



Government of Bengal
Public Health Department

Malaria and Agriculture
in Bengal
How to Reduce Malaria in Bengal
by irrigation

by
CHAS. A. BENTLEY, M.B., D.P.H. & D.T. G., F.S.S.
Director of Public Health, Bengal.

CALCUTTA
Bengal Sales and Distribution Depot.

Price—Indian, Rs. 2-2 ; £ 5s. 4s.



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CALCUTTA :

Bengal Secretariat Book Depot.

1925.

Published by the Bengal Secretariat Book Depot, Writers' Buildings, Calcutta.

Agents in India,

Messrs. S. K. Lahiri & Co., Printers and Booksellers, College Street, Calcutta.

Messrs. Thacker, Spink & Co., Calcutta.

**Publications are obtainable in England either direct from the
Office of the High Commissioner for India or through any Bookseller.**

PREFACE.

The following report on malaria in relation to the agricultural conditions of Bengal is submitted for the information of the Government of Bengal.

CHAS. A. BENTLEY.

CALCUTTA,
WRITERS' BUILDINGS.

The 20th March 1925.

MALARIA AND AGRICULTURE IN BENGAL.

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Malaria and Agriculture in Bengal.

INTRODUCTION.

Malaria and Agriculture.

"Only the greatest wilderness or the most complete culture of the land protects a district from malaria."

ASCHENFELDT.

"The neglect of cultivation of the soil and the decay of land recently built on are conducive to malaria, whereas, on the contrary, a rational culture of the soil causes the gradual disappearance of malaria."

SCHEUBE.

"Experience teaches that the soil is the more insalubrious the less it is cultivated. In the cultivation of the soil, we include several factors, namely, the regulation of the ground moisture by canalisation, drainage, etc., the growing of plants, which, by using up the water, contribute to the drying of the soil, and finally, the number of the population, etc."

MANNABERG.

1 - Malaria and Agricultural Decline.

A close association has always been recognised between malaria and agricultural conditions, and it has long been known that a greatly increased prevalence of the disease almost invariably accompanies the decay of agriculture and the decline of cultivation. For example, Pliny, in his Natural History, writing of malaria in ancient Italy, records that :

"The Pontine marshes were anciently a fertile and well-cultivated plain occupied by twenty-four villages, but towards the close of the republic gradually fell into their present condition, *owing to the decline of agriculture.*"

A similar explanation has been given of the increase of malaria in the Tuscan Maremma :

"During the Etruscan period, it possessed several considerable towns, but *on the decline of agriculture* in Italy and the conversion of the farms into pasture lands, the desolation of the coast districts made rapid progress."

Of the Roman Campagna also, it is stated :—

“Once a densely-peopled land with numerous and prosperous towns, it is now a dreary waste, of which barely one-tenth part is furrowed by the plough share. In May, when malaria begins to prevail, herdsmen and cattle retire to the mountains; while the few individuals, who are compelled to remain behind, lead a miserable and fever-stricken existence. The cause of this change dates from as remote a period as the last centuries of the republic, when the independent agricultural population was gradually displaced by proprietors of the large estates and pastures. This system inevitably entailed the ruin of the country, for a dense population and a high degree of culture alone can avert the malaria which is produced by defective drainage and the collection of stagnant water in the undulating and furrowed volcanic soil.”

2. The great epidemic of malaria in Mauritius and Reunion in 1867 followed a deterioration of agriculture. Hirsch points out, when describing this outbreak, that—

“The coast and level country of the Mauritius, which formerly afforded a rich soil for the growing of coffee, indigo and cotton, had been gradually allowed to go out of cultivation and had become entirely barren.”

“Mauritius is over-drained,” says one of the reports on the epidemic, “the localities which are the driest, and where health and agriculture suffer most, being low lands on the eastern, north-western and northern coasts.”

“Meanwhile, the yield of sugar estates on and near the eastern, north-western and northern coasts began to decline and, their unproductiveness continuing to increase, some of them were at length abandoned. Since 1864 or 1865, about 35 sugar houses on the low land have been closed and extensive plains, which at one time were highly fertile, are now barren. The present sterility of these lands is generally ascribed to want of sufficient moisture. It is said that, owing to the clearings which have been made on the elevated lands to windward, the soil and air on the low lands to leeward have become too hot and above all too dry for sugarcane. Others again, while not disputing that *déboisement* on the high land has produced injurious effects on the low lands, consider that the principal cause of the sterility is exhaustion of that soil induced by long continued cultivation of the same plant.”

3. Hirsch associated the increase of malaria in Georgia (U. S. A.) with very similar conditions :—

“In Georgia, the disease prevails widely and in severe forms, not only in the numerous creeks of the coast, but also in the interior, the neglect of agriculture having greatly conduced in quite recent times, as it seems, to an increase both in the amount and intensity of endemic fever.”

“There was waste land,” says Winwood Reade, “in abundance at the South; but it was *dead*. Their style of agriculture was precisely that which is pursued in Central Africa. They took a tract from the wilderness and planted it again and again with cotton and tobacco till it gave up the ghost and would yield no more.

They then moved on and took in another piece. Obligated to spend all their cash in buying prime slaves at two hundred pounds a piece, they could not afford to use manure or to rotate their crops. The Northerner, who travelled down South, was astonished to find that the cities of the maps were villages and the villages clusters of log huts. Fields covered with weeds and moss-grown ruins showed where farms once flourishing had been."

Norcom, writing in 1874 regarding the remarkable increase of malaria in the Southern States of the Union, remarks :—

"Before the war, the Southern States were in a high state of cultivation and the lands thoroughly drained; hence the malignant forms of malarial disease as a general rule were not known, except in very low, badly-drained swamp lands. Within the past eight years, owing to so much land lying waste, defective drainage and the general insanitary condition of the country, the malarial poison has acted with intense virulence and caused the disease we are now considering."

4. At a much later date, Laveran, when describing the malarious districts of France, states that :

"La Sologne florissante sous Henry IV était devenue au commencement de ce siècle, à la suite de l'abandon de la culture du sol, une des régions les plus misérables et les plus insalubres de la France."

5. The passages quoted above emphasize the overwhelming importance of cultivation of the soil in relation to malaria, and with good reason, for the question of rural malaria is so closely bound up with that of agriculture that the one cannot be properly understood without some knowledge of the other. Moreover, as will be shewn later, there are grounds for believing that the mitigation and prevention of malaria in the rural districts of Bengal, a problem for which no adequate solution has yet been suggested, may eventually be secured by measures, designed as much for preserving or restoring agricultural prosperity as for directly dealing with malaria.

APPENDIX I.

Some Economic Aspects of Bengal Malaria.

1. One hundred and thirty years ago Malthus, an obscure country clergyman, stated in his now famous essay that "everything depends on the relative proportions between population and food." Fifty years later Darwin was led to apply this doctrine to the whole animal and vegetable world, and the results of his work, published long afterwards, laid the foundations of the modern science of biology and produced a revolution in every department of thought. The laws of population enunciated by Malthus and extended by Darwin have thus exerted a profound influence upon nearly every branch of knowledge; and their fundamental importance in connexion with the study of epidemiology and the problem of disease prevention is at last being recognized.

2. Every organic being naturally increases at so high a rate that, if not destroyed, the earth would soon be covered by the progeny of a single pair. There is no exception to the rule; even slow-breeding man has doubled in twenty-five years. But a continual doubling of his numbers every quarter of a century cannot take place. In any long settled country mankind cannot increase at anything like the maximum rate. The fundamental reason of this is to be found in the tendency to diminishing returns from the soil. On any given area that tendency shows itself for all agricultural produce. The tendency towards increase in population must then be counteracted; and it may be counteracted in two ways, to which Malthus gave the names 'positive' and 'preventive' checks. By positive checks he meant those which cut down numbers already brought into the world—starvation, disease, war, misery in all its forms. By preventive checks he meant those which prevent numbers from being brought into the world.

3. The present paper concerns disease, one of Malthus' positive checks, which operates through a high death-rate, or in other words through an excess of deaths.

4. Bengal is a huge swamp, peopled, as the *Raghubansa* puts it, with eaters of rice and fish and dwellers in boats. "A good rice swamp is a bog at all seasons, and at one season a bog covered with water," says Adam Smith; and he points out, it is "unfit either for corn or pasture and the lands fit for those purposes are not fit for rice." But it has one great advantage: "A rice field produces a much greater quantity of food than the most fertile corn field." Rice itself is an aquatic grass which cannot thrive without ample water and which suffers from deficiency far more than from excess. It can adapt itself to floods but it cannot stand drought. The long-stemmed varieties will grow 12 inches in 24 hours and withstand submerging for three days; and provided the crop is not drowned outright the greater the depth of water on the fields the better the yield of grain. Besides producing rice, swamps abound in fish, another valuable food of man. Hence rice-swamps supplied with sufficient water tend to become very densely populated. "The numbers of a population," says Darwin, "depend primarily on the

means of subsistence and this depends partly on the physical nature of the country, but in a much higher degree on the arts which are there practised."

5. Agriculture is the art most widely practised in Bengal; rice occupies 85 per cent. of the cultivable area, and jute, another swamp crop, a further 10 per cent., and as we shall see later, these facts have an important bearing on the density and growth of population which are by no means uniform throughout the country.

6. Bengal is divided by its main river systems into four natural divisions, viz., Western, Central, Northern and Eastern Bengal, respectively. Since the first Census of 1872, there have been remarkable variations in the rate of growth of the population in these four divisions as may be seen from the statements noted below:—

Increase of population.

		Population in 1872.	Population in 1921.	1872—1921. Increase per cent.
Western Bengal	...	7,604,661	8,039,704	+ 5.7
Central	"	8,202,760	9,433,544	+ 27.1
Northern	"	8,045,432	10,358,303	+ 28.8
Eastern	"	10,980,504	18,650,139	+ 69.8

Density of population.

		Density per square mile		Increase.
		1872	1921	
Western Bengal	...	545	570	+ 25
Central	"	424	539	+ 115
Northern	"	418	538	+ 120
Eastern	"	479	815	+ 336

7. The extraordinary development of the population in Eastern Bengal is due entirely to natural growth by excess of births over deaths; there are few towns and no important industries to attract immigrants; this natural division also, as a matter of fact, has lost rather than gained by migration. This area affords therefore an example of normal expansion occurring in an agricultural population living under relatively favourable conditions. Conditions are obviously very different in the other divisions, all of which possess important industries which attract immigrants in large numbers. Western Bengal, for example, possesses coal, iron and mills, etc., Central Bengal has a number of towns with many mills, and factories and Northern Bengal includes nearly 200,000 acres under tea. Estimates of the gain by migration from these and other causes are difficult, but the excess of immigrants over emigrants in 1901 and 1911, respectively, was found to be about 6.3 and 7.4 per cent. of the population in Northern Bengal and 5.8 and 8.8 per cent. in Central Bengal. Much of the expansion in this latter division is undoubtedly due to immigrants to its many towns. Western Bengal, on the other hand, lost nearly as much by emigration from certain of its rural areas as it gained by immigration into its towns and industrial tracts.

8. What would the present populations of Western, Central and Northern Bengal be, respectively, if they had expanded since 1872 by 69·8 per cent., the rate of growth which has actually occurred in Eastern Bengal? Western Bengal would have nearly five millions, Central Bengal nearly four millions and Northern Bengal over three millions more inhabitants; and the province as a whole would possess a population greater by more than twelve millions than it does at present; that is 58,605,420 against 46,481,690. Why is it that this expansion has not occurred? A partial explanation is to be sought in the fact that for a very long period the population of large areas in the several divisions has ceased to expand at a healthy rate; but a factor of even greater importance is the actual decline of population that has taken place in tracts covering many thousands of square miles. The statement below gives particulars of the area in each natural division in which population has shown a decline at each of the last five census enumerations.

Area in square miles in which population has declined.

	1872-81	1881-91	1891-01	1901-11	1911-21
West Bengal ...	7,149	5,027	1,428	5,339	11,515
Central „ ...	2,590	4,444	4,488	5,262	7,126
North „ ...	6,534	5,483	3,878	3,175	6,964
Eastern „ ...	6,476	1,109	2,180	1,388	465
Total ...	<u>22,749</u>	<u>16,063</u>	<u>11,974</u>	<u>15,164</u>	<u>26,070</u>

9. With the exception of the period 1872-81, the decline of population has affected a relatively small area in Eastern Bengal at each succeeding decade. The cause of the large area found decadent in 1881 was the storm wave of 1876, which affected much of Bakarganj and Chittagong and parts also of Noakhali and Tippera and resulted in an appalling loss of life. The figures for the last decade give the best idea of the relative conditions of the different parts of the province. They show that 83 per cent. of Western Bengal is decadent, 60 per cent. of the inhabited portion of Central Bengal is in a similar condition, and 36 per cent. of Northern Bengal is affected by decline of population, whereas in Eastern Bengal only 2 per cent. of the total area has shown a reduced number of inhabitants.

