself the instrument in causing large numbers of people to take quinine for prolonged periods in doses which appear excessive to many, and doses which year to year tend to increase in amount. I have watched the effect of its administration with care, and if it is producing any ill-effects, they are of such a nature as not easily to be detected—at any rate I have not detected them—and they are of infinitely less consequence than malaria.

I have rarely given more than 20 grains daily, unless on microscopic examination the patient's blood was so full of parasites as to show there was immediate danger to life. In such cases I have given up to 40 grains mostly per rectum, retaining the mouth for the administration of nourishment.

I have never seen a case of quinine blindness, nor have I had in my practice any patient who complained of deafness or ear symptoms for more than a few days. Occasionally, a patient the subject of malaria, who does not take quinine in sufficient quantity complains of 'indigestion.' If on sulphate I may order hydrochloride in increased doses, which usually puts him right. Time and again when a man has complained that he has 'not been up to the mark,' and thought he has been taking too much of the drug, I have advised increasing instead of reducing the dose with the most satisfactory results. Miscarriage

is often attributed to a dose of quinine. Yet I could quote instances of patients who have taken quinine throughout pregnancy and been delivered at full time. On the other hand, an attack of malaria is notorious as producing abortion, and if the attack comes on within the last two months of pregnancy labour will almost certainly follow, It is true quinine is often given in these cases, but the utter futility of quinine in ordinary doses when given to induce or accelerate labour in a healthy woman, excludes the theory that quinine is the active agent in producing the abortion of the malarious patient.

Occasionally, but very rarely, a cutaneous eruption appears, when doses of quinine are first given, but the rash usually disappears with the continued use of the drug. One man when first put on 15 grains daily developed a severe nettle-rash, which was intensely irritating. It disappeared within a week.

Cost of Quinine Administration. It must not be forgotten, too, that the administration of quinine in effective doses in a malarious locality is by no means an inexpensive method of combating malaria. To give 10 grains daily to 1,000 people without any extra to those who actually have pyrexia, for ten years, would cost about £1,900 sterling. Such a sum, if lent by a Government to a community at a reasonable rate of interest, would free a very large area from malaria if drainage methods suitable to the local Anophelines were employed. And in ten years the community would have nine years of prosperity and health in which to repay the loan. In the case of many small villages it would probably be possible to eradicate the breeding-places of Anophelines, where they are in the midst of the community, at a mere fraction of the money which would be required to dose the population effectively with quinine, even for a year. While for larger communities the cost of drainage would be relatively much less than in the case of the smaller ones, since the same expenditure would protect a relatively larger number of people.

Relative Values of Quinine Administration and Drainage. We have seen that quinine at its best and when administered with a thoroughness the result of a discipline impossible of attainment in an ordinary population, still leaves a large percentage of the population capable of infecting others. It can, therefore, never eradicate malaria

in the presence of new comers and the presence of many Anophelines. We have seen, too, that to attain this best result in a malarious place costs a fairly considerable sum. Quinine, therefore, in my opinion, cannot for a moment be ranked with drainage.

It cannot be too strongly urged that efficient land drainage not only is a radical anti-malaria measure, but is of first-class importance in practically all forms of agriculture; and malaria is essentially a rural disease. In dry forms of culture it often makes the difference between good land and bad land; between good crops and poor crops. And in wet culture it is no less important. Cromer insists that in Egypt the success of irrigation depends no less on the channels for taking off the water than on the irrigation channels for its supply. It is notorious, too, that badly drained irrigated land is not only of less value agriculturally, but is also more malarious than irrigated land where, by means of an efferent system, the water on the land is more fully under control.

Finally, I would urge that when the time comes for unanimity as to what should be done, the malaria problem will still be, as it now is, essentially a financial one. In the end the affected community must find the means of combating the disease. To me it appears that any means which will enrich the population will also enable it to make greater effort to overcome the disease. If by drainage we can enrich not only the people and the land, but by the same measure help to reduce the disease, drainage must be *the* measure of first importance.

Whether quinine be supplied free by a Government, or sold at cost price, or at a loss to the Government, a price is being paid, and the people are practically being assessed an amount which, however small, would still have paid the interest on a loan for a radical drainage work. Perhaps the work would only be a small one, but no matter, for it would definitely and for all time, if upkept, place the inhabitants beyond the reach of the disease.

It is here that I think a Government can help to break the vicious circle which makes the malarious poor and the poor malarious, and assist a people to initiate drainage works, which from poverty they themselves cannot begin. Even if Government cannot pay for drainage works out of revenue, then by pledging its credit a Government can obtain money on loan. Both capital and interest can

be paid by assessment* of the land benefited. Of course, care must be taken that the works will improve the area.

Malaria over large areas cannot be eradicated in a day. But from what I have seen of the results of radical measures I feel strongly that by radical measures will the end be attained soonest: that every success will help to others: that people will be saved who will never consent to take quinine in sufficient doses, if at all; and that only by radical measures will be stopped the infection from, and the death of, the vast mass of those who suffer from 'Malaria sine pyrexia,' those who fail to recognise they suffer from malaria, and who, as we saw from the Klang figures, account for a very large percentage of the death-rate of a malarious community.

XI.—Anti-Mosquito Measures for Stream-Breeding Anophelines. Closed drains have long been used in agriculture, and are a development of open drainage. Closed drains render less land useless for agricultural purposes than does an open drainage system, and it is also possible where fields are not cut up very much by open drains to employ animals in agricultural operations, thus cheapening the work.

The value of these closed drains as a means of reducing malaria is, of course, well known to the Italians, and is figured in their works.

When reading Howard's[10] account of malaria in Central Africa, in which he states that the cost of lime is £6 per ton, and of English cement £17 per ton, it occurred to me that the employment of the closed system of drainage by means of agricultural tiles made on the spot would be an extremely economical and efficient means of drying the small ravines of tropical countries and so preventing malaria.

On my arrival in England, early in 1908, I at once made enquiries into the methods of agricultural drainage, and possessed myself of the available literature. On returning to Klang in October, 1908, I discussed the subject with the chairman of the Klang Sanitary Board, Mr. J. Scott Mason, and Mr. John Gibson, general manager of one

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* The following Rule 2 under Section 6 of the Drainage Rate Enactment of Selangor F.M.S. :—'The annual drainage rate shall ordinarily be an amount 'calculated to yield 5 per cent. on the original cost to the Government of the 'drainage works, together with the annual cost to the Government of the 'maintenance thereof. For the purpose of this rule all necessary sluice-gates and 'other protective works constructed in connection with the drainage of the whole 'or any portion of any drainage area shall be deemed to be drainage works.'

of the large rubber estates, who was familiar with the drainage in Scotland; and it was decided to try it on one of the drains in Klang. A Chinese roof tile-maker was approached, and after several attempts he succeeded in turning out about fifty very respectable looking tiles, and agreed to make more at a cost of two cents each.

Then appeared Mr. Simm's[11] paper in the Liverpool Annals of Tropical Medicine, from which it appeared that the system had been adopted with success in Panama by the Americans some two years previously. The idea thus was fully justified, and no further action was taken in Klang.

The proof, however, that although *N. karwari* and *M. umbrosus* x. can be completely eliminated from ravine streams, *N. willmori* persists despite the utmost care, brought this method again into prominent consideration. To me it appears to offer the only hope of ever eradicating malaria from ravine land, since quinine has failed entirely to do more than keep the disease in check, and is, in fact, only a palliative, and not a radical method of treatment.

As it is the head of a ravine which is notoriously unhealthy, it is possible that in Malaya tile-draining of the head of the ravine where there is little water to be dealt with may be a very economical method of dealing with malaria, while in the lower portions of the ravine where there is a wider stream and more water, clean weeding may be sufficient. I think it is not improbable that the mosquito lays its eggs chiefly where the ground is just damp, in the eye of a spring so to speak, for the larvae are found there most easily, and that larvae found lower down the stream have been carried there. If, however, the only water to be found in a ravine is at a point where it has already acquired a considerable current, any eggs laid there might be carried away before they hatched into the larval stage. If this be so, then the cost of dealing with the ravines will be very small indeed. It will, of course, be advisable to concentrate labour into certain portions of the estates, into sanitary areas, rather than attempt to deal with the drainage of the whole of the water in all the ravines of the estate.

I may add that expenditure for this purpose has already been sanctioned by the directors of one of the largest estates, and that work will be begun at once.

XII.—On the possibility of altering the Composition of Water and the Anophelines breeding in it. It has long been established that mosquitos, including the Anophelines, exercise discrimination in the water in which their larval stage is passed. Each species has the special type or character and quality of water which it prefers. Some have a comparatively wide range within their taste, others are peculiarly selective. *N. willmori* is one of the latter. In Malaya it is found exclusively in hill streams and in the springs which feed these. I consider that the eggs are laid in, and that the larvae prefer, the shallowest possible waters; indeed, they are to be found in greatest abundance in ground with so little water on it, that in order to take the larvae, it is often necessary to make an excavation in the earth into which the water from the surrounding ground flows, carrying the larvae with it. As these springs are very common at the head of a ravine, the presence of this mosquito in them probably accounts for the well-recognised danger of living at the head of a ravine. The old reason for this was that mists were carried up the ravine and naturally struck with special force those living at its head.

From these springs the larvae are carried down the streams, but they cannot be entirely washed out even by the strongest currents or rains. I have found them in a drain after a two-inch shower. When one attempts to take them they often wriggle completely out of the water on to the damp ground. I have watched them at play in a clear pool at the foot of a rock down which water was flowing with considerable force, since the rock sloped to the pool at an angle of forty-five, and its face was a foot long. The current of water was still further increased in strength by the rock being funnel-shapel, and all the water coming down the face was gathered into a solid stream as it entered the pool. The larvae were playing, not exactly like trout, head to stream, but were floating round in the current, and every now and then one would swim right into the stream, up it for a short distance, and then hang on to the side of the apparently bare rock in the full strength of the current.

As *N. willmori* is never found in the flat land, it is obvious that this mosquito requires water of a special character, and a character which appears to be water well aerated and quite free from vegetable decomposition.

In May, 1909, having accepted an invitation from Mr. C. Malcolm Cumming, Chairman of the Planters' Association of Malaya, to visit a Tamil settlement which he had successfully established, I motored into Negri Sembilan and saw the paddi swamps, or 'sawahs,' there. These consist of valleys, the whole bottom of which have been rendered flat, so that they can be irrigated by the waters coming down the valleys. They seemed to me ideal breeding places for Anophelines, and I asked if they were unhealthy. I was assured that the inhabitants were extremely healthy, and that malaria was unknown. It occurred to me then that the process of paddi cultivation must alter the composition of the waters in some way, so that what I should regard as the normal inhabitant of the valley stream, namely *N. willmori*, had been driven out.

The following day when passing an estate Mr. Cumming informed me that the estate had been healthy until Tamils had been introduced, and since then had been extremely unhealthy. I remarked that the valley through which we were passing was very swampy, and he then told me that it originally had been 'sawah,' but that the Malays now were employed on the estate, where they got better wages, and had abandoned the 'sawah.'

It appeared to me that if there was any truth in the statement that 'sawahs' were healthy, then the abandonment of the 'sawah' and not the introduction of the Tamil coolie was responsible for the outbreak of malaria on the estate. The idea was that by abandoning the 'sawah' the *N. willmori* had been enabled to return to the valley. It was obvious, too, that it might be a method of treating ravines on rubber estates where the drainage was difficult or where weeding was so expensive that it might be an economy to abandon the ravine if this could be done without impairing the health of the labour force on the estate. The matter appeared to be of importance economically, and investigation seemed called for.

I accordingly spent that night on the edge of a 'sawah.' In the evening three Anophelines were taken, one *N. nivipes*, one *M. sinensis* and one *M. rossii*. Under ordinary circumstances I should have expected to find at least one *N. willmori*. I learned that this 'sawah' was considered healthy. In the morning I examined 50 Malay children at Kampong Batu Malay School, of whom 20, or 40 per cent., had enlarged spleens.

These results appeared to bear out the theory in part, but I had no opportunity of further investigation until August, when I went to the Krian Irrigation Paddi Fields and also to those at Bukit Gantang. I was only able to spend a week on the work at that time. and was unable to return to this investigation until November.

The investigation consisted of an examination of the children and of the species of Anophelines breeding in the waters and found in the houses in the two places. Although both were paddi swamps, the most extraordinary difference in the health of the two places was discovered, and a difference in the species of Anophelines was also found.

Krian Irrigation Paddi Fields. This irrigation scheme, carried out at the cost of about 1½ million dollars, was completed in 1906, and was at once a success financially. It enabled the people to reap a good crop in a dry year when their neighbours outside the irrigation area were suffering from want of water. The area irrigated is about 60,000 acres.

The water supply is from two rivers, the Sungei Merah and the Sungei Kurau, which are dammed at a pass in the hills. Above the dam, overflowing their banks they spread over ten square miles of jungle. The effect of the constant water on the jungle has been to kill it out slowly, and in passing along the railway which crosses the reservoir one sees comparatively few of the larger trees now alive. Many dead ones are still standing.

These rivers have already traversed considerable distances before they reach the impounding reservoir, but the waters of both have originally come from the hills.

From the impounding reservoir the water is led by the usual canals, and after flowing over the land is led off by drains to the nearest rivers, as will be seen from the map.

Health of Children of Krian. During my two visits I examined 304 Malay or Tamil school children, and 47 estate Tamil children, and Dr. Delmege, the Government Medical Officer of the District, has kindly furnished me with the figures of 367 school children whom he has examined. Out of the total 718 examined, only 20

or 2·7 per cent. had enlarged spleen. The details of the examinations are as follows:—

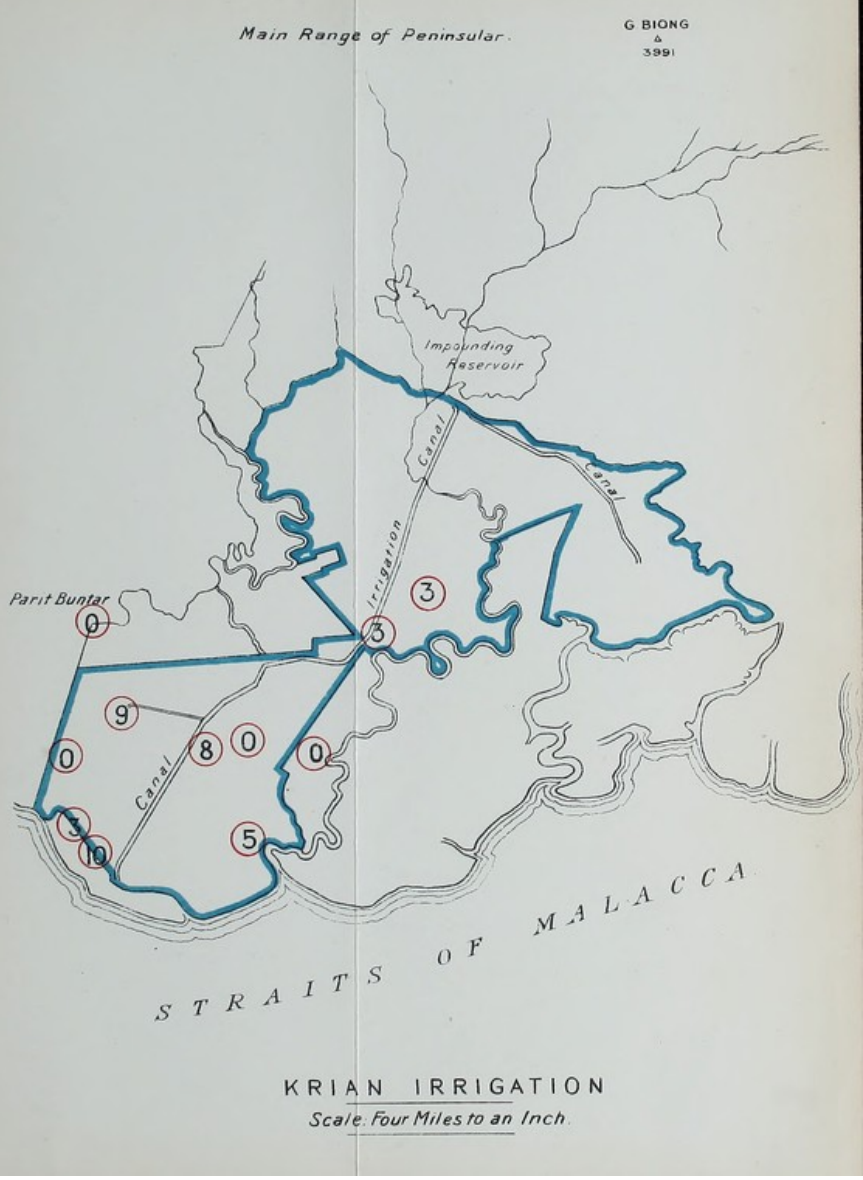
Observer	Place	No. examined	No. enlarged	Percentage enlarged
Dr. Delmege ...	P. Buntar			
,, ...	,, Malay boys	52	0	0·0
,, ...	,, ,, girls	39	0	0·0
,, ...	,, Enlarged mixed ...	28	0	0·0
,, ...	Sungei Star...	47	0	0·0
,, ...	,, ...	31	0	0·0
,, ...	Sungei M. Aris	59	2	3·3
,, ...	,, Labu	28	3	10·7
,, ...	Titi Serong	57	5	8·7
,, ...	Jalan Bharu	26	2	7·6
Dr. Watson ...	Bagan Serai Malays	66	3	4·5
,, ...	,, Tamils	34	0	0·0 } 3
,, ...	Telok Maiden	71	2	2·7
,, ...	Jin Heng (Estate Tamils)	47	0	0·0
,, ...	Sungei Siakap	65	3	4·6
,, ...	Sungei Bharu	68	0	0·0
	Grand Total	718	20	2·7

A reference to the map will show that these examinations cover practically the whole district, and can be considered quite representative of it. They show conclusively that this irrigation area is to a striking degree free from malaria. This is the general idea. and Dr. Delmege writes me as follows:—'I quite agree with you 'that there is very little, if any, malaria contracted in the paddi 'fields.'

The Anophelines of Krian Irrigation. The Anophelines of the Krian District were found to be—*M. rossi*, *C. kochii*, *M. sinensis*, *M. barbirostris*.

The two latter mosquitos are found breeding freely in the irrigation channels and in the paddi fields. They are also found in the houses, where they feed freely on the inhabitants.

The low percentage of infected children in a place in which adult Anophelines are so abundant is strong evidence that these species do not carry malaria, or, if they do, that they act as extremely inefficient hosts for the parasite. The fact that the percentage of



KRIAN IRRIGATION

Scale. Four Miles to an Inch.

children with enlarged spleens is practically the same as in Klang and on the healthy estates, where a history was obtained of the affected children being immigrants who had suffered from malaria before their arrival, makes it extremely probable that the affected children in the Krian Irrigation area had contracted their malaria outside its limits.

I was unable to make any investigation into the health of the children on the estates in the Krian District beyond that of the one mentioned, which was on the opposite side of the road from the irrigation area and where the spleen rate of the forty-seven children was found to be nil. An examination, however, shows the death-rates of the estates on the flat land of Krian to be so low that malaria can hardly be a serious consequence. One estate, however, which is shown to be on the edge of a Government forest reserve has a death-rate of 100, evidence that malaria is to be found near to the jungle in Krian as in Klang, and that opening of the land gives freedom from malaria there also.

Bukit Gantang Valley Rice Fields. About ten miles South-east of the Krian Fields the main range of the peninsula is cleft by a valley leading to what is locally known as the Bukit Gantang Pass (Bukit in Malay means a hill or mountain). The valley runs in some five miles, and its mouth, two miles wide, has Chankat Jering and Bukit Tebok on the North and South sides respectively. From side to side, from end to end, the valley is a sea of paddi in which are studded Malay Kampongs, as the 'islands' of an archipelago. There is a considerable Malay population along the hills and on the 'islands.'

An examination of the children living at the foot of the hills showed that they were suffering severely from malaria.

In thinking over the theory of excluding certain species by altering the water, it had occurred to me that if an experiment were to be carried out, the foot of the hills and sides of the ravines being the places most likely still to permit *N. willmori* to breed would be the places to avoid in housing the coolies; and that if an island in the middle of the paddi could be made, there the coolies would be in the best health.

Having ascertained that the children on the edge of the hills were very unhealthy, I at once realised that in this valley the conditions of the experiment I had thought of were actually to be found on a

magnificent scale. The valley being two miles wide the possibility of mosquitos flying from the sides to the centre of it, in such numbers as to carry malaria was excluded. It remained, therefore, to ascertain the percentage of children infected on both sides of the valley and in the centre and to determine the species of the Anophelines. Starting at Chankat Jering the Malay schools were examined. At Chankat Jering fifty-one children were examined, of whom twenty-two, or 43 per cent., had enlarged spleens.

Two miles further up towards the Pass, Jelutong School was examined. Of the thirty-nine children seventeen, or 43 per cent., had enlarged spleens, and several others had fever at the time of the examination without having enlargement of the spleen.

Still nearer the Pass, Bukit Gantang School was found to contain fifty children, of whom twenty-five, or 50 per cent., had enlarged spleens.

Thus out of 140 children living at the foot of the hills and on the edge of the paddi no less than sixty-four, or 45·7 per cent. had enlarged spleen, strong evidence of the prevalence of malaria. While at Simpang, two miles from Chankat Jering, out of thirty-three children examined at the school only three, or 9·9 per cent., had enlarged spleens, showing that as we passed from the hills, malaria was less severe.

I next examined the Bendang Siam school, in the middle of the valley on the road running south towards Bukit Tebok. On this road in the two miles where it runs through the paddi swamps there are no less than ten bridges, each indicating a small stream running down the valley. In the school out of thirty-one children, nineteen, or 61 per cent., had enlarged spleens. There were sixty-two on the register, but as examination was made at the time of the fruit season the attendance at the school was then about sixteen daily, and it took three visits before the thirty-one children were obtained. In order to broaden the basis of the observation, and at the same time to obviate error due to children from the south side of the valley, I examined fifty children in the houses of the 'Islands.' I was accompanied and assisted in this by Dr. Bryce Orme, of Taiping, and we spent the best part of a day in going through the valley, which consisted of patches of dry land and of paddi swamp irregularly mixed together. On the dry patches the Malay planted his house and his trees, and in the swamp grew his paddi. Of the fifty children in the islands, eleven, or 22 per cent., had

BUKIT GANTANG VALLEY.

SCALE ONE MILE TO THE INCH.