10. It may be that when population has ceased to expand rapidly it is merely because local circumstances, as for example the food supply, are not specially favourable to expansion. But an actual loss of population means very much more than a lessened rate of expansion. It points to some definite change in the climate or in other conditions vitally affecting the welfare of the population which has made a reduction of their numbers inevitable. The effect of such a change is likely to be very far-reaching, as Darwin has pointed out in his *Origin of Species*. "We shall best understand the probable course of natural selection," he says, "by taking the case of a country undergoing some physical change, for instance, of climate. The proportional numbers of its inhabitants would almost immediately

undergo a change, and some species might become extinct." "We may conclude," he adds. "from what we have seen of the intimate and complex manner in which the inhabitants of each country are bound together, that any change in the numerical proportions of some of the inhabitants, independently of the change of climate itself, would seriously affect many of the others." What Darwin wishes to convey by this passage is that when a change occurs sufficient to affect the numbers or distribution of any living organism, animal or vegetable, the other organisms, living in the same area, are bound to be affected also. When, therefore, a change of climate or of local conditions has resulted in a decline of the human population living in an area, it is bound to be reflected in the flora and the fauna of the locality also. The history of Kassimbazar affords a striking example of this and incidentally serves as an illustration of the sort of change to which Darwin refers in the passage just quoted.

11. "The decay of Kassimbazar dates from the beginning of the nineteenth century," states the *Imperial Gazetteer*, "when its climate, which had previously been celebrated for its salubrity, underwent an unexplained change for the worse, so that the margin of cultivation receded and wild beasts increased." Here is an instance in which both the plant and animal life of the locality are noted as having been influenced as the result of a change which affected the human population. The receding cultivation and the increase of wild animals indicate a serious alteration of former conditions.

12. Knowing what we do of the causes of tropical disease, we can safely affirm also that a corresponding change took place in the number and distribution of such lower forms of life as anopheles mosquitoes and malarial parasites, and hence the "unexplained change for the worse" of the former salubrious climate. We shall have occasion to refer to the cause of the change of climate at Kassimbazar a little later. Meanwhile, we must return to the discussion of the larger question regarding the more recent serious depopulation of so many portions of Bengal.

13. Attention has already been called to the fact that a serious decline of population indicates that a definite change has come over the affected area; and as we have seen, the effects of such a change are not limited to man but are certain to exert a very marked influence also on both the flora and fauna of the locality, resulting in an increase of certain species and a decrease of others. This view is borne out by the evidence which shows that both the plant and animal life of the areas undergoing depopulation exhibit an increase in certain directions and a decrease in others, and many of these increases and decreases are of special importance to man from an economic standpoint, affecting as they do the question of available food supply very greatly.

14. The most prominent and best recognized change in relation to fauna is to be seen in the great increase of malaria. If we compare a map of the areas suffering from a decline of population with another showing the relative prevalence of malaria we shall see that there is a rough correspondence between them. Depopulation is, therefore, generally associated with intense malaria. Evidence points to the fact that in the areas in which the human population is declining, malaria has increased very greatly during the last sixty years.

The relative prevalence of malaria.

	Fever indices.		
	1878 Per cent.	1912 Per cent.	1920 Per cent.
Western Bengal ...	21·9	40·9	51·7
Central „ ...	17·3	32·3	44·9
Northern „ ...	22·3	23·7	33·5
Eastern „ ...	9·3	7·5	14·0

15. Burdwan, Birbhum, Bankura, Midnapur and Hooghly in Western Bengal were at one time relatively free of malaria and were regarded as sanitarium. Similarly Murshidabad and Nadia and a great portion of Jessore in Central Bengal were formerly healthy, and Pabna and Malda in North Bengal were also relatively salubrious. In Eastern Bengal, Tangail in Mymensingh, Manikganj in Dacca and the northern portions of the Faridpur district, which are now malarious, were formerly relatively free of the disease.

16. This admitted increase of malaria can only be explained on the assumption that there has been a corresponding increase in the number and distribution of anopheles mosquitoes and malaria parasites in the areas affected. Unfortunately, there are no actual observations on this point. But it must be remembered that the malarial parasite was only discovered in 1880, and the part played by anopheles mosquitoes in its transmission as late as 1898, long after this increase of malaria had taken place. Many healthy localities in which population is increasing usually show scanty signs of malaria. But anopheles mosquitoes of species capable of harbouring the malarial parasite are to be found everywhere and often occur in large numbers in these healthy areas. They do not, however appear to multiply greatly during the wet season as they do in the unhealthy areas, so that the period of their greatest prevalence does not correspond with that most suitable for the proliferation of malarial parasites. Meanwhile, it may be noted that there are grounds for believing that in the decadent areas anopheles mosquitoes are now far more prevalent during the period of July to October than they used to be, and that this change is associated with a greatly lessened supply of water.

17. Other important variations in the fauna of the areas undergoing depopulation are the notable decrease in fish of all kinds and the great increase in the prevalence of certain mammals, wild hog for example. The decrease of fish is generally recognised and has been reported on by Sir K. G. Gupta, I.C.S., and Mr. K. C. De, C.I.E., I.C.S. The increase of wild hog and other vermin is also generally admitted and is often ascribed to the increase of jungle. Both of these changes are important from an economic stand point; the reduction in fish, because it means a lessening of the food supply, and the increase of wild hog, etc., because it results in greater damage to crops. A further minor change in the fauna of certain of the areas now undergoing depopulation is the reduction in the number of silkworms produced. This is also a matter of economic importance to man.

18. We have now to consider certain changes that have taken place in the flora of the areas undergoing depopulation. As will be seen, many of these changes are of supreme importance to man from an economic standpoint.

19. The most noticeable change is the lapsing of cultivated or inhabited areas into jungle. This was previously noticed in the case of Kassimbazar, but it has become so apparent in later years as frequently to be accepted as a primary cause both of the general increase of malaria and of depopulation. Certain facts require to be noted about this increase of jungle. In the first place, it is confined almost entirely to the more elevated and drier localities, the high banks of the rivers and on village sites for instance, and it is especially noticeable in places where population has declined. In the second place, contrary to what is often stated, this growth of jungle, as the Nadia Fever Commission pointed out, "is of a kind that prefers a dry to a damp *habitat*." It is not swamp vegetation that increases, but trees and shrubs whose roots require a soil in which aeration occurs. This fact has a very important bearing upon the nature of the climatic change that has occurred in the areas undergoing depopulation.

20. Turning to the broad question of cultivated and waste land respectively, some idea of the relative distribution of the various classes of land may be got from the following tabular summary which gives the percentages for each natural division.

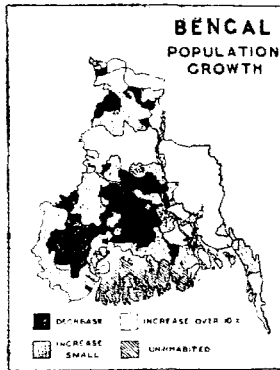
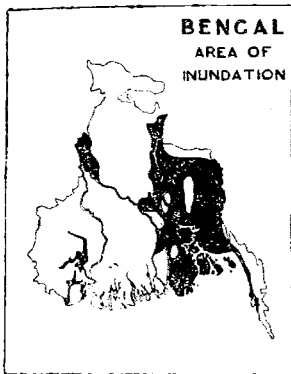
	Percentage cultivable area cultivated.	Percentage cultivable waste.	Percentage current fallow.
	Per cent	Per cent.	Per cent.
Western Bengal ...	.... 61	26	12
Central ,, ...	... 58	18	24
Northern ,, ...	... 71	14	15
Eastern ,, ...	... 90	7	3

21. There is little statistical information regarding changes in the proportions of cultivated and uncultivated land respectively, but a few general statements are on record relating to particular areas. For example, it is reported that in Burdwan prior to the epidemic fever seven-eighths of the land was under cultivation, whereas the latest returns show only 47 per cent. of the cultivable area as being cropped. This latter figure compares very unfavourably with Dacca, where during the same season 92 per cent. of the cultivable area was cultivated. A progressive contraction of the cultivated area in Nadia has been reported by the successive Collectors. And a loss of fertility and consequent agricultural deterioration has been noted in many other districts of Central and Western Bengal and elsewhere. Take for example the following remark from page 50 of the Settlement Report of Faridpur: "*It was impossible for landlords to enhance rent and to evict tenants when the fertility of the soil was declining and land was gradually going out of cultivation.*"

NOTE.—The italics are mine—C. A. B.

SOME ECONOMIC ASPECTS OF BENGAL MALARIA.

BY DR. C. A. BENTLEY.



AGRICULTURAL CONDITION OF BENGAL

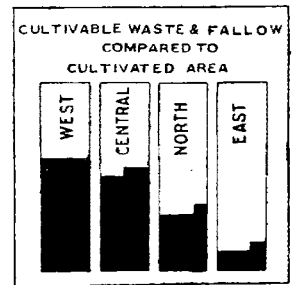
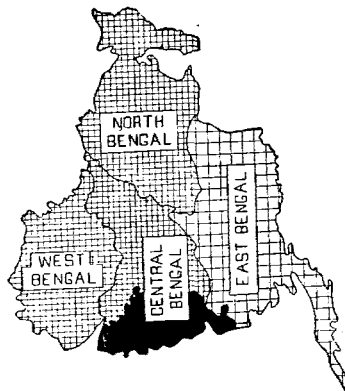
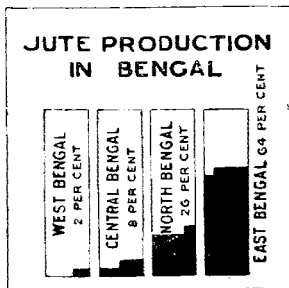
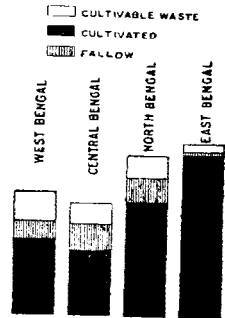
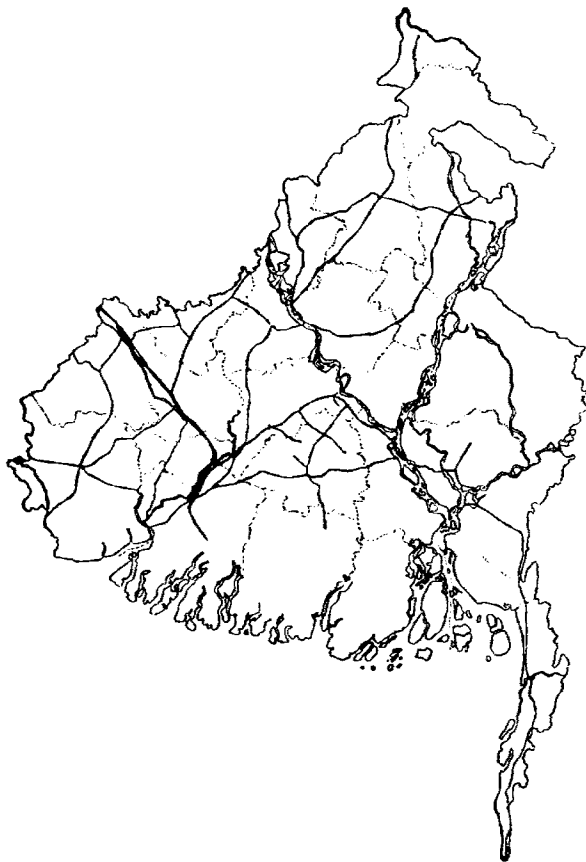


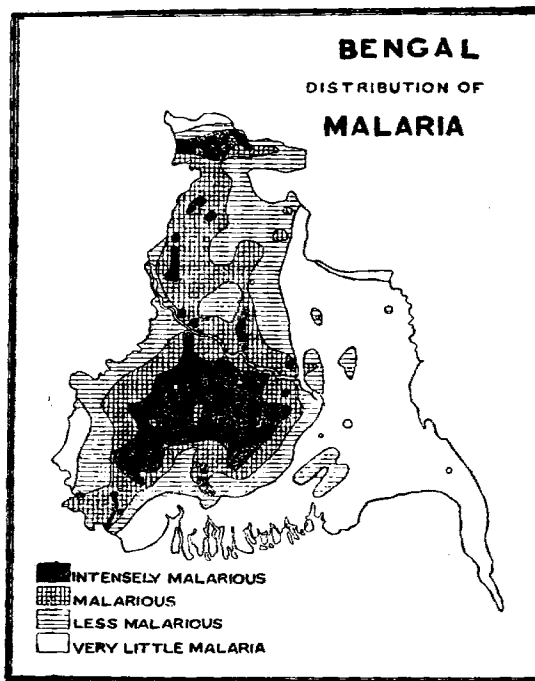
Diagram indicating proportion of roads and railways in each natural division.

SOME ECONOMIC ASPECTS OF BENGAL MALARIA.

By Dr. C. A. BENTLEY.

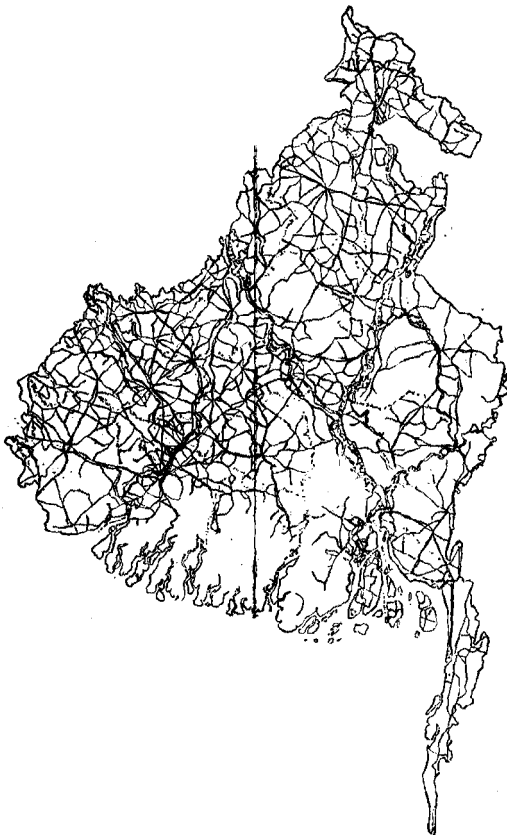


Roads and railways in Bengal in 1870.



**SOME ECONOMIC ASPECTS OF BENGAL
MALARIA.**

By Dr. C. A. BENTLEY.



Roads and railways in Bengal in 1920.

22. Taking into consideration the broad fact that only 58 and 60 per cent. of the cultivable area is under cultivation in Central and Western Bengal, respectively, compared with 90 per cent. in Eastern Bengal, it would appear, in view of the marked decay of population that has taken place in the former areas, that some climatic change has occurred which has affected the flora of these areas to such an extent as to diminish very seriously the food supply of the people.

23. When we come to examine in some detail the crops grown, certain very significant facts are brought to light. Take the character of the rice grown in different parts of the country. There are three main varieties of rice, *Aman* or Winter rice, *Aus* or Autumn rice and *Boro* or Summer rice. These different classes of rice flourish best in different situations and differ in the amount of water they require. *Aus* paddy grows on relatively high land and requires least water; *Aman* requires abundant water and *Boro* grows best along the edges of rivers or permanent swamps. The proportions of these three kinds of rice grown in different localities vary very greatly and depend primarily on the water supply. *Boro* paddy gives the most abundant yield, *Aman* paddy the finest grain and *Aus* paddy the smallest outturn and the coarsest rice. In spite of this fact *Aus* paddy is gradually replacing *Aman* in certain areas.

24. The *Gazetteer* of the Jessore district, for example, states that the area under *Aman* rice is contracting owing to deficient floods; and a comparison of the agricultural statistics of 1920-21 with those of 1906 shows that in Jessore the normal area under *Aus* has been increased by 10 per cent. and in Nadia by 50 per cent. Wherever the supply of water is scanty *Aus* paddy tends to replace *Aman*. The figures for individual *thanas* in the Faridpur district are very instructive in this respect, showing as they do that the extraordinary variation in the growth of *Aus* paddy in different parts of the district bears a relation to the water supply. "In the north of the district," says the Settlement Report, "water for drinking and other purposes has become very scarce." The north of the district is malarious and in the malarious northern *thanas* of Pangsa, Bhushna, Baliakandi, Goalundo and Faridpur the proportion of *Aus* paddy grown is from 34 to 46 per cent. of the total, whereas in the non-malarious more southern *thanas* it is very small, ranging from 6.3 per cent. in Kotwalpara to 7.5 and 7.9 and 9.6 per cent., respectively, in Madaripur, Gopalganj and Muksudpur. The outturn of *Aman* rice varies greatly according to the supply of water. The yield of *Aman* rice grown in the south of Faridpur is very heavy, says the Settlement Report, "but in the north of the district it is ordinarily much poorer and only becomes good when inundations come early and are widespread."

25. Jute comes next in importance to rice. As in the case of rice so for jute also ample water is necessary, largely governing the distribution of the plant and the character of the crop. Abundant water is also required for the retting of the fibre. "It is necessary to have water conveniently near," says the Settlement Report of the Faridpur district, "in which the jute can be steeped. This limits the amount of jute that can be grown in the north of the district considerably, but in the Madaripur subdivision the limit, owing to the abundance of small rivers and streams, has not been reached." The figures for jute cultivation in the province as a whole show that

64 per cent. is grown in Eastern Bengal, 26 per cent. in Northern Bengal and only 8 and 2 per cent. in Central and Western Bengal, respectively. And a comparison of data regarding the relative abundance of water indicates a close relationship between the supply of water and the yield of jute. Generally speaking also a rapid increase of population occurs in areas where jute is largely grown, whereas a reduction in the cultivation of jute is often followed by decline of population.

26. Among other minor changes in the flora of areas that are losing population, the disappearance of indigo and the reduction of mulberry may be mentioned. Indigo was formerly cultivated very widely, especially in Western and Central Bengal and in parts of Faridpur and Dacca; but it is no longer grown in any quantity and the indigo factories are all in ruins. Mulberry, too, has already undergone a very marked reduction in consequence of the decline in sericulture. Another change is the practical disappearance of cotton as a cultivated crop in the greater majority of the districts within the last century. But this latter change appears to have occurred long before the great increase of malaria and the rapid decline of population with which we are now concerned, and it is only therefore mentioned in passing.

27. Putting aside for a moment the increase of malaria and the loss of population, it will be seen that the other changes that have been noted as occurring among the fauna and the flora, respectively, of the decadent areas we have been discussing, point to the conclusion that a reduction in the water supply is the origin of the trouble. First of all there is the receding margin of cultivation. This is invariably associated with a lack of water. It is always the drier and more elevated lands that go out of cultivation. Then there is the increase of jungle which is largely confined to the relatively high banks of rivers and old village sites, showing that the type of vegetation is one which prefers a dry situation rather than a damp water-logged one. The tendency for *Aus* paddy to displace the *Aman* variety is also an indication of diminished moisture. The decreasing supply of fish affords further evidence of a lessened supply of water; and the increase of wild hog and other animals which has followed the increase of jungle points in the same direction. The only fact, therefore, which appears to militate against this view of the situation is the very great increase of malaria which has taken place along with these other changes, and which at first sight appears to preclude the possibility of a diminished supply of water being the cause of the trouble.

28. But we have only to recall two well-known facts in regard to malaria in order to realise that this difficulty is only an apparent one. Ever since Empedocles flooded the marshes surrounding Selinos in Sicily by a canal constructed for the purpose, and in this way freed the city from malaria, it has been known that swampy low-lying localities cease to be unhealthy when temporarily submerged; and in the old days flooding was often deliberately applied both in Italy and Holland for ameliorating malaria, with most excellent results. But while the flooding of swamps has long been resorted to for checking malaria the partial removal of water from a marshy area has always been regarded as a most dangerous proceeding, calculated to produce a serious intensification of the disease; this belief being justified by the numerous occasions in which the

reclamation of swamps has led to severe outbreaks of malaria. Three well-known instances of this kind are the case of the Grand Chartreuse Swamp in France, the low lands of Biensten and de Wonner in Holland and the Whittlesea Mere in England. Such outbreaks were formerly ascribed to miasma given off from the exposed bottom of the marsh. But now-a-days the accepted explanation is the great increase of anopheles that takes place when, by partial drying up, a large expanse of water is converted into many small shallow pools.

29. We see therefore that all the important changes which can be shown to have occurred in association with the loss of population that has taken place in so many areas in Bengal are consistent with a reduction in the water supply of the affected localities. This naturally prompts the question: Is there any direct evidence of such a diminution having taken place? In reply it may be stated that for many years the complaint has been general throughout the areas afflicted with severe malaria and undergoing depopulation, that water supplies have diminished. In 1867, the Revd. G. Schurr, of Kaspadanga in Nadia, reported in a letter to the Magistrate: "During the twenty years I have been in this district I have observed a gradual diminution of water supply in old tanks and *khals* as well as in the rivers."

30. The following year Dr. Sutherland observed of the same district: "The district is becoming more and more arid, tanks and other reservoirs of water dry up even before the hot weather, tanks full to overflowing in the rains rapidly dry up—facts which prove that there has been of late no increase or excess of moisture in the soil." Similar complaints have been put on record at various times in regard to every malarious district. As late as 1912, Mr. Bholā Nath Banarji, Executive Engineer in charge of the Special Drainage Division, while at work in Jessore reported: "If we draw a line from Pultia on the Ichamati to Jhikergacha on the Kabadak, the country lying to the north of this line may be generally taken as suffering from a scarcity of good drinking water." "It is reported," he adds, "that tanks in those parts do not hold water but dry up with the subsidence of the rivers." And he concludes by pointing out that most of the Jhenida subdivision and parts of Magura where people suffer from want of water are the most malarious parts of the district. Quite apart from general statements of the kind quoted, there is a certain amount of direct evidence pointing to the abnormal dryness of many localities that have long been suffering from increased malaria and depopulation. The Nadia Fever Commission, state that: "Observations in December of the water level in wells showed it to be from 15 to 24 feet from the general soil surface level in the west and north-west of the district." A few years earlier similar observations were placed on record for Birbhum district by Dr. Jackson, the Sanitary Commissioner. Recent observations in Burdwan, Nadia, Jessore, Pabna and Murshidabad have shown very similar results and have proved that, contrary to commonly accepted ideas, the areas in which the level of the subsoil water is specially low are far more malarious and unhealthy than those in which it approaches within three to five feet of the ground surface. In Burdwan, which is one of the worst districts for malaria and depopulation, the mean level of the subsoil water,

taken in twenty-eight wells in different parts of the district, is 26 feet in the dry weather and 9 feet in the rains; whereas in healthy parts of Howrah, Dacca and Mymensingh it varies from 3 to 5 feet in the dry weather and is level with the ground surface in the rains. Apart from the moisture that is stored in the subsoil and which, as we have seen, is subject to very great variations in different parts of the province, the unhealthy, malarious and decadent tracts possess the lowest supply. The sources from which the country derives its supplies of water are the rainfall and the overflow from the rivers in the flood season. Although the rainfall fluctuates from year to year there is no reason to suppose that the average amount precipitated has undergone any marked diminution. On the other hand, there is plenty of evidence to show that the embankments that have been constructed along the margin of the rivers and for the purpose of roads and railways have had the effect of shutting out from the surface of the country a large amount of water which found access to it in former times. There are now many thousands of miles of embankments, which cover the country with a net-work extending in almost every direction. And there is no doubt that their effect has been to deprive the country of much of the moisture it formerly enjoyed. Time and again it has been suggested that these embankments have obstructed drainage and led to water-logging which has resulted in an increase of malaria. But repeated investigations have only served to show that, except in a very few places, the country within the influence of the embankments, instead of being damper than formerly, is actually much drier than it used to be. And in the light of the facts brought forward in this paper the explanation is a simple one. It is in the main to the construction of these embankments that we must look for the cause of the increase of malaria and the depopulation that has accompanied that increase. The decay of Kassimbazar, which has already been referred to, followed the construction of an embanked *pakka* road from Berhampur cantonment to Murshidabad, city. That decay was, as we have seen, accompanied by a decline of agriculture and a change in the climate. And the same sequence of events can be traced in the history of almost every decadent tract in P Bengal at the present time.

APPENDIX II.

Areas most in need of Anti-malarial Projects in Bengal.

What are the areas in Bengal most urgently in need of measures for the amelioration of malaria? This question can best be answered by reference to statistics relating to the prevalence of malaria in different districts and the census reports showing the growth or decline of population. These are safer guides than death-rates. Death-rates are largely influenced by high birth-rates and are also affected by the accuracy of the reporting agency, and are in consequence sometimes misleading. For example, some of the most unhealthy districts of Central and Western Bengal, whose death-rates always exceed their birth-rates, show a lower fever death-rate and total death-rate than healthier areas in Northern Bengal, which have birth-rates far above the average. Mortality rates do however, give valuable information which will be used in this note, but population figures and fever indices will be first referred to. Before dealing with individual districts, attention must be directed to the general condition of the four natural divisions of the province in these two respects.

2. *Expansion of population.*—The recent census has disclosed the following results regarding the expansion of population in the four natural divisions of Bengal, viz., Western, Central, Northern and Eastern Bengal, the first three of which correspond to the respective administrative divisions of Burdwan, Presidency and Rajshahi, while Eastern Bengal includes the two administrative divisions of Dacca and Chittagong :—

Natural division.	Expansion of population.	
	1872—1921. Per cent.	1872—1921. Per cent.
Western Bengal (Burdwan Division)	- 5·1	+ 5·7
Central „ (Presidency „)	- 0·1	+ 27·1
Northern „ (Rajshahi „)	+ 2·2	+ 28·8
Eastern „ (Dacca and Chittagong Divisions)	+ 8·0	+ 69·8

The Chittagong Hill Tracts are excluded from the latter, as they differ in every way from ordinary plains districts.

The figures for total expansion since 1872 suggest good health conditions in Eastern Bengal, unsatisfactory conditions in Central and Northern Bengal and very bad condition in Western Bengal and those for the last decade especially point to a very serious state of affairs in Western and Central Bengal.

3. The figures relating to the density of population per square mile in 1872 and 1921, respectively, are equally illuminating :—

	Density of population.		Increase. Total.
	1872.	1921.	
Western Bengal	545	570	+ 25
Central „	424	539	+ 115
Northern „	418	538	+ 120
Eastern „	479	815	+ 336

The extraordinary development of the population in Eastern Bengal is due entirely to natural growth by excess of births over deaths; there are few towns and no important industries to attract

immigrants; this natural division also, as a matter of fact, has lost rather than gained by migration. This area affords therefore an example of normal expansion occurring in an agricultural population living under relatively favourable conditions. Conditions are obviously very different in the other divisions, all of which possess important industries which attract immigrants in large numbers. Western Bengal, for example, possesses coal and iron mills, etc., Central Bengal has a number of towns with many mills and factories and Northern Bengal includes nearly 200,000 acres under tea. Estimates of the gain by migration from these and other causes are difficult, but the excess of immigrants over emigrants in 1901 and 1911, respectively, was found to be about 6·3 and 7·4 per cent. of the population in Northern Bengal and 5·8 and 8·8 per cent. in Central Bengal. Much of the expansion in this latter division is undoubtedly due to immigrants to its many towns. Western Bengal, on the other hand, lost nearly as much by emigration from certain of its rural areas as it gained by immigration into its towns and industrial tracts. The conclusion to be drawn from the facts mentioned is that attention to the conditions affecting the growth of the rural population, especially in Western, Central and Northern Bengal, is urgently required.