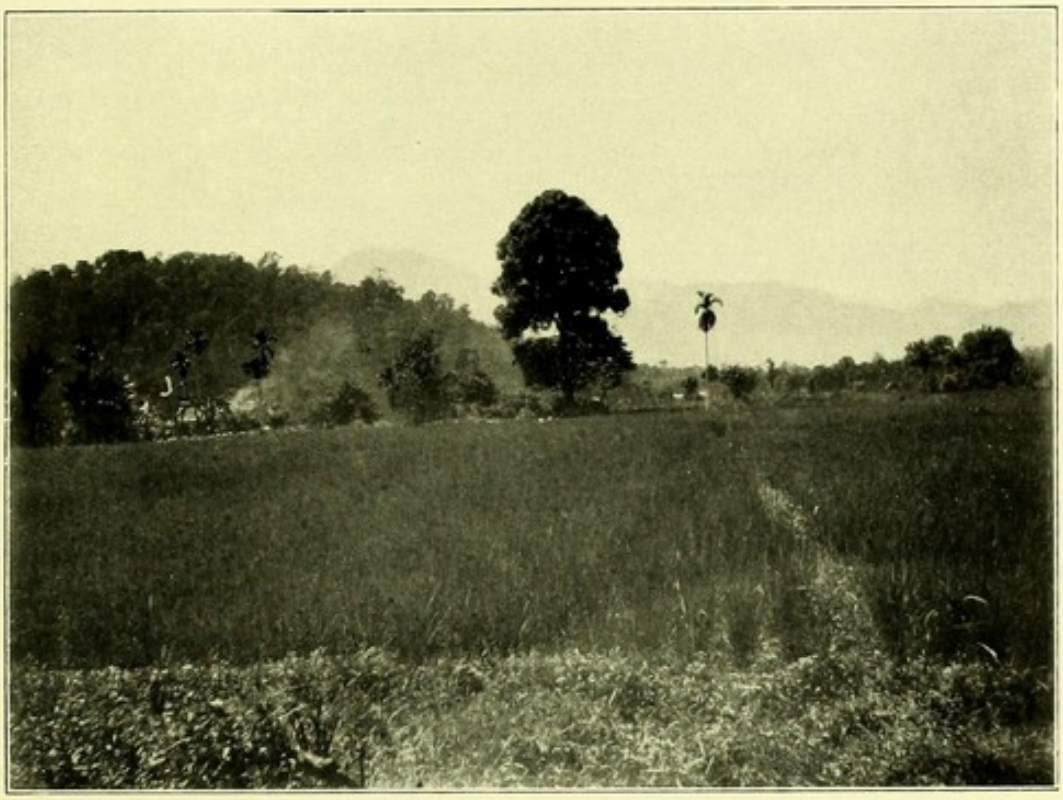


FIG. 11. BUKIT GANTANG VALLEY.

The photograph shows the paddi (rice) fields in the foreground, and Malay houses along the foot of the hill on the left. On the right the valley widens out, and the small clump of trees is the beginning of the series of kampongs which I have likened to 'Islands' in a sea of paddi.

FIG. 12. MOSQUITO-PROOF COOLY LINES.

Under the 'attap' (palm leaf) roof there was a wooden ceiling. The verandah was closed by weather boarding for about three feet, and to the ceiling by iron wire gauze. There were two doors closed by spring hinges.

enlarged spleens. Only one case of fever was found among the fifty children, and the inhabitants insisted that fever did not trouble them. The children found in the houses were mostly younger than those at school. It was thus obvious that both at the sides and in the centre of the valley malaria were present in serious amount among the children, but that the adults, presumably from having had the disease during childhood, were now immune, and consequently regarded the locality as healthy.

Apart from the evidence of the children, the history of the making of the railway which runs over the Pass, records severe malaria, especially at Ayer Kuning and Bukit Gantang, where large cuttings and a tunnel had been made. While the Malays native to Bukit Gantang who had acquired immunity in their childhood could live in the valley, the non-immune Tamils on the railway construction suffered severely. We often see Javanese who generally have acquired immunity in their childhood, living in places which Tamils have had to abandon.

I may here remark that the spleen rates of Malay children in their Kampongs is not comparable with that of Tamil immigrants on an estate, since among the latter the non-immune new arrivals of all ages up to ten form a larger proportion of the total population than do the new-born of the Malays. While a number of the Malays in the higher ages will already have acquired immunity and lost the enlargement of the spleen, the Tamils at all ages will still be suffering from the disease.

Places newly populated by an immigrant coolie population showing a spleen rate of 100 may really differ considerably in the amount of malaria present.

Anophelines of Bukit Gantang Valley. During the four days (16 to 19 November, 1909) 26 adult Anophelines were taken in the houses of the 'islands,' or as the places are locally known as Kampong Paya and Bendang Siam. They were the following:—

M. rossii	10
M. albirostris	6
M. sinensis ... ...)	
M. barbirostris ...)	9
Myzorhyncus umbrosus x.	1
	26

The larvae of these mosquitos were found breeding as follows Enormous numbers of *M. barbirostris* and *M. sinensis* were in the paddi fields. *M. rossii* were in pools near to the houses. *M. albirostris* was found breeding in a stream running through the paddi swamps and in swampy grass through which water was flowing slowly. Larvae of *M. umbrosus* x. were not found.

In addition, one specimen of *N. nivipes* was hatched from a paddi swamp about a mile in from the road.

On the Chankat Jering side of the valley three adult *N. willmori* were caught in a few minutes in a set of coolie lines at Ayer Kuning. At Bukit Gantang village fifteen adults were taken in houses, of which fourteen were *M. rossii* or *M. sinensis* and one *M. albirostris*. In a stream flowing down from the railway at Bukit Gantang numerous larvae with simple unbranched frontal hairs were found in a backwater. These failed to hatch out, but were probably *M. albirostris*.

On the Bukit Tebok side of the valley, in a house at the eleventh mile, two adults were taken, one of which was *M. barbirostris* and the other *N. nivipes*. Larvae were taken in a spring at the edge of a swamp near this with the characters of *N. willmori*, but they failed to hatch out; while in a ravine running towards Bukit Tebok numerous larvae belonging to the *Myzorhyncus* group, possibly either *M. separatus* or *M. umbrosus x*, were found among the swampy grass. They, however, suffered, as did the other larvae, from the two hundred mile journey to Klang, and failed to hatch out. A few miles further down this road, in the lines of a very unhealthy estate, ten *N. willmori* were taken in half an hour. The estate is traversed by hill streams.

Table showing the Anophelines taken at Bukit Gantang Valley and at Krian.

At the foot of the hills forming Bukit Gantang Valley	In the rice fields of Bukit Gantang Valley—' the islands '	In Krian Irrigation area
Much malaria	Much malaria	No malaria
N. willmori	—	—
M. albirostris	*M. albirostris*	—
N. nivipes	*N. nivipes*	—
M. umbrosus x	*M. umbrosus x*	—
M. barbirostris	*M. barbirostris*	*M. barbirostris*
M. sinensis	*M. sinensis*	*M. sinensis*
C. kochii	*C. kochii*	*C. kochii*
M. rossii	*M. rossii*	*M. rossii*

Reviewing these facts, we may conclude that in the hill ravines and springs of Ayer Kuning, and of the main range generally, *N. willmori* is acting as an efficient carrier of malaria, but the entire failure to take it in the 'islands' when it was so easily taken at the sides of the valley warrants the conclusion that it does not spread far from the hills and does not breed in the paddi swamps. It is, however, evident that some of the other Anophelines found there are carriers of malaria. *M. rossii* and *M. barbirostris* and *M. sinensis* can be excluded, since their presence in Krian caused no malaria. Suspicion must therefore rest on the other three, namely *M. umbrosus x*, *N. nivipes* and *M. albirostris*. The first of these is the great carrier of the flat, undrained jungle land in Klang. It is easily seen and captured, as it is a large mosquito. As only one was taken, it is probably not the important carrier at Bukit Gantang rice fields. *N. nivipes* is closely related to *N. willmori*, and *M. albirostris* is one of the small black-legged *Myzomyia* group to which *M. funesta* (the African carrier) and *M. culicifacies* (the Indian carrier) belong. The time at my disposal did not permit me to complete the investigation of this point.

Conclusions from the Observations of the Krian and Bukit Gantang Irrigation Paddi Fields. Incomplete though they be, the investigations have established certain important points. These are:—

(1) That the conversion of ravines into ordinary 'sawahs' would not improve the health of a rubber estate.

(2) That these 'sawahs,' or paddi swamps at the foot of hills or in ravines are extremely malarious, and that although the adults appear to enjoy good health, the immunity from malaria which they possess has been acquired through their having suffered from malaria when children.

(3) That the estate in Negri Sembilan, which was supposed to become unhealthy on the introduction of the Tamil coolies, had always been unhealthy, and the adult Tamils had only suffered in the same way as the children of the Malays and other new-comers did.

(4) That vast areas may be put into wet paddi or irrigated land without causing malaria was seen from Krian.

(5) That paddi land at the foot of hills irrigated by the water from the hills is very malarious.

(6) That different groups of Anophelines are found in (*a*) the water of hill streams, (*b*) the water close to the foot of the hills, (*c*) the water at some distance from the hills.

(7) That on the difference of species of these Anophelines depends the presence or absence of malaria.

It is not my purpose to record speculation here, but rather the facts regarding malaria which have come to my notice during the past nine years. I cannot, however, pass from this subject without pointing out the great hope which these observations raise of dealing with malaria on new lines.

Hitherto the attitude towards the malaria of rice fields—and all rice fields were supposed to be malarious—has been that rice and malaria are inseparably connected. Rice, being the staple food of many millions in the tropics, must be grown. The choice appeared to be starvation or malaria, and this is, of course, really no choice, since people must always run the risk of disease rather than starve.

The only attempts to destroy malaria where it was impossible to remove the breeding-place entirely by destruction of the larvae, have been by the use of petroleum and by the use of certain poisons put into the water. The Italians favour an aniline dye.

The cost of such applications on the very large scale which would be required for rice fields prohibit their use.

Very powerful larvacides are infusion of tobacco leaves, and the powdered flowers of the Dalmatian chrysanthemum. But here again expense prohibits their use. Daniels[12] experimented with the Tuba root—*Derris eliptica*—but even if it could be applied on a very extensive scale it is doubtful if it is not too comprehensive a poison, since it poisons fish, and, as Daniels says, 'few forms of animal life are unaffected.' Such wholesale poisoning would probably interfere with the equilibrium of life in the paddi fields, and produce consequences of an unwished-for character.

But in Krian we have seen that Nature has carried out in the most successful way a method of so altering the composition of the waters of the hills that the carriers of malaria no longer find it suitable for their existence, and malaria practically does not exist. I can imagine few greater benefits which the Federated Malay States Government

could confer on its Malay inhabitants than the discovery of the alteration which has occurred in the water, and its application* to the numerous paddi fields of the Peninsula. A very large Malay population lives on the paddi fields of Perak, Negri Sembilan, and Pahang, who are now suffering from malaria in a severe form, unrecognised, it is true, since the children are the chief sufferers. This malaria must in the course of generations have left its stamp on the race, and possibly is responsible for the indolence of the Malay. Perhaps the Malay would become a less likable character were he to acquire the energy of his Chinese competitor.

In the past the struggle was perhaps no uneven one, for what the Malay lacked in energy and capacity for constant work he made up for by force of arms. In a sense peace has disarmed but one of the competitors, and in the struggle for existence the Malay has now, unaided by the weapons of the past, to face an alien foe full of the energy and strength of the colder North.

If he is to survive in the struggle, it is essential that every obstacle be removed, and I can imagine no greater obstacle than malaria. Nor can I imagine how the West can more gloriously crown the benefits, which it has heaped on the Malay in the past, than by the overthrow of the pestilence which saps the springs of his childhood life, and stamps the happy years of youth with pain and death.

The Effect of Drainage on Different Species of Anophelines. Now, from the observation of species in Malaya and their behaviour to drainage, I would suggest it would be of practical importance to classify the Anophelines of each country according to such behaviour.