4. *Decline in expansion of population.*—A moderate estimate of the normal rate of expansion for healthy populations in Bengal is 10 per 1,000 per annum or over 10 per cent. in a decade. We may assume, therefore, that the expansion of population since 1872 should everywhere have been roughly speaking at least 50 per cent. Examining the population expansion figures for the four natural divisions on this basis, we find that, whereas the total expansion of population in the 22,879 square miles of Eastern Bengal (excluding the Chittagong Hill Tracts) for the whole period has exceeded this estimate of normal healthy growth by as much as 19·8 per cent., the populations of Central and Northern Bengal, respectively, have shown on the other hand little more than half the estimated expansion; while in the course of 49 years, the population of Western Bengal has expanded by only 5·7 per cent. The figures for the last decade are even more significant. The population of Eastern Bengal has shown an expansion of approximately 8 per cent., a figure rather below the normal 10 per cent. and very much less than its former rate of growth; the population of Northern Bengal has expanded by less than a quarter of what might have been anticipated, and in both Central and Western Bengal there has been an actual decline.

The figures given below show, for each of the natural divisions, the deviations from the estimated normal rate of expansion for the whole period, 1872—1921, and for the last decade :—

Deviation from estimated normal expansion of population.

		Period of 1872—1921.	Decade, 1911—1921.
		Per cent.	Per cent.
Western Bengal	...	- 41·3	- 15·1
Central	..	- 22·9	- 10·1
Northern	..	- 21·2	- 7·8
Eastern	..	+ 13·8	- 2·0

5. What would the present populations of Western, Central and Northern Bengal, respectively, be if since 1872 they had expanded at the estimated normal rate of 10 per 1,000 per annum, or if they had grown by a total of 69·8 per cent. equal to the expansion which has actually occurred in Eastern Bengal? The table below gives the answers to these questions :—

	Population in 1872.	Expansion at 50 per cent.	Actual population, 1921.	Difference.	Expansion at 69·8 per cent.	Difference.
Western Bengal	7,604,661	11,406,391	8,032,704	- 3,367,287	12,912,714	- 4,873,010
Central „	8,202,780	12,304,170	9,433,544	- 2,870,626	13,381,424	- 3,947,360
Northern „	8,045,432	12,068,148	10,358,303	- 1,709,845	13,551,143	- 3,302,660
Eastern „	10,980,504	16,470,756	18,650,139	+ 2,179,383	18,650,139	.....

From the figures given above, it will be seen that if the population in Western, Central and Northern Bengal had expanded at the estimated normal rate no less than 7,947,758 persons would in the aggregate have been added to the total actually found to be existing at the recent census; and that had the populations in these three divisions increased in the same proportion as in Eastern Bengal, the increase would have added 12,123,730 persons to the existing number, thus making the total population of the four divisions 58,605,420 in place of the actual figure of 46,481,690. Why has this expansion not occurred?

6. The commonest explanation offered is the prevalence of malaria; and colour is given to this view by available data regarding the relative distribution and intensity of the disease in the different natural divisions. Malaria may check the growth of even a prosperous population by increasing the death-rate and reducing the birth-rate. And when malaria is associated with deficiency of the available food supply, healthy expansion of population becomes absolutely impossible. The food supply of a population is governed by the agricultural production. The statistics relating to agriculture in Bengal show that production varies greatly in the four natural divisions. In Eastern Bengal generally, agriculture is prospering, but in the areas in which malaria is prevalent and normal expansion of population has been checked, agriculture appears to have suffered relative decline.

7. On comparing the figures relating to the total cultivable area and the net area normally cropped in the various divisions with those of the respective populations, we get the results noted below per head of the population :—

Acre per head of population.

	Cultivable.	Net cropped.
Western Bengal ...	0·87	0·54
Central „ ...	0·69	0·40
Northern „ ...	0·90	0·64
Eastern „ ...	0·54	0·43

These figures point to a vast difference in the relative fertility of the various divisions. Eastern Bengal is obviously the most fertile area, Northern Bengal comes second with a relative fertility 80 per cent. that of Eastern Bengal, and land in Western Bengal and Central Bengal appears in the ratio of 70 and 65 per cent. when compared with the same standard. In other words, an area of a size sufficient to support a population of 100 persons in Eastern Bengal will only serve for 80 in Northern Bengal, 70 in Western Bengal and 65 in Central Bengal. As a matter of fact, the number given for the two latter divisions is an over estimate, because it makes no allowance for the much larger proportion of the population in these two divisions supported by industry rather than agriculture. Further light is thrown on this question of relative fertility and its effect on the agricultural prosperity of the different divisions by statistics relating to the approximate proportion of the cultivable area cultivated, that lying waste and that occupied by current fallows.

8. It will be seen from the figures given below how much more favourable conditions appear in Eastern Bengal than in the other natural divisions :—

		Percentage	Percentage	Percentage
		cultivable area culti- vated.	waste.	current fallows.
		Per cent.	Per cent.	Per cent.
Western Bengal	...	61	26	13
Central "	...	58	18	24
Northern "	...	71	14	15
Eastern "	...	90	7	3

Western Bengal is apparently only just over two-thirds and Central Bengal under two-thirds as well cultivated as Eastern Bengal and in Northern Bengal only 4 acres are cropped against every 5 cultivated in Eastern Bengal. Again for every acre of cultivable land lying waste in Eastern Bengal there are in proportion 2 acres lying uncultivated in Northern Bengal, $2\frac{1}{2}$ acres in Central Bengal and 3.7 acres in Western Bengal. As regards land lying fallow, it would appear to be in proportion 4.3 times as common in Western Bengal as in Eastern Bengal, five times as common in Northern Bengal and eight times as common in Central Bengal. In connexion with the question of fallows it must be remembered that the term as ordinarily applied in Bengal is really a misnomer. The fallows of Europe and American farming consist in land that is ploughed but on which no crop is actually sown. Whereas in Bengal current fallow usually means land which is temporarily out of cultivation in contradistinction to waste land which is permanently uncultivated.

9. To those familiar with the relation between lack of cultivation and growth of useless vegetation and the presence of malaria, these facts have a special significance. It may be asked why do not the people in Western, Central and Northern Bengal cultivate a larger proportion of the land than they do? The answer to this question lies at the root of the problem of malaria prevention in Bengal, and before dealing with it attention must be directed to a few more figures relating to the agricultural conditions existing in the various

divisions. The figures noted below refer to the average deviation from the estimated normal production of rice during the period 1901—1911 and for the year 1918 :—

	Percentage crop deficiency.	
	1901-11.	1918.
Western Bengal ...	- 22	- 38
Central „ ...	- 21	- 34
Northern „ ...	- 12	- 49
Eastern „ ...	- 7	- 27

The figures that have been quoted show how very much less favourable are agricultural conditions in Western, Central and Northern Bengal than in Eastern Bengal.

10. What is the explanation of the remarkable difference in the agricultural prosperity of the four natural divisions? The main causes of the disparity observable may be summed up in three words : (1) water, (2) manure and (3) labour. The area that is most prosperous is the one enjoying the largest water-supply, receiving the greatest amount of manure and in which the population, hence the labour efficiency, is least affected by malaria. And conversely, the least prosperous areas are those where the majority of the population is subject to recurring attacks of malarial fever.

11. *Water-supply.*—In agriculture, water-supply is of supreme importance. “It is only when we fully appreciate the important role played by water in crop production that we are in position to see how necessary to large yields is the right amount of water at the right time”, says King. Water not only renders cultivation possible but largely governs the resulting outturn. “Experience as well as numerous rigorous experiments have shown,” says Hilgard, “that under ordinary conditions of culture and within limits varying for different soils and crops, production is almost directly proportioned to the water-supply during the period of active vegetation.” Turning to the following rainfall statistics of the province, we find that Eastern Bengal, where agriculture is most flourishing, where population has grown most rapidly and where malaria is least prevalent, enjoys a much heavier rainfall than the other natural divisions. Whereas Western and Central Bengal, where malaria is intense, population decadent, and agriculture is in a parlous condition, receive the lowest rainfall :—

RAINFALL OF BENGAL.

Normal average of natural divisions.

	Inches
Western Bengal ...	57·00
Central „ ...	61·02
Northern „ ...	81·77
Eastern „ ...	94·85

The normal average rainfall of Eastern Bengal is about 60 per cent. greater than that of Western and Central Bengal. Apart from any other factor this alone is sufficient to secure an immense

superiority in agricultural production. The cultural experiments of Tucker and Von Seelhorst have shown for example that an increase of less than 60 per cent. in the moisture provided raised the yield of oats by 65 per cent. on unmanured and 97 per cent. on manured soil, respectively. An abundant supply of water is even more essential in the case of wet crops. Take the case of rice. A former Director of Agriculture in a special report on the cultivation of rice emphasizes its need of abundant water in the following words:—"Compared with the advantages of a proper supply of water all other questions in its cultivation, namely, the quality of the seed used, the nature of the soil on which it is grown, the manures applied and the mode of cultivation adopted are things of very minor importance." If this view is correct, Eastern Bengal, which enjoys the heaviest rainfall, should produce the best rice crops; and what do we find? "The yield per acre of cleaned rice is estimated at 11·02 cwts. for winter rice and 7·34 cwts. for the early and spring crops", says the Imperial Gazetteer. And then it qualifies the statement with the significant remark: "In the rich rice swamps of Eastern Bengal, the return is at least half as much again." Local rainfall is not the only source of the water supplied to the land in Eastern Bengal. Much of this favoured area is subject to natural irrigation with river water. "It is the height and duration of the flood, even more than the local rainfall, which decides whether the harvest in Dacca will be good or bad", writes Mr. B. C. Allen, I.C.S. "These floods serve a double purpose for they not only supply the crop with the moisture it requires, but they restore fertility to the soil by the rich deposits of silt which they bring down." The process of natural irrigation by river water, referred to in the above passage, increases the yield partly as a result of the abundance of moisture supplied to the crops and partly owing to the manurial value of the silt, which the river waters contain. "The gneissic, laterite and old alluvial soils are alike mainly dependent upon artificial manures to maintain their fertility." Whereas the recent alluvium is periodically fertilized by fresh deposits of silt from the overflowing rivers. "The latter process," adds the Census Report, "is most active in Eastern Bengal in the deltas of the Ganges and Brahmaputra, whose waters possess the fertilizing properties of the Nile." Nile silt has a high manurial value. "At soluble commercial fertilizer rates," says Foaden, "the value of the mud deposited on an acre is approximately equal to £ 1·50."

There is a little question that inundation by the silt-laden waters of the rivers conduces very greatly to the agricultural prosperity of Eastern Bengal and the portions of Northern Bengal, which also enjoy this advantage. It is these areas in particular which provide the bulk of the jute harvests upon which so much of the prosperity of Bengal depends. Silt-laden water possesses a further advantage: it checks the growth of weeds in the fields and in the drainage channels; and at the same time it reduces the breeding of anopheles mosquitoes owing to the fact that for some unexplained reason the larvæ of these insects appear to be unable to flourish in silty water.

12. *Labour efficiency.*—It is not easy to form an estimate of the relative efficiency of agricultural labour in different parts of the province. But the great prevalence of malaria in many areas cannot be without its effect. Malarial fever, as is well known, tends to relapse again and again, and it is therefore a potent cause of

sickness and disability. Over-exertion and fatigue are potent factors also in determining relapses in the case of infected individuals. In many parts of Western and Central Bengal, over 90 per cent. of the rural population is probably infected with malaria, and in these circumstances the loss of working efficiency must sometimes be very great indeed, especially at the time of harvesting the winter rice crop. The average fever indices of the four natural divisions, which are cited in a succeeding paragraph, show a great disparity in favour of Eastern Bengal. In connection with labour efficiency, the fact that the twice-cropped area is far greater where there is least malaria is possibly not without some significance. With these facts before us, we can begin to grasp the causes underlying the more rapid growth of population in Eastern Bengal when compared with the other natural divisions. And when we have considered the figures relating to the relative prevalence of malaria in the different areas, we shall begin to understand the special character of the remedies most likely to effect the amelioration of malaria in the parts of the province specially subject to the disease.

Natural Divisions.	Normal twice-cropped area.	Percentage of cultivable area.
Western Bengal ...	379,000 acres	5·3
Central " ...	784,500 "	12·3
Northern " ...	1,649,100 "	17·0
Eastern " ...	2,046,700 "	20·0

13. *The relative prevalence of malaria.*—The fever indices given below also show that malaria is far more prevalent in Western, Central and Northern Bengal than in Eastern Bengal:—

	1868.	1912.	1920.
	Per cent.	Per cent.	Per cent.
Western Bengal ...	21·9	40·9	51·7
Central " ...	17·3	32·3	44·9
Northern " ...	22·3	23·7	33·5
Eastern " ...	9·3	7·5	14·0

What is the cause of the disparity? Before attempting to answer this question, we must briefly glance at the salient facts relating to the disease. Malaria is caused by a small animal parasite inoculated into the blood of men through the bite of anopheles mosquitoes. These mosquitoes are not naturally infected with malaria but have first to obtain the parasites by sucking the blood of human beings already infected. Now mosquitoes require water in which to breed; the adult insects cannot exist for many days in a dry atmosphere; and the malaria parasite also requires a certain temperature to enable it to develop in the body of an anopheles mosquito. Before malaria can become prevalent in any locality, or at any given season therefore certain conditions must be fulfilled: (a) *firstly*, infected human beings must be present; (b) *secondly*, suitable collections of surface water for the breeding of anopheles in sufficient numbers must

exist; (c) *thirdly*, the humidity of the atmosphere must be favourable to the longivity of anopheles, and (d) *fourthly*, the temperature of the atmosphere must be high enough to allow the parasite to develop. Although (a) and (b) often occur at every season of the year, malaria cannot spread unless the conditions (c) and (d) are satisfied also, which usually occurs only during the wet season. Malaria naturally tends to increase therefore during the wet season, and the majority of new infections are as a rule contracted during this period. But owing to the variable incubation period, which may extend to several weeks, and the fact that the sudden onset of colder days and nights tends to determine attacks of fever in those who have become infected and bring out relapses in persons who harbour the parasite, it often happens that the greatest number of actual cases of malarial fever occurs after the end of the rains just at the beginning of the cold season. Thus, it often happens that when cases of malaria are most numerous the conditions actually responsible for the presence of the infection have for the moment passed away with the change of the season. The greatest mortality from malaria is usually met with at a still later period owing to the fact that persons who are chronic cachectics fall victims to malaria in far greater numbers than do those who are suffering from the initial acute attack that usually follows first infection. Malaria, as we have seen, is chiefly propagated during the wet season, as a direct result of the climatic conditions and the great increase of facilities for the breeding of anopheles, which ordinarily occur at this time of the year, owing to the multiplication of collections of surface water. But in certain circumstances, to which special reference will be made subsequently, an increase of surface water instead of favouring the breeding of anopheles, tends to diminish their number. The nature of collections of water in which anopheles breed, their size, the character of the water and the temperature to which this water is raised by the heat of sun, all have an important bearing on the multiplication of anopheles. Small collections of water in pools, drains and streams, which possess a large proportion of weedy edge, are most favourable to anopheles larvæ, owing partly to the amount of shelter and food provided and also because the temperature of the water remains relatively low. Large collections of water possess a relatively smaller ratio of dangerous edge to surface and tend to have a higher temperature. Exposure to the sun may render them very unfavourable for mosquito larvæ while muddy river water appears to be inimical to anopheles larvæ. Now the cultivation of rice is carried on during the rainy season, which coincides with the periods when anopheles mosquitoes ordinarily tend to multiply, and the transmission of malaria infection therefore becomes most active. In the circumstances best suited to the growth of rice in Bengal, it might be thought that the amelioration of malaria was a hopeless undertaking, because it is often assumed that increasing the water must also increase the mosquitoes and the resultant malaria. But, as we have seen, there is a point beyond which an increase of surface water instead of being favourable to anopheles larvæ becomes unfavourable to them, and results in their rapid destruction. This explains the apparent anomaly that those districts, which have the highest rainfall and possess the greatest amount of surface water during the cultivating season, are the areas where malaria is least prevalent, where agriculture is in a most flourishing condition and

where the rural populations have multiplied at a rate far in excess of what might have been thought possible. An ample supply of surface moisture therefore confers a double benefit, improving the yield of the crops and protecting the population from malaria, and these benefits are most conspicuous in the areas liable to inundation with silt-laden river water. Although malaria is chiefly propagated in the wet season, its ravages become most apparent when that season is over. The anopheles have by this time practically finished their season's work, and no attempt to reduce their numbers can therefore have much effect. It follows that when malaria is causing the greatest amount of sickness and mortality the only remedy that can prove immediately useful is the relief of the sufferers by adequate treatment of the disease. If sufficiently intensive to cure the individual and sufficiently extensive to improve the general health of the community the remedial treatment of malaria by quinine may effect a considerable improvement in the conditions of a limited population. But it offers little hope of effecting a permanent amelioration of malaria in a locality, because it leaves conditions relating to the breeding of anopheles (which are those primarily responsible for the existence of the disease) absolutely unaltered. The aim of the sanitarian, therefore, must be to change or control the environment, so that conditions during the season when malaria is actually propagated are made as unsuitable as possible for the breeding of anopheles mosquitoes, while at the same time the human population is benefited directly and indirectly by the measures adopted.

14. *Western Bengal*.—We are now in a position to examine the data relating to individual districts in Western Bengal with a view to discovering the areas in that division most urgently in need of remedial measures. The expansion of population in the districts of this area between 1872—1921 and 1911—1921, respectively, are given below :—

	1872—1921.	1911—1921.
Burdwan ...	... - 3·1	- 6·4
Birbhum ...	... - 0·5	- 9·5
Bankura ...	... + 5·3	- 10·5
Midnapur	... + 4·6	- 5·9
Hooghly ...	... - 3·6	- 1·1
Howrah ...	... - 56·2	+ 5·3

The figures show that, since 1872, there has been an absolute decline of population in three districts and that during the last decade the process of depopulation has extended and accentuated, five out of the six districts being largely decadent. The area of the decadent thanas aggregated 5,339 square miles in 1911, and there is little doubt that the recent census will show a considerable increase when the figures become available. Some idea of the waste of human life that has occurred in this division during the past 50 years may be obtained by an estimate of the deviation that has taken place

from the normal rate of increase at 10 per 1,000 per annum. The following figures give the districts arranged in order to show the greatest loss of natural increase :—

				Since 1872. Per cent.
Hooghly	...	...	...	- 53·6
Burdwan	...	...	...	- 53·1
Birbhum	...	...	...	- 50·5
Midnapur	...	...	...	- 45·4
Bankura	...	...	...	- 44·7
Howrah	...	...	...	+ 6·2

These figures show that the Howrah district is the only one that has experienced a satisfactory growth of population. Part of this growth is owing to gain by immigration. The remaining districts are in a parlous condition, and it is obvious from the figures of the last census that radical measures of relief are required in every one of them.

15. *Fever indices in Western Bengal.*—The fever indices noted below show that with the exception of Howrah every district is seriously affected with malaria :—

			1920.	1917.	Mean.
Burdwan	...	...	62·8	54·4	58·6
Hooghly	...	...	56·4	36·8	47·6
Bankura	...	...	55·1	24·7	39·9
Birbhum	...	...	54·0	29·1	46·6
Midnapur	...	...	40·2	31·6	35·9
Howrah	...	...	20·1	23·6	21·9

The disease is, as a whole, less intense in Midnapore and Howrah than in the remaining four districts. There are considerable variations in the local intensity of the disease in the different districts. The data available regarding the fever indices of a number of different localities in each district suggests the following classification for each district :—

		Intensely malarious.	Malarious.	Slightly malarious.
		Per cent.	Per cent.	Per cent.
Burdwan	...	72·4	24·0	3·4
Hooghly	...	47·8	39·1	13·0
Bankura	...	46·1	38·4	15·3
Birbhum	...	31·2	68·0	0·0
Midnapur	...	26·9	46·1	26·9
Howrah	...	0·0	50·0	50·0

The healthiest portion of Burdwan is situated in the Asansol subdivision in the extreme west of the district ; in Hooghly, the low-lying portions of the Singur and Chanditola thanas are relatively free of malaria ; in Bankura the high undulating tract in the west of the district is the most healthy area ; in Midnapur, the low-lying Contai and Tamluk subdivisions contain the least malarious localities ; and in Howrah, the southern half of the district is less malarious than the portion to the north-west,

Fever death-rates.—The following mean fever-death rates of the ten years 1911 to 1920 emphasize the extreme unhealthiness of every district except Howrah, but show that Midnapur is not yet quite so bad as the other four districts; this is owing to the fact that nearly a third of the district is still relatively healthy :—

Mean of 1911-20.

Birbhum	...	...	...	34·5
Burdwan	...	...	...	28·9
Bankura	...	...	...	26·2
Hooghly	...	...	...	24·3
Midnapur	...	..	...	21·2
Howrah	...	...	...	11·9

16. *Conclusion regarding the Burdwan Division.*—(1) The need of remedial measures in the majority of the districts of the Burdwan Division is obvious from the facts stated above.

(2) Work is urgently required in at least five out of the six districts.

(3) Hooghly and Burdwan have been longest unhealthy and have lost in the aggregate the greatest population.

(4) Birbhum and Bankura have both suffered very severely from malaria and loss of population in recent years and are rapidly approaching the condition of Burdwan and Hooghly.

(5) A large portion of Midnapur is retrograde.

(6) Howrah district is at present far less unhealthy than the others.

17. *Central Bengal.*—The following statement gives the expansion of population in the districts of Central Bengal for the total period 1872—1921 and the decade 1911-21 :—

		1872—1921.	1911—1921.
24-Parganas	...	+65·0	+7·8
Nadia	...	-0·3	-8·1
Murshidabad	...	+2·5	-9·3
Jessore	...	+19·7	-1·2
Khulna	...	+39·5	+6·8

Nadia district has experienced an absolute decline of population as compared with 1872, whereas all the other districts have shown some increase, though that in Murshidabad is insignificant. During the last decade, three districts, Nadia, Murshidabad and Jessore, have lost population, the two first very considerably. 24-Parganas and Khulna, which show the greatest aggregate increase, are the only districts that have gained population in the last decade. Jessore in which the aggregate gain of population since 1872 is about half that of Khulna, has lost ground slightly since 1911. The decadent thanas in the division at the time of the census in 1911 covered an area of 5,262 square miles, situated almost wholly in Nadia, Murshidabad and Jessore. At the time Jessore had in proportion the largest area decadent, but there is little question that precedence in this respect must now be given to Nadia and Murshidabad. The deviation from the estimated normal rate of increase of population for each district

during the past 49 years may be seen by reference to the figures noted below which are arranged in the order of the greatest proportional loss:—

		1872—1921.	1911—1921.
		Per cent.	Per cent.
Nadia	...	- 50·3	- 18·1
Murshidabad	...	- 47·5	- 19·3
Jessore	...	- 30·3	- 11·2
Khulna	...	- 10·5	- 3·2
24-Parganas	...	+ 15·0	- 2·2

It will be seen that, with the exception of the 24-Parganas, where the growth of population has exceeded the normal rate of increase, every district has lost ground; the two most decadent districts being Nadia and Murshidabad, while Jessore comes midway between these two districts and Khulna, where the deviation from the normal has been relatively small. These figures suggest the need of remedial measures in the first three districts named, the need being *especially urgent in Nadia and Murshidabad*.

18. *Fever indices*.—The fever indices given below relating to various districts of Central Bengal show that malaria is widely prevalent, but that while the disease is intense in Nadia, Murshidabad and Jessore, it is less prevalent in the 24-Parganas:—

		1920.	1912.	Mean.
24-Parganas	...	35·4	29·4	32·4
Nadia	...	53·9	36·7	45·3
Murshidabad	...	57·4	33·9	45·7
Jessore	...	45·8	42·0	43·9
Khulna	...	37·2	23·1	32·7

The examination of different localities in each district gives the following results:—

		Intensely malarious.	Malarious.	Slightly malarious.
		Per cent.	Per cent.	Per cent.
Murshidabad	...	50·0	45·8	4·1
Nadia	...	36·0	60·0	4·0
Jessore	...	15·0	85·0	0·0
24-Parganas	...	3·7	62·9	23·3
Khulna	...	0·0	70·8	29·1

These figures show that half of Murshidabad, more than a third of Nadia and about a sixth of the localities in Jessore are intensely malarious. In Murshidabad and Nadia, a few localities near live rivers are still relatively healthy. In Khulna, considerable proportion of the low-lying Sundarbans tracts are healthy and in the 24-Parganas the Diamond Harbour subdivision is, as a whole, relatively free of malaria.

19. *Fever death-rates.*—The following mean fever death-rates of the decade 1911-20 show that Murshidabad and Nadia have been especially seriously affected, and so far support the conclusions arrived at by a consideration of the population figures and the fever indices :—

<i>Mean 1911-20.</i>			<i>Per thousand.</i>
Murshidabad	...	...	34.0
Nadia	...	...	32.8
Jessore	...	...	24.9
Khulna	...	...	19.0
24-Parganas	...	...	16.3

The Drainage Committee for the Presidency Division in 1906-07 put forward the view that the districts of Jessore and Nadia were the most malarious in the division, although they mentioned that there was a tract of some 1,919 square miles in the Murshidabad district in which the disease was of marked virulence. But the facts that have been brought forward in this note seem to show that Murshidabad, at least in recent years, has suffered as severely as Nadia and that these two districts are in a worse condition than Jessore, which has long been notorious for its unhealthy climate. It would appear, therefore, that while every district in Central Bengal requires attention, efforts should be concentrated especially upon Murshidabad, Nadia and Jessore, and that if any order of precedence be given it should be assigned to the districts in the order named.

20. *Northern Bengal.*—The following statement, which gives the percentage increase of population for each district of Northern Bengal since 1872 and during the decade 1911—1921, shows that conditions in this area compare favourably with those of Western and Central Bengal. But they are not wholly satisfactory. No district, it is true, has suffered an actual decline of population since 1872, but the increase has been very small in Rajshahi and in Pabna; Rangpur and Dinajpur also indicate very slow expansion. The figures for the last decade also indicate a loss in two districts, Pabna and Malda, and an insignificant increase in Rajshahi and Dinajpur, while in no district has the increase exceeded the very moderate rate of 6.6 per cent.