We have seen that *M. umbrosus* x. is only to be found in a pool without a current, while a current of water means its destruction and disappearance. It can, however, breed in very weedy and obstructed ravine streams as there the current is practically nil.

N. karwari, on the other hand, is a pool breeder, which prefers a gentle stream of fresh water flowing through its pool. Such pools are

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* It is not inconceivable that an industry might be found which requires the maceration of a fibre which, while changing the composition of the waters, might also provide the inhabitants with work. The culture of flax and hemp in Italy supplies a line upon which to work.

It may be that only improved drainage is required in these valleys, since their drainage does not compare with that of Krian.

commonly found in the springs at the foot of a hill, and this I consider is the normal habitat of *N. karwari*. A ravine stream, if much obstructed by weeds, has so little current that it closely simulates the normal habitat of *N. karwari*, and so we find this mosquito in weedy ravines. Remove the grass and the mosquito disappears. There is then too much current for it.

N. willmori appears to prefer clear running water. There may be weeds, but they must not too seriously interfere with the free current of water. When disturbed it can leave the water and it has powers of attaching itself to objects, not possessed by pool-breeding larvae. These habits it doubtlessly has acquired, and it is perhaps due to evolution that the species of Anophelines (both Myzomyia and Nyssorhyncus) which breed in streams are generally smaller than the pool breeders, since thereby they offer less surface to the current. We have seen that since this mosquito prefers a current of water, an open drain is its normal habitat, and open drainage fails to eliminate it, and the malaria it carries. Open drainage can only eradicate malaria carried by pool breeders.

Therefore, in Malaya, whether a hill stream be clean weeded or full of weeds, malaria remains; only the species of Anopheline carrying it differs.

M. rossii is at the opposite end of the scale from *N. willmori*, and is a puddle breeder. Since it is always found near to human habitations, the presumption is it prefers pools soiled to some extent by human sewage (*Culex fatigans* can breed in pure sewage such as is found under a Malay house.) On some estates both on the hill and the flat land, this mosquito cannot be found. It therefore does disappear with thorough open drainage, although common enough in Klang Town.

We have thus a series of waters different in quality and the rate of current. Each has its own mosquito inhabitants, and each of these inhabitants has a limited range within which it breeds. On whether the inhabitants carry malaria or not, and on the difficulty or ease of eliminating it by drainage, depend the amount of malaria in a country and the difficulty or ease of eradicating it.

The Breeding Places of some common Malayan Anophelines and the Effect of Drainage

Breeding place	Condition	Mosquito	Carrier in nature	Effect of weeding and drainage on mosquito	Effect of weeding and drainage on Malaria	Remarks
Hill Stream	Free from grass	N. willmori	Yes	Nil	Nil	
	Grassy	N. willmori	Yes	Nil	Nil	Malaria remains because N. willmori remains
	,,	N. karwari	Yes	Disappears	Nil	
	Choked with grass	Myz. umbrosus x.	Yes	Disappears	Nil	Malaria remains because N. willmori which had been driven out, reappears
Springs and Hill-foot Swamps	Grassy	N. karwari	Yes	Disappears	Disappears	Upkeep of drainage does not require to be very perfect
		M. umbrosus x.	Yes	,,	,,	
		N. nivipes	?	,,	,,	
		C. kochii	No	,,	—	Upkeep must be perfect to eliminate these mosquitos
		M. barbirostris	No	,,	—	
		M. sinensis	No	,,	—	
Pools not polluted; must be perfect	Grassy	C. kochii	No	Disappears	—	Surface drainage and upkeep must be perfect to eliminate these mosquitos. Fortunately they do not carry Malaria
		M. barbirostris	No	,,	—	
		M. barbirostris	No	,,	—	
		M. separatus	No	,,	—	
		M. rossii	No	,	—	
Pool	Polluted	M. rossii	No	Disappears	—	As above

We see that in Malayan hill land, as long as there is an open system of drainage, malaria must remain, and in these hill lands malaria is as intense as anywhere in Africa.

On the other hand by good fortune, *M. rossii*—which only perfect surface drainage can abolish—does not carry malaria, hence, as Daniels points out, Malayan towns do not suffer from malaria as much as African towns where *P. costalis*, a mosquito with breeding habits similar to *M. rossii*, carries the disease. Consequently although *P. costalis* can be destroyed by open drainage, to eradicate

malaria in Africa would require a more thorough drainage and more perfect upkeep of drainage, than is necessary on the flat land of Malaya, where mosquitos like *N. karwari* and *M. umbrosus* are the carriers.

Finally I would urge that our knowledge of the prevention of malaria would be materially advanced if more attention were paid to the places where malaria does not exist. A truer idea of the part played by Anophelines will thereby be obtained, and a less pessimistic view of the prevention of malaria will be taken than is often the case.

XIII.—Experiments with Mosquito-proof Netting. In October, 1900, a Beri-Beri Convalescent Hospital at Jeram was opened. It is on a stretch of sandy shore. But at Jeram, as in Italy, the shifting sand is continually blocking the drains, so much so that one tide will undo a week's work. In fact, the task of keeping them open was abandoned, and the water was ultimately led off by a circuitous route. The result of the defective drainage was that the patients suffered from malaria. When I took charge in January, 1901, I went through all the case sheets of the patients who had contracted the disease, and tabulated the results. From 1901 to 1907 the record was kept continuously. The population was under complete control, its number was definitely known, and in many ways it presented a very satisfactory field for observation.

The patients were provided with mosquito nets from the beginning, and yet, despite these, they continued to suffer from malaria.

It was then decided to make the hospital mosquito proof. This appeared on the estimates for 1902, and was actually completed on 17 November, 1902. The gauze was of iron wire, the sea air rusted it, and on the night of 11 October, 1903, a strong wind carried it away. I did nothing then for a year to observe the result. From 1st January, 1905, no malaria case was admitted into the hospital, in order to see to what extent the local admissions of malaria influenced the spread of the disease in the hospital. From the beginning of 1906 all the Beri-Beri patients were on a weekly dose of 10 grains of quinine.

In this way I have tried to gain some idea of the relative importance of some of the factors influencing the epidemic.

The following are the figures obtained :—

Table showing the number of Beri-Beri patients attacked by Malaria at Jeram. Daily average about 50.

Condition of Hospital	Mosquito nets only	Ward mosquito proofed	Mosquito nets only	Malaria cases not admitted
Years	Oct., 1900, to Nov., 1902	Nov., 1902, to Oct., 1903	Oct., 1903, to Dec., 1904	Jan., 1905, to Dec., 1905
Number of months	26	11	15	12
Number of patients attacked	75	5	48	20
Average number attacked per month ...	2·87	0·45	3·20	1·66

It is to column No. 3 particularly to which I would direct attention. It will be seen that malaria was greatly reduced by the use of the gauze, and returned at once when the gauze was removed. That any malaria occurred is probably due to the purposely lax conditions which prevailed. No restraint was put on the patients to be indoors after sunset. Two double doors permitted entrance and exit after 6 p.m., and the patients often wandered to the native village only about a quarter of a mile away.

I was proposing to prevent the possibility of outside infection by locking the hospital after 6 p.m., when the storm put an end to the experiment.

The value of this experiment in my eyes is that the conditions were lax enough to permit their being applied to coolies on an estate, or to coolies engaged on Government construction work, such as the making of railways or waterworks, where malaria is as great a scourge as it is on the worst estate.

With these results I accordingly approached the Government in 1904 with a suggestion for an experiment on the above lines, on the proposed extension of the Klang Waterworks. Dr. E. A. O. Travers

supported the suggestion, and Government instructed the State Engineer to include my requirements in his estimates.

There was some delay in the preparation of the plans of the new works, and the Government then, at my suggestion, sanctioned a special vote of $2,000 (about £240) to be spent on mosquito-proofing lines on an estate. I chose the most unhealthy spot I knew. The object of the experiment was, of course, not to test the mosquito theorem, but to discover whether lines could be built which would be sufficiently mosquito proof to reduce malaria and yet would be acceptable to the ignorant coolie and in which he would be willing to live.

The spot chosen for one of the lines, the only one which was completed, was on a saddle at the head of two ravines, one of which was opened and drained by the estate but still contained *N. willmori*; the other ravine was unopened and undrained jungle. There had been trouble in building the lines originally, and the first gang of coolies who inhabited it had practically been wiped out by malaria. All children under the age of fifteen were found to be infected with malaria on blood examination. These coolies were soon removed, two contractors and many coolies who tried to build the lines died from malaria since they refused to take quinine. Ultimately the lines were finished. No coolies on the estate would inhabit them, and further it was desirable to put in new coolies who presumably were free from malaria. A gang of coolies was put in during November, 1907. (See fig. 12, p. 110.)

They were not given quinine daily as the other coolies were, but were carefully examined by the dresser of the estate, and I paid as many visits to them as possible. Unfortunately my health was not satisfactory at the time, and I had to go on leave. Before going, however, I was able to determine that it was impossible to find Anophelines or other mosquitos within the lines, although my observations, extending over a year, had shown that before proofing it was always possible to take about ten Anophelines by looking through all the rooms, and other mosquitos were much more numerous. The mosquito-proofing, therefore, certainly succeeded in reducing the number of Anophelines within the lines. Within a short time the coolies learned the character of the lines they were in, and asked to be removed. On one occasion I was told by a coolie

that a devil had been heard the previous night knocking on the walls.

I am unable to give any evidence as to the termination of the experiment. The manager states that as long as the coolies were there they did not suffer from malaria, but that on account of their terror it was impossible to keep them there long. He strongly suspected they left the lines at night and went to ôther unprotected lines. He also informed me that the coolies said the lines were very close, and that they would often lie outside in a blanket at night. The lines had a wooden ceiling, and as they also were more enclosed than other lines are, it is probable they were close.

I had, unfortunately, to leave this experiment, and therefore am unable to draw any conclusions. Doubtless the F.M.S. Government will take an early opportunity of testing the value of mosquito-proof lines on the railway extensions now being carried out towards the Siam States, where malaria will be as serious an obstacle as it has been in the previous railway and other public works.

In view of the knowledge we now possess of the method of ridding estates of malaria, the question of the practicability of mosquito-proof coolie lines is of less concern to the estates than it was, when it appeared that years might elapse before an estate could be made healthy.

XIV.—Conclusions from Malayan Observations. The conclusions I would draw from these observations are:—

(1) That both flat and hill land in Malaya before opening are very malarious, and blackwater fever has been found on both.

(2) That hundreds of square miles of the flat land of Malaya have been freed from malaria by simply draining and felling the jungle.

(3) That the cost of these rural anti-malaria measures in Malaya (where labour is dear) is about £3 sterling an acre, being two pounds to drain and one pound to fell the heavy virgin jungle. This expenditure at the same time is the first step in agriculture, and the land has then acquired a considerably increased value.

(4) That this freedom from malaria coincides with the disappearance of an Anopheline which breeds in undrained jungle, and does not breed in open earth drains when kept clear of weeds and flowing.

(5) That certain hilly land intersected by ravines, although opened and drained, is as malarious as when first opened.

(6) That the continuance of malaria in the hilly land is due to an Anopheline (*N. willmori*) which, breeding in ravine streams, cannot be driven from them despite the utmost care in keeping these streams free from weeds, and cannot be completely washed out of the ravines even by the heaviest tropical showers.

(7) That quinine given regularly greatly reduces the sick and death-rate of those exposed to malaria.

(8) That doses of less than six grains daily are of little value if the malaria be intense—say where the spleen rate is 75 or more.