Population expansion.

		1872—1921.	1911—1921.
Rajshahi	...	+ 4.8	+ 0.7
Dinajpur	...	+ 18.9	+ 0.8
Jaipauri	...	+ 124.8	+ 3.8
Darjeeling	...	+ 196.2	+ 6.0
Rangpur	...	+ 16.3	+ 5.0
Bogra	...	+ 63.5	+ 6.6
Pabna	...	+ 15.1	- 2.4
Malda	...	+ 47.3	- 0.5

21. If we examine the deviation from the estimated normal rate of growth since 1872, Rajshahi, Pabna, Rangpur and Dinajpur appear to have suffered severe checks of normal expansion. In the case of Malda also, where population has developed at a rate closely approaching the normal, it is clear from the small loss reported at the last census that the district is now on the down grade. Bogra has more than exceeded the natural rate of growth and in Jalpaiguri and Darjeeling the expansion has been extraordinary. In the former district, population has on the average grown at $2\frac{1}{2}$ times the normal rate and in the latter at almost exactly four times this figure.

Rajshahi	...	...	- 45.2	- 9.3
Pabna	...	...	- 34.9	- 12.6
Rangpur	...	...	- 33.7	- 5.0
Dinajpur	...	...	- 31.1	- 9.2
Malda	...	...	- 2.7	- 10.5
Bogra	...	...	- 13.5	- 3.4
Jalpaiguri	...	...	- 14.8	- 6.2
Darjeeling	...	...	- 146.2	- 4.0

22. The fever indices of the various districts, noted below, throw a rather different light upon the health conditions of North Bengal:—

Fever Indices in Northern Bengal.

			1920.	1912.	Mean.
Rajshahi	...	...	29.7	28.6	29.2
Dinajpur	...	...	38.4	33.1	35.8
Jalpaiguri	...	...	38.1	21.2	29.7
Darjeeling	...	...	20.2	23.0	21.6
Rangpur	...	...	28.0	17.1	22.6
Bogra	...	...	42.0	16.6	29.3
Pabna	...	...	37.8	23.0	30.4
Malda	...	...	42.4	39.4	40.9

In 1920 Malda, Bogra, Dinajpur, Jalpaiguri and Pabna were the most feverish, whereas eight years earlier Bogra was relatively less malarious and Malda, Dinajpur and Rajshahi headed the list.

Further information as to the relative intensity of malaria in different localities in the various districts is given below:—

			Intensely malarious.	Malarious.	Slightly malarious.
			Per cent.	Per cent.	Per cent.
Jalpaiguri	...	...	27·2	63·6	9·0
Malda	...	...	23·5	76·4	0·0
Bogra	...	...	16·6	77·7	5·5
Pabna	...	...	14·2	71·4	14·2
Dinajpur	...	...	15·0	82·6	4·3
Darjeeling	...	...	9·0	54·5	36·3
Rangpur	...	...	7·5	52·5	40·0
Rajshahi	...	...	0·0	77·7	23·2

23. *Fever death-rates.*—The main fever death-rates of the decade 1911—1920 show Dinajpur, Malda, Rajshahi and Jalpaiguri to be more unhealthy than the remaining districts, while Pabna is low down on the list. It must be remembered that these rates are all calculated on the census populations of 1911 and as a result the fever death-rates for Jalpaiguri, Rangpur, Darjeeling and Bogra appear too high and that for Pabna too low. In so far as the figures appear to represent Pabna as more healthy than Malda and Rangpur, they are probably misleading. The tendency in this division as a whole is to find the largest proportion of death recorded under the head of "Fever" and the fewest under "Other causes," hence the fever death-rates are swelled to abnormal proportions.

				Mean.
Dinajpur	...	...	...	34·3
Malda	...	...	...	31·3
Rajshahi	...	...	...	31·2
Jalpiguri	...	...	...	30·7
Rangpur	...	...	...	29·4
Darjeeling	...	...	...	28·8
Pabna	...	...	...	27·4
Bogra	...	...	...	24·3

24. *Eastern Bengal.*—Reference has already been made to the extraordinary expansion of population in Eastern Bengal, and the figures for the individual districts are merely given below for the sake of comparison with those of the other divisions:—

Dacca	...	...	+ 76·0	+ 8·5
Mymensingh	...	...	+ 105·2	+ 6·8
Faridpur	...	...	+ 44·3	+ 4·8
Bakarganj	...	...	+ 39·0	+ 8·0
Chittagong	...	...	+ 42·8	+ 6·8
Tippera	...	...	+ 89·4	+ 9·4
Noakhali	...	...	+ 74·9	+ 12·9

It will be seen at once that this natural division exhibits a very marked contrast to the other three. The causes of this difference will be discussed later; meanwhile attention may

be directed to the figures relating to deviation from the estimated normal expansion in the last 49 years. In four districts, the actual expansion is in excess of this, a fact which proves conclusively that the standard assumed is not too high. In three districts, the rate of expansion is below the normal. In the case of Bakarganj, the fact that the total expansion since 1872 has not reached the normal estimate of 50 per cent., is largely due to the great storm wave of 1876, which directly or indirectly caused enormous loss of life. In the case of Chittagong, emigration is a very constant and heavy factor. For example, in 1877 emigrants exceeded immigrants by 8 per cent. and in 1911 by 5 per cent. In the case of Faridpur, the northern half of the district is decadent and has long been suffering depopulation from causes similar to those affecting the neighbouring districts of Nadia and Jessore. This part of the district requires measures for the amelioration of malaria. The figures for the last decade show that only one district, Noakhali, has actually exceeded the estimated normal rate of growth but in the case of Tippera the deviation is very small. As we shall see by the fever indices referred to below, these two districts are at present less affected by malaria than any other part of the province :—

		1873—1921. Per cent.	1911-21. Per cent.
Bakarganj	...	... - 11·0	- 2·0
Chittagong	...	... - 7·2	- 3·2
Faridpur	...	... - 5·7	- 5·2
Dacca	...	... + 16·0	- 1·5
Noakhali	...	... + 24·9	+ 2·9
Tippera	...	... + 39·4	- 0·6
Mymensingh	...	... + 55·2	- 3·2

Fever Indices.

	1920.	1912.	Mean.
Dacca	... 16·4	7·1	11·7
Mymensingh	... 13·0	5·3	9·1
Faridpur	... 26·9	16·9	21·9
Bakarganj	... 13·9	10·6	12·2
Chittagong	... 20·2	6·8	13·5
Tippera	... 7·6	4·2	5·9
Noakhali	... 11·6	4·4	8·0

The figures relating to incidence of fever show that Faridpur is more seriously affected with malaria than any other district of Eastern Bengal. But the data relating to localities, given below, throws more light upon the relative distribution of the disease in this division :—

	Intensely malarious.	Malarious. Per cent.	Slightly-affected malarious. Per cent.
Faridpur ...	0	42·8	57·1
Dacca ...	0	20·4	79·5
Chittagong ...	0	20·0	80·0
Mymensingh ...	0	11·6	88·3
Bakarganj ...	0	8·5	91·4
Noakhali ...	0	5·2	94·7
Tippera ...	0	0	100

These figures accord with what we know about Faridpur, viz., that about half the district is malarious, although as a whole the disease has not yet reached the degree of severity met with in Western and Central Bengal. In Dacca, about a fifth of the district is malarious, the disease being most prevalent in parts of the Manikganj subdivision and Madhupur Jungle Tracts. In Chittagong, portions of the district are malarious; in Mymensingh, parts of Tangail and Jamalpur subdivisions are specially affected. In the other districts the malarious localities are few and far between. Altogether Eastern Bengal offers a striking contrast to the other parts of the province in respect to malaria, the only areas calling for immediate attention being those named above; and even in their case although certain localities are no doubt very badly affected, the problem of amelioration does not present the same urgent need of solution as that is offered by the districts in Central and Western Bengal. On the other hand, Eastern Bengal has its own special need, viz., malaria prevention. In its way this is as important as malaria amelioration. Signs are apparent pointing to the threatened extension of malaria eastward, and precautions are necessary, if the tragedy of Western and Central Bengal is not to be repeated. But this question does not concern us at the moment and must be made the subject matter of a further note.

25. *Conclusions as to districts in which work must be undertaken.*—Having examined figures relating to the various districts of the province we can state that in four, Burdwan, Birbhum, Hooghly and Nadia, where population has declined below what it was in 1872, measures of amelioration must be undertaken without further delay. And if this is admitted, the districts of Bankura, Murshidabad, Midnapur, Pabna, Jessore and Malda, which have lost population since 1921, must be included in the list. But this selection would exclude districts, such as Rajshahi and Dinajpur, which have long been suffering from malaria, and Bogra, in

which the disease appears to have recently undergone great intensification. The best method of coming to a conclusion is to arrange the data for all districts in the order of intensity :—

Deviation fr. m normal expansion, 1873—1921.	Deviation from normal expansion, 1911—1922.	Mean fever indices.	Percentage localities intensely malarious.
Per cent.	Per cent	Per cent.	Per cent
Hooghly ... - 53·6	Bankura ... - 20·5	Burdwan ... 58·6	Burdwan ... 72·4
Burdwan ... - 53·1	Birbhum ... - 19·5	Hooghly ... 47·6	Murshidabad ... 50·0
Birbhum ... - 50·5	Murshidabad ... - 19·3	Birbhum ... 46·6	Hooghly ... 47·8
Nadia ... - 50·8	Nadia ... - 18·1	Murshidabad ... 45·7	Bankura ... 46·1
Murshidabad ... - 47·5	Burdwan ... - 16·4	Nadia ... 45·3	Nadia ... 36·0
Midnapur ... - 45·4	Midnapur ... - 15·7	Jessore ... 43·9	Birbhum ... 31·3
Rajshahi ... - 45·2	Pabna ... - 12·4	Malda ... 40·9	Jalpaiguri ... 27·2
Bankura ... - 44·7	Jessore ... - 11·2	Bankura ... 39·9	Midnapur ... 26·9
Pabna ... - 34·9	Hooghly ... - 11·1	Midnapore ... 35·9	Malda ... 23·5
Rangpur ... - 33·7	Malda ... - 10·5	Dinajpur ... 35·8	Bogra ... 16·6
Dinajpur ... - 31·1	Rajshahi ... - 9·3	Khulna ... 32·7	Jessore ... 15·0
Jessore ... - 30·3	Dinajpur ... - 9·2	24-Parganas ... 32·4	Dinajpur ... 15·0
Bakarganj ... - 11·0	Jalpaiguri ... - 6·2	Pabna ... 30·4	Pabna ... 14·2
Khulna ... - 10·7	Faridpur ... - 5·2	Jalpaiguri ... 29·7	Darjeeling ... 9·0
Chittagong ... - 7·2	Rangpur ... - 5·0	Bogra ... 29·3	Rangpur ... 7·6
Faridpur ... - 5·7	Howrah ... - 4·7	Rajshahi ... 29·2	24-Parganas ... 3·7
Malda ... - 2·7	Darjeeling ... - 4·0	Rangpur ... 22·6	
Howrah ... + 6·2	Bogra ... - 3·4	Faridpur ... 21·9	
Bogra ... + 13·5	Khulna ... - 3·2	Darjeeling ... 21·6	
24-Parganas ... + 15·0	Mymensingh ... - 3·2	Howrah ... 21·9	
Dacca ... + 16·0	Chittagong ... - 3·2	Chittagong ... 13·5	
Noakhali ... + 24·9	24-Parganas ... - 2·2	Bakarganj ... 12·5	
Tippera ... + 39·4	Bakarganj ... - 2·0	Dacca ... 11·9	
Mymensingh ... + 55·2	Dacca ... - 1·5	Noakhali ... 8·0	
Jalpaiguri ... + 74·8	Tippera ... - 0·6	Mymensingh ... 9·1	
Darjeeling ... + 146·2	Noakhali ... + 2·9	Tippera ... 5·9	

APPENDIX III.

Relationship between obstructed Rivers and Malaria in Lower Bengal.

In Lower Bengal, it has long been observed that a deterioration of the public health, more especially from an increase of malaria, almost always occurs in association with the decay of the river systems of the delta. It is often stated that the blocking of river channels is the immediate cause of this ill-health and Government is continually being asked to arrange for the removal of obstructions from the beds of *khals* and rivers in order to diminish sickness and reduce mortality.

2. An extraordinary amount of misconception exists regarding the epidemiology of Bengal malaria. Malaria in the delta tracts, contrary to what has long been taught and is still generally believed, is rarely associated with a great excess of surface water, even when this excess produces actual water-logging of the land and damage to crops.* On the other hand, an intensification of malaria results wherever the drying-up of the delta tracts is carried beyond a certain point. This is particularly noticeable in the case of Burdwan, Hooghly, Nadia and Jessore. The Nadia Fever Commission of 1881 remarked in their report:—

“In fact as Dr. Sutherland observed in 1868, the district is becoming more and more arid, tanks and other reservoirs of water dry up even before the hot season, tanks full to overflowing in the rains rapidly dry up—facts which prove that there has been no increase or excess of moisture in the soil. The very jungle, contrary to the assertions of some natives we met, as Dr. Lidderdale points out, is of a kind which prefers a dry to a damp habitat.”

3. More recently Babu Bhola Nath Banarji, Executive Engineer in charge of the Special Drainage Division, who has been investigating conditions in Jessore, states in his report of September 1912:—

“If we draw a line from Pultia on the Ichamati to Jhikergacha on the Kabadak, the country lying to the north of this line may be generally taken as suffering from scarcity of good drinking water . . . This is due to the silting of this part of the country by action of deltaic rivers; smaller *bils* do not get any flushing from the rivers . . . There are no big-sized tanks in most of the villages, and people have to travel a long distance to the nearest river or *bil* for their supply of drinking water. It is reported that tanks in those parts do not hold water, but dry up with the subsidence of the rivers, and are consequently too expensive to be excavated below the subsoil water level. It will not be out of place, if we note the fact that the tracts away from the river and also places which complain of scarcity of water and where *bils* and pits dry up much earlier, are not free from malaria as it ought to be, if dampness alone was the cause of malaria. Most of Jhenida subdivision and parts of the Magura subdivision, where people suffer from want of water and which are away from the big rivers and high lands constitute the most malarious parts of the district.”

*This is the exact opposite of what takes place in naturally higher and drier areas, such as the Punjab and Upper Burma.

4. The increase of malaria which has gone on side by side with the partial drying-up of certain of the delta tracts of Bengal is in accord with observations in other parts of the world, for it is well-known that large swamps usually remain quite healthy while they are abundantly supplied with water, whereas they often tend to become malarious during the process of reclamation and may remain intensely unhealthy as long as they are only partially dried. The explanation of this is that large water surfaces are rarely a source of anopheles mosquitoes, whereas the grassy or weed-grown edge of a ditch, stream or pool, may often be found to harbour enormous numbers of their larvæ. And the partial draining or drying-up of a swamp greatly increases the *ratio* of this dangerous "edge" and may lead to an enormous increase in the output of anopheles mosquitoes. When this fact is grasped, the great increase of malaria that has gone on *pari passu* with the decay of rivers and the drying-up of delta tracts in Bengal may be readily understood.

5. The Presidency Division, which includes the western half of the Gangetic delta, is now much more malarious than when its network of river channels was active. Formerly, it was kept free of malaria by the same agency which maintained the activity of these rivers, namely *the flooding of almost the whole surface of the country during the rainy season with spill water from the rivers*. This flooding of the country temporarily levelled up the surface, abolishing for the time the greater part of the dangerous "edge" of the myriads of *dobas*, ditches and pools, which would otherwise have supplied enormous numbers of anopheles mosquitoes. And although mosquitoes undoubtedly increased when the floods began to fall, the season was then so far advanced that no great spread of malaria could occur. This was probably owing to the fact that anopheles mosquitoes do not become infected with malaria when the temperature has fallen below a certain minimum, neither do they survive sufficiently long to gain infection from malarious patients and become capable of transmitting it again if the atmospheric humidity is low. The flooding of the country with spill water from the rivers, besides preventing malaria, had the effect of flushing the *bils* and it also kept the water-courses open. This was owing to the fact that the enormous volume of comparatively clear water, which had to be discharged from the land surface at the end of each flood season effectually scoured out every channel. Hence the increase of malaria in the delta tracts of Bengal, the silting up of the rivers and *khals* and the obstructed condition of the drainage to which the increase of malaria has been commonly ascribed, are all due to a common cause, namely, *the shutting-out-spill water from the surface of the delta*.

6. The following passage extracted from an unpublished report explains the mechanism of the process of the river decay in the delta—:

"*The description of an active delta branch river*.—If we examine the head of an active branch river or delta effluent, we may observe that the off-take from the main river is roughly triangular or funnel-shaped, that it gradually narrows to a sort of neck where it cuts through the relatively high banks of the main river, and that after passing through this neck the channel usually widens out a little as it enters the lower country beyond. Suppose we take a boat and sail down one of these effluents during the flood season. We shall first of all observe that its banks are raised slightly above the level of the surrounding

country so that the land slopes away from the river. And if the level of the river is high, we may note that water is spilling over wherever the banks happen to be a little lower than usual and is rushing away inland. At the height of the flood season, we shall find that, with the exception of the narrow strip of higher land on either side of the river, which is usually densely crowded with villages, the country appears to be almost wholly submerged. But the wide expanses of water, which extend in some directions as far as the eye can reach, are broken here and there by distant lines of trees and dense masses of vegetation marking the presence of ridges of higher land, which bound the channel of some other stream. As we pass downwards, we shall come after a time to the mouth of a small creek or *khal* into which water from the river is flowing. Entering this *khal*, we shall find a narrow winding channel passing possibly for several miles inland. At first its banks are fairly high and like those of our river and lined with villages; but if our boat goes forward, sooner or later, we shall pass out into one of the wide expanses of water that we have noted from the banks of the river. On returning to the river and continuing to travel downstream, we pass the mouths of a large number of the *khals* which serve to connect it with lowlands in the interior. These inland depressions form a series of lateral spill basins on either side of the river, and whenever its flood-level is higher than that in the lateral basins, water continues to flow from it through the *khals* into them. If we examine the same river, when the flood season is over and the water is falling, we shall find great changes occurring. In the first place, the current entering the head is sluggish and the wide triangular off-take is rapidly silting up, with the result that a sort of bar is forming across the mouth and probably a large sandbank is showing well above the water in the centre. When we reach the neck of the effluents, we shall find that a decreasing amount of water is entering from the main river, but where the channel narrows there is probably as yet a fair current. Passing down-stream, we shall find that the banks are now well above the river-level and no water is spilling over them; moreover, the shorter and shallower of the *khals* are probably already dry, although the deeper ones still contain water. *But whereas we noticed during the flood that water from the river was passing into these khals and flowing away inland we now find their current reversed with water from the interior of the country pouring through them into the river channel.* And on passing up a *khal*, we find also that the open country beyond, instead of being submerged as at our former visit, has now become a huge expanse of rice-fields with the crops nearly ready for cutting. The *khal* winds through those rice-fields and finally opens into a *bil* or permanently-flooded area of lowland in the centre. *Bils* which are the lowest parts of the spill basins on either side of the river form the drainage sumps of the country, and the *khals* which lead from them are the discharge channels through which the immense volume of water contained by the spill basins during the flood season eventually passes into the river after having deposited its silt and fertilized the land.

7. *"The mechanism of silting and scour.*—Broadly speaking, a stream of water, such as a delta branch river which flows through a channel composed of sand and silt, may be said to be in a state of silt-saturation. That is, it always tends to carry the maximum amount of silt in suspension that its velocity will allow; and if the velocity of a silt-laden delta effluent were to remain constant it would neither scour nor deposit silt. Hence the silt-laden water, which has entered a branch delta channel from the main river, can only take up more solid matter in suspension if its velocity increases, and on the other hand, it must deposit some of its burden of silt wherever its velocity diminishes. The velocity of a stream of water is largely governed by its volume, its depth and the slope of its surface. And in the case of delta rivers, which experience alternating periods of flood and low water, these factors are constantly varying so that the velocity of the stream is subject to very frequent changes. As a consequence of this, most delta channels (especially those above tidal influence) tend to silt up at certain times of the

year. During the flood season, active delta effluents take off from the main river much larger volumes of water than can be accommodated in their channels; and this surplus water spills over their banks or finds its way into their lateral spill basins by backing up through the *khals*. Thus it comes about that an immense volume of water collects upon the surface of the low-lying country adjacent to an active delta river and is held up there as long as the stream is in flood. And at the end of the flood season as the water-level in the stream is falling, this huge volume of spill water escapes, producing tremendous scour in every *khal* or discharge channel through which it passes, flushing them out in a very effective manner. This scouring action extends to the river-bed also, and thus effectually counteracts the natural tendency for it to become silted up at the end of the flood season.

8. *The system of a delta effluent.*—A delta effluent possesses a very complex system, consisting of (A) the head or off-take from the main river, (B) the central channel, (C) the numerous *khals* or small branches leading off from the central channel, one season acting as distributaries and at another as feeders, and (D) the lateral spill basins on each side of the central channel of the effluent, with their *bils* or drainage sumps, which are connected with the river system by means of the *khals*. Under natural conditions, a river system of this kind performs a double function: during low water the *bils*, *khals* and the central channel serve the purposes of drainage, carrying off water from the depressed land surfaces of the lateral river basins: but in the flood season the water-courses cease to be drains, and entirely reverse their action, taking on at this time the character of irrigation channels. It is to this system of natural irrigation that active deltas owe their fertility. But this fact has attracted little attention in Pengal, so that the importance of maintaining free river spill from the point of view of agriculture has been almost entirely overlooked. Moreover, the other important function of the river spill in the delta to provide for the natural scouring-out of the water channels has almost escaped notice with the result that irretrievable damage has been done to the rivers in many parts of the delta owing to the restriction of free river spill as a direct consequence of the construction of thousands of miles of embankments. These embankments have been designed either for the controlling of the rivers or for the purpose of railways and roads. But whatever their object, their effect has been the same, namely, in the first place, preventing the flood irrigation which formerly enriched the land and kept it free from malaria and in the second place, disorganizing the natural system of flushing or scour which is so essential to delta channels if they are to remain open. As a direct result of these embankments, the soil of many districts has become impoverished, harvests have diminished and malaria has increased; moreover, silt and sand have accumulated in the beds of many of the rivers to such an extent that they have ceased to be active streams.

9. *The importance of river spill.*—The importance of free river spill in keeping open the channels of the delta is, perhaps, more easily grasped if a few points are illustrated by figures. Let us take, the case of an active delta effluent with a total course, allowing for curves of about 150 miles. A stream of this length will traverse in a direct line about 100 miles of country and in its active

state may possibly feed 1,000 square miles of lateral river basins. At flood season, it will take off from its parent stream a far greater volume of water than that required to completely fill its own channel. This excess water spills over its banks and probably submerges a great part of the 1,000 square miles of lowland or spill basin adjoining it. If, at the height of the flood, the mean depth of water upon the 1,000 square miles of land surface is three feet, over 83,000,000,000 cubic feet of water will be held up alongside the river, ready to be discharged from that channel as soon as the flood-level permits. At the height of the flood, the spill water on the land surface becomes nearly stationary and owing to its loss of velocity is forced to deposit almost the whole of the solid matter it originally carried. As the level of the river falls, this enormous volume of silt-free water begins to move once more and passes gradually from the surface of the country into the river channels. And as soon as it is in motion, it begins to take up solid matter into suspension and scours out the channels through which it passes. If the flood water on the 1,000 square miles of spill area runs off at the rate of an inch in the 24 hours it will form a stream larger than the Thames at Teddington with a volume of 27,000 cubic feet a second; and if, in its passage through the *khals* and the river channel, this water attains a mean velocity sufficient to enable it to lift and carry away one volume of silt in, 400 (the water of the Ganges and Hooghly during flood often carries 250 parts of silt per 100,000), it will have removed by the time it has entered the sea over 200,000,000 cubic feet of solid matter from the beds of the watercourses along which it has flowed. Roughly speaking, this would represent a deposit a foot deep and 100 feet wide in about 400 miles of channel. This is the kind of scouring-out process which goes on during the time of a falling flood throughout the whole length of an active effluent channel below the off-take; and it is entirely owing to this process that the upper reaches of branch channels in the delta are kept open and active.

10. *Silting at the head of an effluent.*—The off-take of a delta branch river, as we have already seen, is wide at the mouth and contracted at the neck. This contraction has a double effect: during a falling flood in the main river it serves as a check to the velocity of the entering water with the result that silt is deposited in the wide triangular mouth: and with a rising flood in the main river an increasing amount of water is poured into the off-take with the pressure of the rising flood behind it, producing tremendous scour at the contracted neck so that much of the silt and sand deposited in the off-take during low river is washed away. Therefore, the tendency of a delta effluent to silt up at its head during a falling flood is largely counteracted by this tendency to scour with a rising flood; thus as long as every other part of its system is working efficiently, the vitality of the stream is restored at every flood season. The silting at the off-take when the main river is falling seems to be a protective process which automatically shuts off the supply of silt-laden water at a time when the decreasing velocity of the current would tend to cause a deposition of silt in the lower channel. And just at the time when this silting of the off-take is taking place the lower channel is being thoroughly scoured out by the run-off from its lateral spill basins. Hence a silted-up off-take and deeply-scoured lower channel would appear to be the natural condition of a healthy branch delta river at the end of the flood season.

11. *Silting-up of the khals.*—In the case of *khals* leading from the *bils*, an alternate process of silting and scouring also occurs. But in this case the process is the exact opposite of that which occurs at the off-take of a branch river, for silting takes place with a rising flood and scour during a falling flood. We have already seen that *bils* are the lowest portion of lateral river basins which form the spill reservoirs of the rivers in their vicinity. *Bils* are usually possessed of both afferent and efferent *khals*. The former are merely the drainage channels which serve to carry the water from the periphery of the basin to the *bil* or drainage sump, whereas the latter are the channels through which the water collected in the lateral spill basins is finally discharged into the river during a falling flood. Spill water enters river basins either by free flow over the banks of the rivers or through small *khals* which take off from the river. During high flood in the river also water not only pours over the banks into the basins but *backs up through the khals or discharge channels until the level in both basins and river is the same, and at this time silt, often in large amount, is deposited in the khals*. But when the water-level of the river falls, the rush of clear water from the spill basins clears out these channels most effectually as the following example from the Dacca district will show. In 1877, there was a very low flood in the Brahmaputra, and the *khals* in the Manikganj subdivision became partly silted up as a result of it. But in 1879, there was a high flood and it is recorded that—

“The increased volume of water which left the surface of the *tanas* during October and November 1879 had the effect, as stated by the District Engineers, of deepening some of these *khals* by as much as 2½ feet.”