(9) That when given in ten-grain doses on six days out of the seven, and in twenty-grain doses when a coolie has pyrexia or in such health that he does not feel inclined to work, between 20 and 30 per cent. of those taking the drug will be found with parasites in their peripheral blood, where malaria is intense, and the population consists of immigrants.

(10) That the use of quinine can therefore never result in the abolition of malaria or even make any material reduction in the liability to infection in a malarious locality.

(11) That mosquito-proof houses have a value, but the attempt to discover a satisfactory mosquito-proof coolie line ended as an inconclusive experiment.

(12) That not only for urban, but for rural districts anti-malaria sanitation should be based on mosquito reduction if this be a physical possibility.

The importance of the thorough study of malaria cannot be over-estimated. Although I have dealt with the estates to which I am medical officer, some estates in Perak are in worse condition than any in Selangor. In one of the worst I found *N. willmori* in the lines as I noted previously. The death-rate of all the estates in Negri Sembilan is about double that of the estates of Selangor. The estates in Negri Sembilan are mainly hilly land estates.

The labour problem is at the present moment undoubtedly one of the most important, and it will become more acute every year. I think, however, that with our present knowledge of malaria there will be no difficulty in eradicating the disease even on the most unhealthy estates, and with the disappearance of this disease the labour problem will become one of little difficulty.

XV.—Malayan and Indian Observations—A Parallel.

'We are aware that India as a whole is not intensely 'malarious. There are wide tracts of country where the disease 'though present is not markedly interfering with the prosperity 'and natural increase of the population. In such areas action 'for the reduction of the prevalence of malaria is unnecessary— 'the disease is sufficiently dealt with by general arrangements— 'such as are taken for the mitigation of other diseases. 'Secondly, there are areas where malaria is constantly present 'to a moderately intense degree; and, thirdly, there are areas 'in which the disease can only be described as decimating 'the people and converting once populous and prosperous 'districts into scantily peopled and decayed ones.'[13]

In the sixth report [14] of the Commissioners of the Malaria Committee of the Royal Society, published in 1902, a map will be found showing the malaria index of Bengal. The report says:—

'The following map and table will at once show how in 'proceeding from Calcutta northwards till the foot of the 'Himalayas was reached—a distance of some 300 miles—we 'passed from a region the endemic index of which was 0·0 per 'cent. through regions with increasing indices of endemicity till 'at the foot of the hills in a district known as the Duars a very 'high degree of infection was reached, 40 per cent. to 72 per 'cent., as high indeed as that found by us in West Africa. We 'have, then, in a region not above 300 miles in latitude, subject 'to almost identical climatic influences, an endemic index 'varying from 0·0 per cent. to 72 per cent.'

If we take a map of the Klang district from the sea to the hills we find that malaria may be represented on, say, an estate on the Kapar Road by a spleen index of nil; passing inwards we find perhaps an increased index due to proximity to jungle. Once, however, we reach the first of the hills, even of the small hills, of the Peninsula the spleen rate rises to from 70 to 100, and the most intense malaria is met with due to an Anopheline which breeds in hill streams. The distance from the place with the spleen rate nil to that with a spleen rate of 100 is about three miles. The climate of the two places is the same.

It is impossible to look at these two maps without the idea at once springing to the mind that the similarity is more than a coincidence. We find that the malaria in both is highest when we reach the hills, and that the carrier of malaria in the hill land of both is an Anopheline which breeds in the hill streams.

In both, when we reach the plains another Anopheline is the carrier. Malaria is much less intense, and may even be entirely absent. Is it too much to believe that our observations in the Malay Peninsula give the key to the malaria of India?

In the Malay Peninsula in the short span of one generation the country has been reclaimed in considerable areas from absolute jungle.

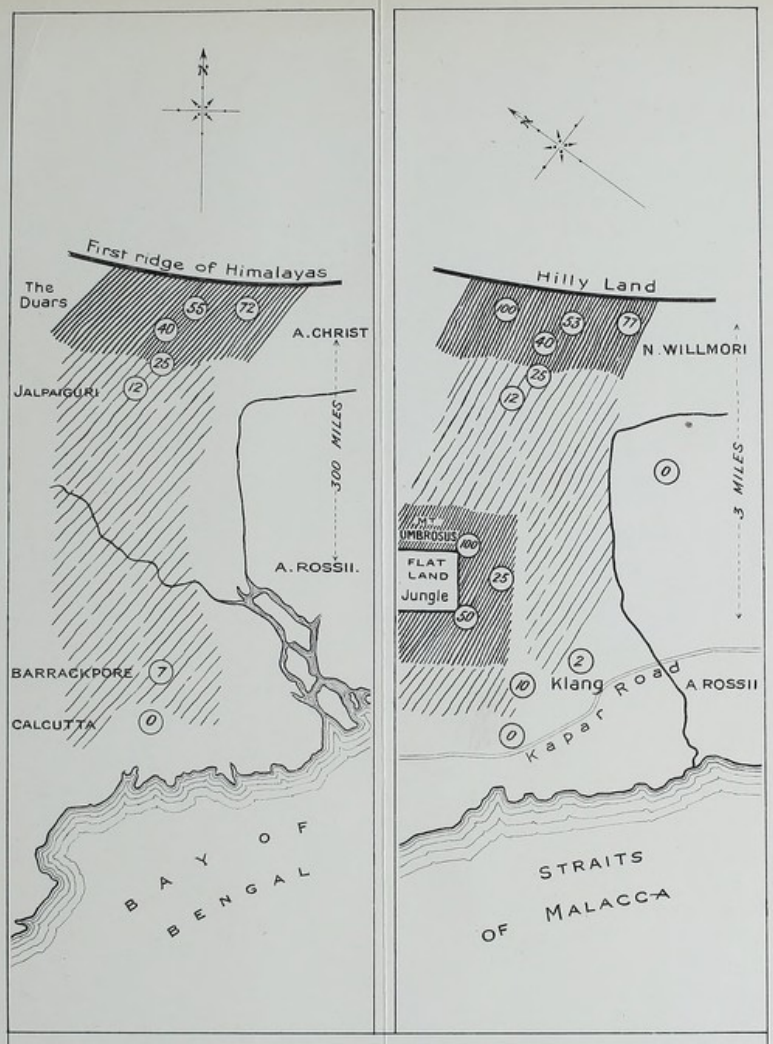
We see that when first inhabited the plains or flat land are no less unhealthy than the hills, but when the land has been drained and cultivated it becomes much less malarious. We can actually see the process going on under our eyes in Malaya.

I suggest that the map and our knowledge of Indian malaria indicates that what is occurring here now occurred in India in the past. Only in India everything has been on a more extensive scale. In Malaya the space is three miles, and the time one generation: while in India the space is 300 miles, and the time perhaps 300 generations. History does not tell us when first the Indian plains were cultivated.

And, if this be so, is it too much to believe that what freed the greater part of the plains from malaria will free the remainder; that the small *foci* remaining on the plains will yield at once to properly devised and probably inexpensive operations, which at the same time will appreciate the value of the land?

Referring to the areas of intense malaria where the population is being decimated, the writers[13] continued:—

> 'It is upon such areas as the last—where malaria is present in 'intensified and epidemic form, and is acting as a pestilence— 'that attention should first be concentrated. Such epidemics 'have causes which can be traced, and even at present it is known 'that the factor of Anopheles mosquitos is only one of many that 'are concerned in bringing about the epidemic result. In the 'great industrial centres, for example, we have malarial epidemics 'whose immediate cause is the immigration under special 'conditions of non-immune people from healthy districts to *foci* 'of malaria started by this very process of immigration. We need



SKETCH MAP TO SHOW VARIATION OF ENDEMICITY IN BENGAL AND IN DISTRICT OF KLANG. F.M.S.

'not here describe the events and conditions that are concerned 'in causing epidemics of malaria in such centres, nor need we 'mention other examples in which recent work has revealed what 'are the really important factors concerned. It suffices if we 'emphasise the fact that the prevalence of Anopheles, though 'always important, is by no means in every case the most 'important factor to be considered.'

After commenting on the great cost of anti-larval measures and the smaller cost of a system of quinine prophylaxis on the Italian lines, the writers[13] proceed: —

'We know that the expense of anti-mosquito operations is 'very great, and that for application to rural areas they are utterly 'unsuitable. At present the expenditure on such operations is 'not justifiable except on the view that further experiments are 'desirable, and that the expenditure is for the purpose of these 'experiments. In the meantime, it is desirable that attention 'should be concentrated upon quinine prophylaxis in accordance 'with the methods that experience has already shown in Italy to 'be best adapted for the prevention and mitigation of malaria on 'a national scale.'

The great industrial centres to which the writers allude are the tea plantations of Assam, etc., and we find their parallel in Malaya in the rubber estates of the hilly land. In both there is 'the immigration under special conditions of non-immune people to *foci* of malaria.' In both there is the most intense malaria. But in Malaya the same immigration of the very same people (indeed, where coolies are transferred from one estate to another, of the very identical individuals) occurs to flat land and hilly land estates equally, but it is only on the hilly places that malaria occurs, while on the flat land estates where the coolies are housed half a mile from jungle malaria is practically unknown, and the spleen rate is nil. If these be facts in Malaya, I would suggest that the Anopheline is the important factor in the areas of intense malaria in India, as I consider it is in Malaya.

With regard to quinine, the observations in Malaya show that even when a people are taking large doses parasites are easily found in their peripheral blood. Major James confirms this in the Transactions of the Bombay Medical Congress, in 1909, on page 87 of which he

records the results of his examination of the blood of ten men who were taking 10 grains of quinine twice weekly, and in the blood of only three of whom he failed to find parasites. This is equal to 70 per cent. with parasites. On the following page he gives a table showing that 80·2 per cent. of 147 children who were getting quinine twice a week had parasites in their peripheral blood.

Captain Christophers, in the second report on Mian Mir, reports, 'That the value of quinine was found to depend entirely upon the 'degree of supervision exercised.'

It is clear, then, from every observation that has been made on people taking quinine systematically, that parasites are to be found in their blood even when in apparent health. I maintain that not only are parasites to be found, but these persons are infectious, and that despite the use of quinine in larger doses and for longer periods than those referred to by the Indian observers. I can see no diminution in the risk of infection to which a non-immune person is liable who visits one of these intensely malarious areas.

The logical conclusion, therefore, seems to me that quinine can never do more than give a temporary relief to India, and that the factor to be dealt with is the Anopheline: that measures must be aimed at it; not only in towns, but also in rural districts.

XVI.—The Influence of Italy on Malariology. The existence of malaria in large tracts of a country like Italy naturally led to its study, and to the Italians much honour is due for the work they have done. Their work has very largely influenced thought in regard to malaria; sometimes, I think, erroneously. For instance, it is a firmly established fact that in Italy the hills are healthy and indeed quite free from malaria, while in the plains, only a few yards below, malaria is severe. Doubtlessly due to this the teaching of the English schools is still to place the house on a high and dry situation, avoiding a clay soil if possible.

Yet the experience of the tropics is quite the reverse. I would say 'avoid the lower hills' should be the rule, if rule there is to be, in the tropics. The reason of the freedom of the Italian hills from malaria in Italy is that the carrier of malaria in Italy is a pool breeder and not a stream breeder, although like many pool breeders it can live in very slowly flowing water where there is much aquatic

vegetation. In the tropics, on the other hand, the hills are usually dangerous from an Anopheline which breeds in the running waters of the hill streams. Italian practice is rightly based on local experience, and Italian thought is influenced by the local conditions affecting malaria, in this case the species and powers of the Italian Anophelines. But we see that to form a general proposition from Italian experience is fallacious.

The attitude of the Italians to quinine is also, in my opinion, due to local conditions. Quinine is put first now by the Italians among the anti-malaria measures, and I believe for Italy this is the correct policy. The Italians have taken to quinine not because they do not recognise the value of drainage. Drainage has been recognised by all nations as the method of freeing land from malaria, and not less so by the Italians until in the past few years. The freedom of Rome by the underground drainage of their forefathers has been a lesson constantly before their eyes.

I believe the reasons they now abandon drainage in favour of quinine are to be found in the local or physical conditions of the country. Italy consists of the high land of the Appenines, and a stretch of flat land to the sea. There is very little fall in this land, and the waters of the land find a difficulty in reaching the sea. The detritus of the rivers particularly tends to be deposited in rivers whose current is slow, and the sea has thrown up sand dunes along considerable stretches of the Italian coast so that some rivers have to make long detours to reach the sea. Such is the case in, and the cause of, the famous Pontine Marshes. Malaria is so prevalent in the Italian littoral that the Tuscan School formulated the theory that malaria was due to a mixture of fresh and salt water.

With such physical conditions drainage is of the greatest difficulty, even if it be not an impossibility, and we can readily understand the Italians abandoning the attempt. Nor need I point out how immensely more difficult drainage becomes where, as in Italy, the sea is practically non-tidal. Celli, in his report to the 14th International Congress of Hygiene, in Berlin, a summary of which appears in the 'Journal of Tropical Medicine,' of 1st April, 1908, says, referring to the attempts to destroy mosquitos:—

> 'Nevertheless, to the old and reliable methods of the 'campaign against malaria, namely, draining and agrarian 'sanitation, our efforts were directed.

'The hygienic effects of the sanitation by drainage already 'carried out were studied. The result was that on large 'extensions of land the best drainage sanitation very frequently 'failed to drain off all the water or to give it sufficient velocity 'to impede the aquatic life of Anopheles.'

The drainage of the coast lands of Italy would be enormously expensive, even if possible, and as a policy there is no doubt the Italians are correct in putting quinine first.

It is an interesting speculation how far malaria has increased in certain parts of Italy from the slow interference with drainage by geological processes. We know that the delta of the Po is gradually extending, and that during the past 2,000 years the annual increase has been at the rate of 55 feet per annum. It may be, too, that slight elevations of the sea beach have also interfered with the flow of the rivers in parts of Italy, and so produced or increased malaria. We know great changes have occurred in the level of the lands around the Mediterranean during Pliocene and recent geological periods, and, subject as it still is, to so considerable volcanic influences, it is not impossible that a hypogenic factor has caused once prosperous places to become desolated by malaria.

Finally, the Italian experience with quinine is identical with that in Malaya. Celli, in the same report, says: 'We have proved over 'and over again that some fevers are pertinacious in recurring in spite 'of the abundant and protracted use of quinine, either alone or in 'association with the so-called reconstituents (iron and arsenic). . . 'It follows from this that even the best treatments in the pre-epidemic 'period do not succeed in preventing, as Koch thought they would, 'the development of malaria in the following summer. Therefore, by 'the quinine treatment alone to exterminate malaria from an extensive 'locality is much more difficult than one would imagine. In any case, 'it must be a work of long duration, that is to say, treating, in every 'period of the year, day by day, energetically and assiduously, every 'case of malarial fever.'

I take this to mean that parasites will appear in the blood from time to time, in spite of the most careful treatment, and practically an admission that infection will always persist.

To me it seems only the vision of a dream that any organisation will ever induce a whole tropical population to take quinine in the

doses required by the Italians. And when it is further considered that the population, even when taking this quinine, would still be infectious, the policy of spending money on quinine for an indigenous population, where drainage is physically possible, appears to me indefensible, either on medical or financial grounds.

XVII.—Acknowledgments. In the past it has often appeared my duty to oppose expenditure which had been suggested with the object of improving the health of coolies on malarious estates. Had I approved and permitted great expenditure on lines and wells, etc., expenditure which could have had no effect on malaria and would only have brought sanitation into disrepute, every cent of that expenditure would have been an obstacle to my present proposals—the creation of a sanitary area, mosquito free, with good water supply, etc., on each estate to which all coolies will be removed.

I cannot close without acknowledgment of my debt to the Government of Selangor for placing at my disposal certain records. To many Government officers in years gone by I am also deeply indebted for assistance. To Drs. Delmege and Bryce Orme my debt is more recent; to Mr. R. A. Crawford, Mr. Byrne and Mr. F. D. Evans I am indebted for assistance in the preparation of plans and charts.

And finally I am indebted to Mr. W. W. Bailey, to Mr. R. W. Harrison, and to Mr. John Gilson for constant support in the struggle against malaria. In planters—Mr. H. R. Quartley, Mr. H. F. Browell, Mr. A. G. Corbetta and Mr. J. Whitham, to name but a few—I have found men determined to overcome the pestilence, if it be possible. To them, to their downright earnestness, to their invaluable suggestions and help, I am indebted more than words can express.

APPENDIX

Since the foregoing was written and put into print a certain amount of further work has been done, and I add some of it as an Appendix.

Anti-Mosquito Measures for Stream-Breeding Anophelines.

It will not be necessary to underdrain the whole of an estate. A certain area should be selected and the ravines thoroughly drained by pipes one and a half to two feet under ground. The coolies should then be housed on this area. The area of drainage should be half a mile all round the lines. I think this will be ample, as *Nyssorhyncus willmori* is a more delicate mosquito than the flat land carrier, whose malaria carrying powers we saw were limited to half a mile. As far as I can see it will not be necessary to deal with the larger streams.

It must be clearly understood that no attempt need be made to carry storm water underground. That will flow, as usual, down the earth drains. What is necessary is to ensure that once in eight or ten days the bottom of the earth drain will be quite dry. This will ensure the destruction of any larvae which may be breeding in them. The heads of ravines, where springs feed the stream, will require particular attention.

The details of the underground drainage system must be worked out by a civil engineer, perferably by one who is familiar with such drainage.

The size of the pipe to be used at any particular portion of a ravine depends, not only on the actual quantity of the water to be seen in the ravine, but in the fall available, the friction created by piping the water, etc.

It will also be necessary to examine in detail, and over a period of a few months, the various ravines of an estate. It is already known that in some *Nyssorhyncus willmori* is never found. Expenditure on these is, therefore, unnecessary.

The most economical and effective method of dealing with malaria on hill estates will be evolved by the consultation of an entomologist, an engineer, and a medical officer. Each estate forms a separate problem.

It is to be hoped that some firm will undertake the production of the pipes. In England 3-inch pipes cost about thirty shillings per 1,000. It is important to avoid adding to the cost by unnecessary transport.

Machines should, therefore, be worked at the most convenient clay suitable for the production of the pipes, and it is to be anticipated that Chinese will soon become expert at working them.

Shortly after I had satisfied myself that the persistence of malaria in the hill land was due to the persistence of *Nyssorhyncus willmori* in the streams, I advised one estate to adopt an underground system of drainage. I had no hesitation in recommending this estate to try the under drainage, since the area to be treated is confined entirely to the heads of ravines. There are no large streams within the area. It is the treatment of these that requires further investigation, and I have accordingly made no recommendation for estates through which larger streams pass. It should be possible from the experience of the estate now carrying out the under drainage to learn something of the measures to be adopted for the larger streams.

It is obvious that if the larger streams must be treated, then it will be better to avoid them in selecting the area to be rendered sanitary. If, on the other hand, it is only necessary to deal with small streams, and it is found that when the small streams have been piped the larger streams no longer contain larvae, then I should prefer to locate the coolies near to the larger streams. In many places this would not only be more economical than dealing with the heads of ravines, but it would also provide the coolies with abundance of water for bathing.

I have, therefore, not recommended the new underground method of drainage on all estates indiscriminately. However urgent the malaria problem may be, this rubber industry is not an industry of to-day only, and I prefer to build surely if, perhaps, somewhat more slowly than both I and others could wish.

The directors of the estate at once provided the necessary money for the preliminary survey, and for some months an engineer has been employed gauging streams, taking levels, and working out the details of the scheme. The accompanying plans and his memorandum show and explain the system. The estimated cost

of the work, which includes the cost of pipes brought from England (a local firm gave definite quotations for the pipes) is approximately $7,000. As the gauging of the streams has taken place mainly in the drier months I have advised that further work on the scheme be suspended until we have had an opportunity of testing the accuracy of the gaugings in wetter weather.

Memorandum on the Plan and Section of Type Estate Ravine Drainage by John Irvine, Assoc.M.Inst.C.E.

'The plans show a drainage scheme which has been designed 'for a rubber estate in the Federated Malay States. The land is 'much broken up by a series of hills and ravines, the latter being 'very steep in the upper reaches. During storms torrents sweep 'down, scouring out the stream beds and forming numerous pots 'and holes in them.

'The denuded soil is carried down to the lower and flatter 'reaches, where it is deposited.

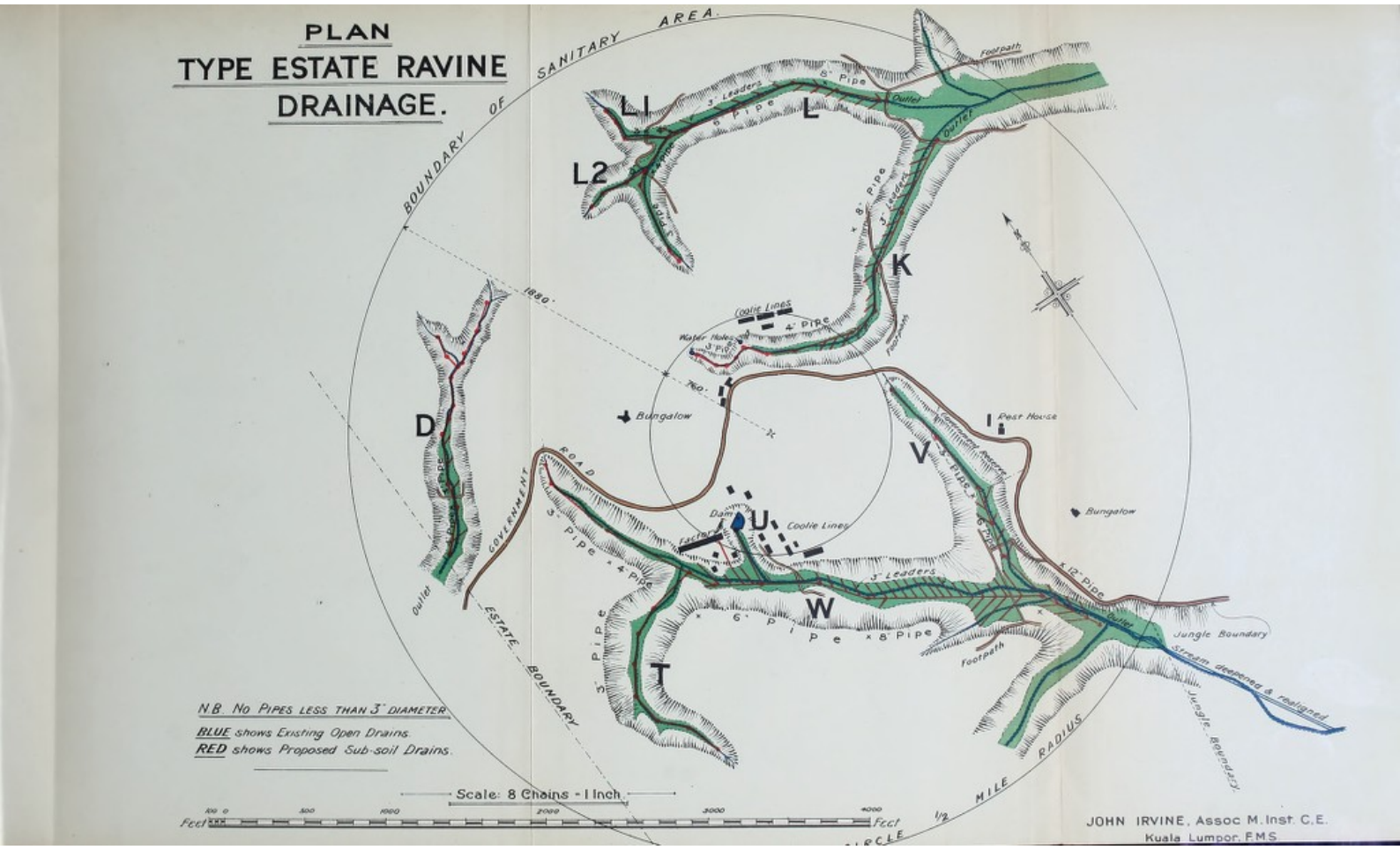
'The soil throughout is a light clay mixed with a varying 'proportion of sand, it possesses little cohesion, and crumbles 'readily when wet.

'The estate is at present drained by a system of open drains 'which average about a chain apart in the ravines. These have the 'drawback of the above-mentioned pots and holes, chiefly at the 'foot of declivities, and the water retained in them forms an 'excellent medium for the culture of larvae. In these, as well as 'in the running water and pools of the stream, *Nyssorhyncus 'willmori* is readily detected.

'The drainage scheme, similar to that of Panama, is not 'intended to take storm water, as this comes down in large volumes, 'frequently with a depth of four feet, and a width of ten feet, 'and a velocity of eight or ten miles an hour. The existing channel 'will be maintained to carry this off, and the object of the sub-soil 'system is to dry the open drains and surrounding ground within a 'few days after the flood has subsided.

'The drains are to be the common agricultural red tiles, with 'second quality spigot and faucet, fireclay Y branches at junctions. 'At the outlets several lengths of that class of pipe end in small

PLAN
TYPE ESTATE RAVINE DRAINAGE.



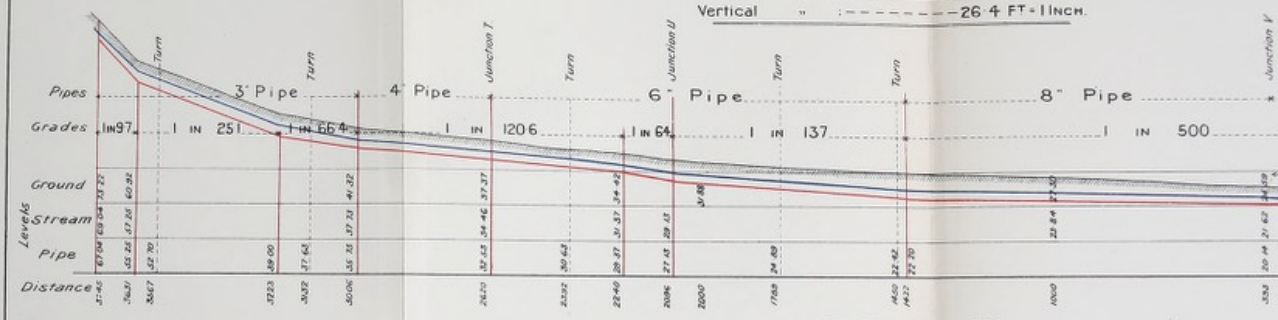
N.B. No Pipes less than 3" diameter.

BLUE shows Existing Open Drains.

RED shows Proposed Sub-soil Drains.

SECTIONS OF PIPE TRACK — TYPE ESTATE RAV

Horizontal Scale : ——— 264 FT = 1 INCH.
Vertical " : ——— 26·4 FT = 1 INCH.



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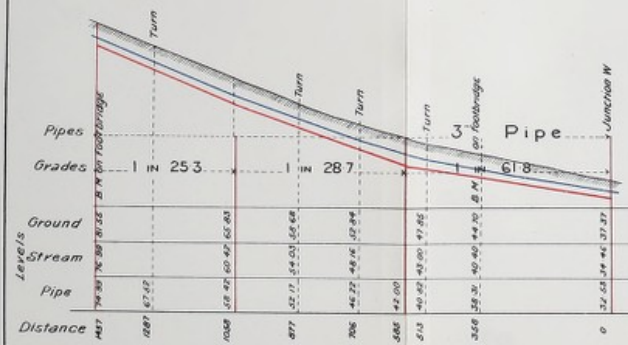

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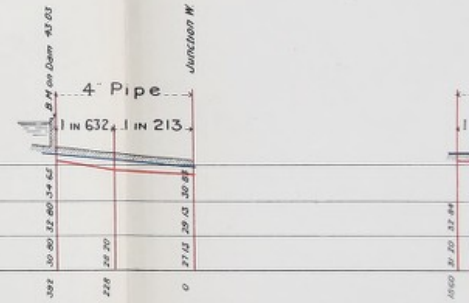
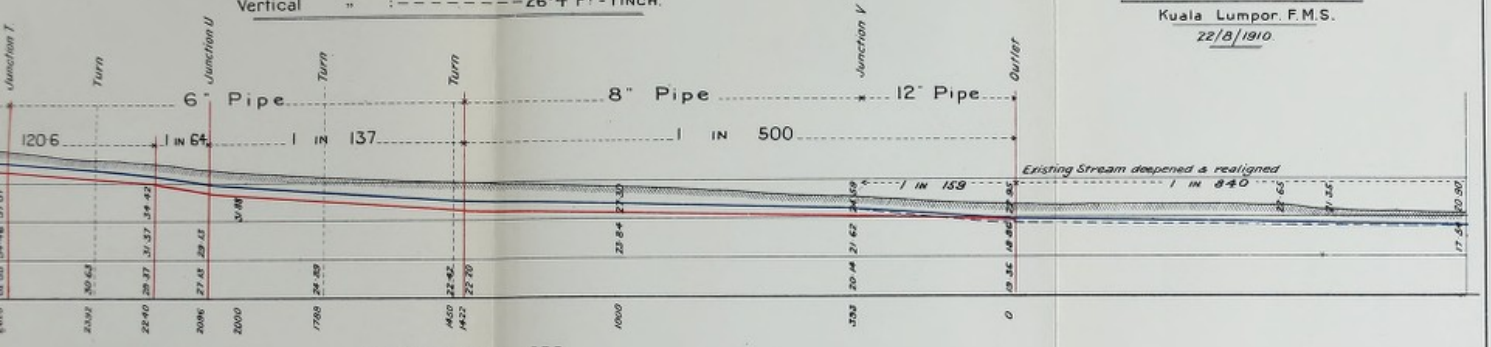


SECTION U

OF PIPE TRACK —— TYPE ESTATE RAVINE DRAINAGE

Horizontal Scale : ——————— 264 FT = 1 INCH.
Vertical " : ——————— 26·4 FT = 1 INCH.

JOHN IRVINE. Assoc. M. Inst C.E.
Kuala Lumpor. F.M.S.
22/8/1910



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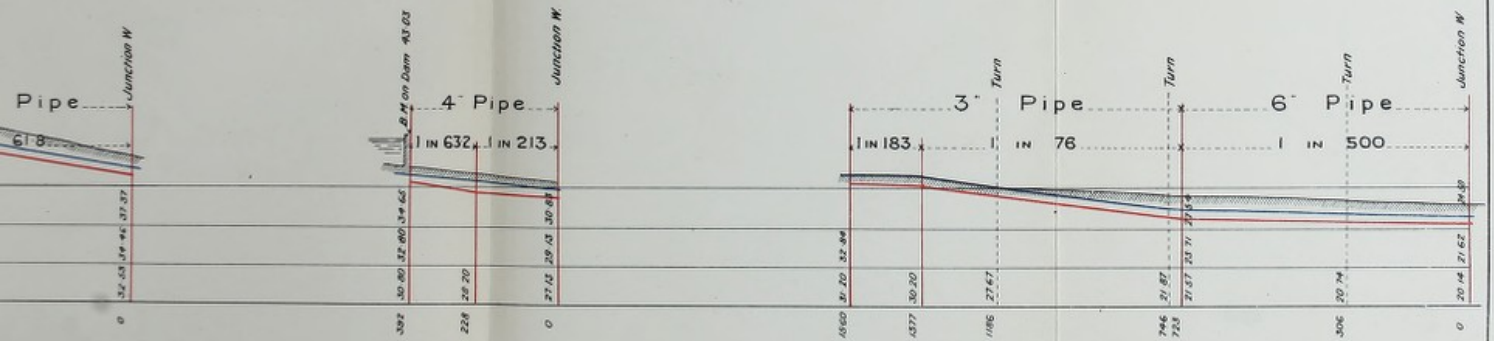


SECTION U

SECTION V

'concrete abutments and discharge into a basin acting as a water 'cushion to prevent scour under the abutments.

'In places where the pipe line crosses the stream it may be 'encased in concrete, or where it is laid in the stream bed, as in 'the upper reaches, it may be necessary to bury it in stones to 'prevent it being washed out during floods.

'The leaders and smallest pipes are three inches in diameter, 'and although smaller ones might have fulfilled the requirements 'it has been deemed advisable not to use them.

'The sizes and general design have been based on weir gaugings 'taken at the governing points of the existing streams, in 'conjunction with records of rainfall, etc.

'A minimum depth for the pipes of two feet below the stream 'bed has been observed and, as a general rule, the top ends should 'not be less than eighteen inches deep, as a fall of at least one in 'fifty should be obtained for the leaders. The fall of the stream 'is very limited in the lower reaches, and the situation of outfalls 'has been governed largely by this.

'In future any additional lines should be built within the 'smaller circle shown in the plan, and, of course, in opening up 'estates a considerable saving might be effected by keeping the lines 'together without unduly crowding them.

'It is essential that these schemes should be properly designed, 'and efficiently executed. Sudden changes from steep to flatter 'grades or in alignment, so say nothing of errors in levels, careless 'or bad construction, tend to deposit and consequent silting up of 'the system.

'Difficulties will be encountered in laying, as it will often be 'done in water; and running sand, mortar formed by the wet soil, 'etc., will cause much hindrance to the work. Wet jobs are 'best tackled in dry weather; and time given to the water in each 'length excavated to drain away through the pipe already laid 'before putting down the pipes. For this reason the laying must 'be started at the outlet and worked upwards.

'Difficultities in each individual case magnify or diminish, 'according to the suitability of the methods adopted.

'Every effort must be exerted to keep sand, etc., out of the 'pipes, and it may be necessary to envelop the joints in clay,

'grass, tarred paper or such like for this purpose. In clay districts 'about six inches of it may be advantageously placed over the 'pipes as building.

'These precautions are entirely directed against sand or silt, 'which, once into a system, waste much time and money to get 'them out. Water has no difficulty in finding its way into the 'drains in spite of them.'

The wage of an Indian cooly on an estate is 27 to 30 cents of the Straits dollar. The Chinese cooly gets about 50 to 80 cents or more in exceptional places.

Variation of Death-rate with Spleen-rate.

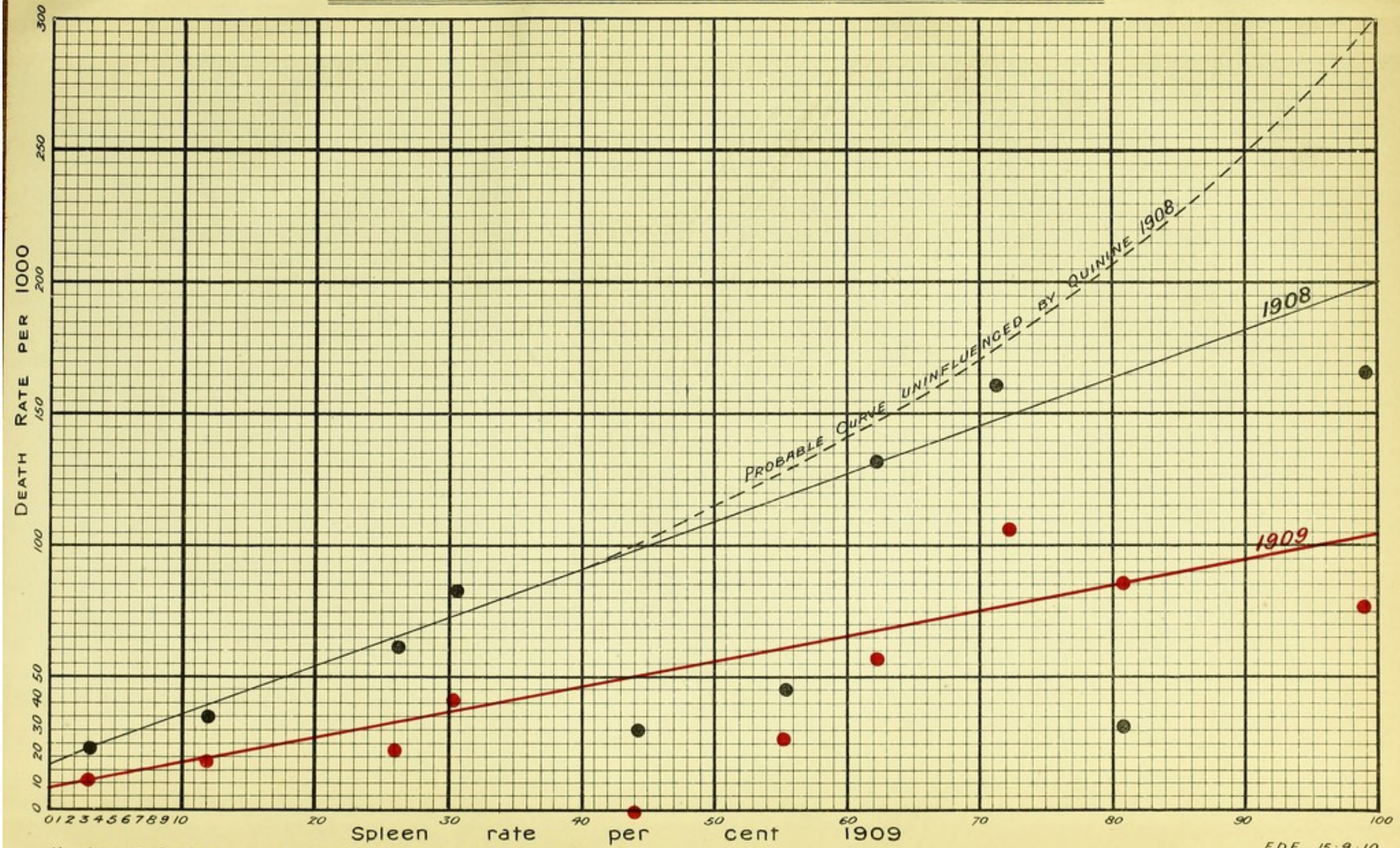
The issue of the Indian Immigration Report for 1909 enables me to produce the chart showing the variation of the death-rates of 1909 with the spleen-rates of 1909, and for the purpose of comparison I have also included in the chart the death-rate of 1908, and what I imagine would be the curve of the death-rates were quinine not given systematically on any of the estates. The exact spleen-rates of the groups have been used in this chart instead of the middle values.

The Death-rate Uninfluenced by Quinine.

(*a*) *Public Works.*—Those who have seen the terrible death-rate on public works in the Federated Malay States, such as the Ampang and Ulu Gombak Water Works of Kwala Lumpor, the Ayer Kunning Water Works of Klang, the Changkat Jong Water Works of Teluk Anson, the Ayer Kunning railway tunnel near Taiping, will readily believe, I think, that a death-rate of 300 per 1,000 is no exaggeration. As Daniel says: 'Under such 'circumstances in Malaya, malaria is as severe and prevalent as in 'bad parts of Africa.'

(*b*) *Estates.*—From what I have seen on the estates under my care, and from what I have gathered when travelling through the Federated Malay States, I have come to the conclusion that malaria is the chief factor in the death-rate of estates. It is entirely in keeping with the observations I have made, that of twenty-one places of employment whose death-rate was over 200 per 1,000, as

VARIATION OF DEATH RATE WITH SPLEEN RATE.



F.D.E. 15·9·10

Number of Coolies on which results have been obtained

08	7106	492	2291	1121	65	767	1738	1165	180	973
09	8210	658	2120	1526	27	842	1602	904	150	943

given in the Indian Immigration Report for 1908, no less than eighteen of these should be estates situated in hill land, and that of the three exceptions two were estates whose cooly lines were close to jungle. I have no information as to the third.

The average labour force employed on these places was 2,130, and the average death-rate was 280 per 1,000. On some of these places quinine was certainly given, though probably not very thoroughly, but in the majority it was not given systematically, I believe, to the whole labour force. Cholera, plague and small-pox were not present to swell the death-rate.

Perhaps to those not acquainted with what malaria can do, the following extracts from the Proceedings of the Imperial Malaria Conference, held at Simla in 1909, will give some idea of how great an effect this disease may have on the death-rate:—

'During the two months of October and November the number 'of deaths recorded in the Punjab as due to fever was 307,310, as 'against less than 70,000 in both 1904 and 1905, and less than 100,000 'in 1907.

'Studied in more detail, the ravages of the epidemic in these 'areas where it was most intense are given more apparent. In 'Amritsar the mortality for many weeks was at the rate of over 200 'per mille. In Palwal the mortality rose to 420 per mille and in 'Bhera to 493 per mille. Curiously, in Delhi, a notoriously malarious 'town, the death-rate rose to only 149 per mille. But a closer 'examination of the statistics shows that parts of this town were 'much more seriously affected than one would judge to be the case 'from the statistics of the whole city. In Ward 1, for example, the 'mortality rose to over 300 per mille.

'The death returns of Amritsar show that the densely crowded 'outer portions of the city were mainly affected. Again, in these 'the mortality was much higher than the figures for the whole city 'would indicate. In Division IX, for example, with a population of '17,206 the death-rate rose to 534 per mille, and for six weeks was 'over 400 per mille.

'In the district returns, with the exception of those relating to 'the Gurgaon district, which show among a population of 687,199 a 'death-rate of 267 per mille. The mortality rates are not so high 'as those given for the towns. This might be taken as showing that

'the mortality was greater in towns than in rural areas, but a study 'of returns from individual thanas and villages modifies this 'conclusion, both thanas and villages frequently showing mortality 'rates during October and November of 300, 400, or even 500 per 'mille.'

I think, therefore, that the curve of the death-rate uninfluenced by quinine, as I chart it, is a close approximation to the truth. It is based on the maxima of the death-rates, and is certainly no exaggeration.

The Death-rates of 1909.

The curve of the death-rates of 1909 show a very marked improvement, therefore, both on the curves of death-rates of 1908 and of that of the uninfluenced death-rates.

Not only have the death-rates been lower in the groups with the lower spleen rates, but it is particularly gratifying that among the higher groups the fall has been also marked. The actual figures are as follows, and should be compared with those on page

True Spleen Rate	Average Population.	No. of Deaths.	Death Rate.
3·1	8,230	95	11·5
12·2	658	12	18·2
26·3	2,120	49	23·1
30·6	1,526	63	41·2
44·4	27	0	—
55·5	887	25	28·1
62·3	1,602	92	57·4
72·2	904	97	107·3
81·0	150	13	86·6
99·0	943	73	77·3
	16,982	527	31·3

The death-rate of the unindentured labour force under my care has therefore fallen from 66·2 to 31·3 per mille. This is satisfactory so far, but I hope it will be still further lowered. For comparison I give the death-rates of the remainder of Selangor and of the other two States:—

	Death Rate.		Average Population
	1908.	1909	1909
Estate Hospitals Association	66·2	31·3	16,982
Remainder of Selangor	62·4	40·6	12,063
Perak	48·9	38·5	8,553
Negri Sembilan	117·1	85·5	5·773

The fall is the result of several factors, viz. :—

(*a*) 1909 was a healthier year than 1908 for all nationalities.

(*b*) On the flat land the further opening of estates has pushed the jungle farther from the lines than in 1908.

(*c*) Acting on my advice, new lines have not been built close to the jungle during 1908 and 1909, but for this advice lines would on several estates have been built close to jungle and would have swelled the death returns.

(*d*) Estate hospitals have been provided.

(*e*) Quinine has been given with greater thoroughness than hitherto.

It will be observed that *b*, *c*, and *e* would have a direct influence in reducing the amount of malaria on the estates, and thus reducing the death-rate.

The Labour Problem in the Federated Malay States.

Much is said about the difficulty there will be in the future in obtaining labour for the Federated Malay States. It is said that the Federated Malay States will never be able to attract from India all the coolies required, and that the estates will have to depend on China.

I confess I am an optimist on this subject, and have no fear for the future. I give the following opinions, as the result of watching coolies and estates for some years, and for what they are worth :—

(1) No healthy estate has failed to get all the coolies it has required. On the contrary, as in a year like this far more coolies have come to the healthy estates than they could employ, and many have been given to other estates where the supply was insufficient.

This applies not only to old estates with established labour forces, but also to comparatively new ones when they are healthy from the beginning, *e.g.*, Estate 'E.E,' which in its third year imported more labour from India than any other estate in the Federated Malay States.

(2) Unhealthy estates are perfectly well known to the coolies, both here and in India, and are generally avoided. Not only have these estates difficulty in obtaining labour, but the annual loss of labour through death, discharge, etc., is 30 to 50 per cent. greater than on the healthy estates.

(3) Chinese labour being non-immune to malaria will, if freshly imported, suffer as much as Indian labour, and in a few years the unhealthy estates will be avoided by the Chinaman as they now are by the Indian.

(4) Healthy estates are not without interest in all becoming healthy, since the unhealthy estates, by the attraction of higher wages, or the promise of higher, by crimps, unsettle the coolies of the healthy estates and often attract their skilled tappers.

(5) When we consider how the healthy estates of the rich Federated Malay States attract in such abundance the poverty-stricken Indian, I can see no reason why, were all the estates of the Federated Malay States made healthy, Indian labour would not pour in equal to the requirements of the country.

And I believe that the labour problem is nothing but the malaria problem, and that the solution of the malaria problem will also be the solution of the labour problem. No estate can ever have an assured labour force where the women wail, 'we cannot have 'children here, and the children we bring with us die.' Such is the cry on the unhealthy estates. It is vain to contend with the instinct of her who 'weeps for her children and will not be comforted.' It is because I believe we do now know how to save the children that I am an optimist for Malaya. This volume has shown how malaria has been driven from great tracts of country, and how the development of the country under the British has been a boon, not only to the native but to the foreigner also. Already irrigation and drainage have, not only assured them of their crops, and given them wealth beyond anything they had known, but have given them freedom from their most deadly disease over wide areas. It remains but to extend these benefits. And although some details have still to be learned, I think, that working on Ross' discovery, and on the method advocated by him, we may confidently hope to drive the disease completely from the land.

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