12. *The vitality of a delta effluent depends upon the integrity of its spill basins.*—Although it is commonly believed that the decay of a delta effluent is primarily due either to the blocking of its off-take or the silting-up of its channel, changes of this sort are not the real cause of the trouble. An effluent system, as we have already seen, consists of a head or off-take from the main river a central channel, and a net-work of *khals* together with a series of lateral basins into which the river spills over when it is in flood. And it is these spill basins that form the most vital, and at the same time the most vulnerable, part of the whole system. For while they continue to receive an adequate supply of spill-water at every flood season, the vitality of the whole effluent system is maintained, whereas deterioration of the central channel, the *khals*, and the off-take through the permanent accumulation of silt is bound to occur whenever the spill area of a river is restricted, either by natural changes or as a result of artificial interference. Mr. Addams Williams, in a recent series of lectures, has graphically described the silting that has been going on in a certain of the tidal channels in the lower parts of the delta, pointing out that this condition occurs wherever tidal spill is restricted. And exactly the same principle applies in the case of the fresh-water channels of the upper delta, the only difference being that in this case we are dealing with a spill of fresh-water during a flood season, in place of a spill of salt or brackish water at every high tide. Once the vital importance of this process of “flush alternating with flood” has been clearly grasped, the necessity for maintaining the integrity of the spill area of delta channels can readily be understood. For it follows

that when the integrity of the spill basins connected with the effluent channels of the delta is destroyed or if from any cause the volume of the flood water passing into these basins is greatly reduced, water-courses are sooner or later bound to be obstructed by silt and sand which gradually accumulates in their beds.

13. *The decay of a branch river in the delta.*—From what has been stated above, it should be obvious that, in the absence of this natural system of flushing, effluent channels can never be self-cleansing, but must eventually become more or less completely blocked. To make this point clear, let us take the case of a hypothetical delta effluent that no longer spills over the country. Suppose this stream to possess a current whose mean velocity during flood exactly equals the velocity at which silt-laden water from the main rivers enters it. In this case the net amount of solid matter carried down to the sea by the effluent during the flood season cannot exceed the amount brought into its channel from the main river, and the scour that occurs in the deep and narrow parts of its channel will be exactly balanced by the silt deposited in the wide and shallow reaches. But when the volume of the stream decreases after the flood season, its velocity will, of course, diminish and a certain amount of silt will then be deposited in its bed. And if year after year this process is continued nothing can prevent the channel from eventually becoming almost completely blocked up. In actual practice, other factors, such as rainfall, etc., have, of course, to be taken into account. But broadly speaking, a process resembling that just described is now going on in many of the river channels in the older parts of the Gangetic delta. For, on examining one of these dying rivers, we find, in the first place, that, at end of every flood season, silt begins to accumulate in its bed as the velocity of the current diminishes, and remains there because the run-off of relatively clear water from the lateral river basins is so small owing to the shutting-out of river spill that it cannot provide an efficient scour. In the second place, we may see that the silt deposited in the *khals* when water from the river is packed up in them at a time of flood, remains in their channels owing to the fact that the *bils* with which they are connected only provide a very little water for flushing out their beds when the water-level of the river falls. From what has been stated, it should be clear that the accumulation of silt in the channels of a delta river system is directly due to the greatly-diminished supply of water received by the adjacent land surface; and this silting-up must not be regarded as the primary cause of the decay of the river channel, but should rather be looked upon as a symptom of the disorganization of the system of lateral spill basins which has led to their being deprived of an adequate supply of water during the flood season. *A change of this sort may come about naturally, as for example, when a delta river has raised its banks to such an extent that water can no longer spill over them even at high flood. But it appears more often to be the result of artificial interference, such as that occasioned by river embankments or to the shutting-out of free river spill owing to the construction of roads and railways.* The causes of river decay are, therefore, to be sought, not in the affected channels themselves, but upon the adjacent land surface of the delta. It follows that attempts at merely clearing the bed

of a damaged waterway can rarely effect any permanent improvement. Moreover, work of this kind may in some cases actually accelerate deterioration, as, for example, when the off-take of a stream, already shut off from its spill basins, is dredged during low flood so as to allow a larger volume of silt-laden water to enter it from the main river. A case of this sort occurred recently near Faridpur station where two or three years ago the dredging of the head of a small river, whose spill had been somewhat limited by the raising of a road that ran alongside it, was followed by the tremendous silting-up of the off-take and channel. It is possible also that the present deplorable condition of the upper reaches of the Bhagirathi is partly a result of the attempts that have been made for years past to keep the head of that river open during the season of low water, whilst at the same time free river spill during flood has been almost entirely prevented by means of embankments."

14. In the past, the question of river decay in relation to the public health has been considered only from the point of view of drainage, for medical men and engineers, as well as the lay public, have been obsessed by the idea, *firstly*, that "obstructed drainage" is the cause of Bengal malaria; *secondly*, that the rivers in the delta are mere drainage channels; *thirdly*, that the collection of silt and other obstacles in the beds of these channels is the cause of this obstructed drainage; and, *fourthly*, that this condition can be remedied by the removal of obstructions from riverbeds or by special drainage schemes. It is these views which led to the passing of the various Bengal Drainage Acts; the same ideas inspired the Special Drainage Committee of 1906; and similar notions underlie every recent proposal for the clearing of dead riverbeds and carrying out of large drainage projects with the idea of improving the public health of rural areas. But none of the remedies yet proposed can possibly effect the purpose intended. For the evils which require relief are due neither to water-logging nor to deficient drainage. On the contrary, they are the results of a greatly diminished supply of surface water. As regards the clearing out of dead riverbeds, a measure which has often been suggested as a remedy for the great deterioration of the public health that has taken place in many parts of the delta, it may be remarked that, in the first place, this measure will not increase the total supply of water nor prevent the growth of weeds, and although it might lead in some cases to more water being temporarily diverted down one or other moribund waterway, in the conditions generally existing, this result can only be obtained at the expense of other channels, and may, therefore, do as much harm as good.

15. Among the arguments put forward in support of attempts to improve dead rivers by the clearing-away of fishing weirs, and *kumars* and by re-opening, if possible, the portions of their beds that have already been brought under cultivation, the question of depopulation has been introduced; and, in a recent case, it has been suggested that "the removal of obstructions alone would do immense good to the drainage and by keeping the river alive, the depopulated villages on its bank may again revive" It may be remarked that the occurrence of depopulation is continually being urged as a reason for carrying out projects of this nature. This being so, it will be well to briefly discuss this phenomenon of depopulation, which, in the

popular mind, is supposed to be a direct result of disease. But this view, it may be remarked, only explains *how* a reduction of population is brought about, and provides no answer to the more fundamental question of *why* a population declines. Yet it is the latter problem that must be solved if we are to check the evil. And in this connexion, the following passage from Mr. Udney Yule's *Theory of Statistics* is illuminating:—

"If the population of a district is increasing at a rate above the average, this is *prima facie* evidence that its industries are prospering: if the population is decreasing or not increasing as fast as the average, this strongly suggests that the industries are suffering from a temporary lack of prosperity or permanent decay."

16. The population of Nadia and Jessore districts, which have long showed a tendency to decline, are dependent almost entirely upon agriculture; and the condition of that industry may be gauged from the fact that during the decade 1901-11 the outturn of crops, per acre cultivated, has fallen very short of the normal in both Jessore and Nadia, the deficiency being over 30 per cent in the former district and nearly 40 per cent in the latter. The cause of this deterioration may be inferred from the following quotations:—

"*Diminished fertility of the soil in Nadia.*—There is a consensus of opinion among Europeans and natives that, except in the lower lands used for the rice crop reaped in the cold weather, there is a distinct decrease in fertility of the soil of Nadia. Considering that no land except that used for sugarcane and tobacco is ever manured, and that the Ganges floods which are so fertilizing are shut out by the embankments of the rivers, it is not to be wondered at that gradually the soil should become partially exhausted." (*Report of the Nadia Fever Commission of 1881.*)

"There is no doubt that the soil is getting less and less fertile. The average yield of crops is low as will be seen from the fact that the average yield of winter rice is 805 lbs. per acre and of autumn rice 835 lbs., while in Jessore it is 1,145 and 870, and in the 24-Parganas it is 843 and 1,014, respectively. Another noticeable feature is that it is becoming necessary to allow the land to lie fallow for longer periods between croppings. During the five years from 1904-05 to 1908-09 only about 40 per cent. of the total cultivable area was actually cropped." (*Bengal Census Report of 1911.*)

"In Nadia the soil is deteriorating on account of the gradual silting-up of the rivers." (*Report of the Director of Agriculture, 1910-11.*)

"It is reported that cultivation has suffered from the deterioration of the rivers, which year by year used to deposit a layer of silt on their banks and in the *bils* during the flood time . . . This natural form of fertilization has ceased. . . . The area under *aman* rice is contracting, owing to deficient floods." (*Jessore District Gazetteer.*)

"Owing to the rivers having silted up at their head . . . the periodical inundations, which used to occur when they were in flood, have ceased. In the Jhenida sub-division there have been no floods for the last 15 years, and the country is the poorer for it, while in the Magura sub-division the floods are now comparatively slight and the land is not fertilized to the same extent as formerly." (*Jessore District Gazetteer.*)

17. The facts recorded in the passages quoted afford an adequate explanation of the decrease of population that is going on in Jessore and Nadia. Any increase of population would be impossible under the circumstances mentioned. Depopulation, therefore, is occurring in these districts, because the land can no longer support a population as dense as it once could, owing to the decrease that has taken

place in agricultural production. To put it briefly, the population must decline, because the available food-supply has been diminished.

18. In Lower Bengal, river decay, agricultural deterioration, increased prevalence of malaria and depopulation are all due to one common cause; namely, the shutting-out from the land surface of the delta of the flood water which, while it remained on the surface of the country, fertilized the soil, kept down the number of anopheles mosquitoes, and thus prevented malaria, and when it passed back into the river channels effectually scoured out their beds and so preserved their vitality. And the evils that have followed the stopping of these annual floods cannot be remedied by schemes for the tidying-up of dead river channels or the further drying-up of a country which is already suffering acutely from a greatly-diminished supply of surface water. From every point of view, therefore, projects of this sort must be condemned. They are based upon an entire misconception, *firstly*, of the character of delta channels; *secondly*, of the origin of their decay; *thirdly*, of causes underlying the increase of malaria in the delta tracts; and, *fourthly*, of the factors responsible for depopulation. Nearly every scheme for the improvement of the sanitation of rural areas by drainage projects or the betterment of rivers that has been put forward in recent years is open to these fundamental objections. Many of these proposals aim at removing from the land surface of the delta as much water as possible, usually by some system of drainage. But measures of this sort, if successful in diminishing the surface water during the rainy season, will almost certainly intensify malaria and increase depopulation—the very evils that they are intended to remedy. On the other hand, any scheme which will provide for *increasing* the supply of surface water during the monsoon and for so controlling it that neither too much is collected on the land for agricultural purposes nor too little allowed to remain there for health, ought to receive every consideration, in view of the fact that we now possess definite evidence to show that in Lower Bengal the greater the amount of flooding of the land surface during the rainy season, the less malaria will there be.

APPENDIX IV.

Drainage of *Bils* as a Public Health Measure.

For many years, it has been supposed that the mitigation of malaria in the rural tracts of Bengal can best be accomplished by drainage. And with this view, proposal for the drainage of large swamps or *bils* are frequently put forward as sanitary measures. But an extraordinary amount of misconception exists regarding the epidemiology of Bengal malaria, because recent investigation has shown that contrary to what has long been taught and is still generally believed, malaria in the delta tracts is not associated with a great excess of surface water, even when that excess produces actual water-logging of the land and damage to the crops.* On the other hand, an intensification of the disease occurs wherever the partial drying up of the country is carried beyond a certain point, this condition being particularly noticeable in the districts of Burdwan, Hooghly, Nadia, Jessore, Murshidabad, and in a few parts of the Dacca and Rajshahi Divisions.

2. The Nadia Fever Commission of 1881 remarked in their report—

“In fact, as Dr. Sutherland observed in 1868, the district is becoming more and more arid, tanks and other reservoirs of water dry up even before the hot season, tanks full to overflowing in the rains rapidly dry up—facts which prove that there has been no increase or excess of moisture in the soil. The very jungle, contrary to the assertions of some natives we met, as Dr. Lidderdale points out, is of a kind which prefers a dry to a damp habitat.”

And more recently Babu Bholanath Banarji, Executive Engineer, in charge of the Special Drainage Division, who has been investigating conditions in Jessore, states in his report of September 1912—

“If we draw a line from Pulia on the Ichamati to Jhikergacha on the Kabadak, the country lying to the north of this line may be generally taken as suffering from scarcity of good drinking water This is due to the silting of this part of the country by action of deltaic rivers There are no big sized tanks in most of the villages, and people have to travel a long distance to the nearest river or *bil* for their supply of drinking water. It is reported that tanks in those parts do not hold water, but dry up with the subsidence of the rivers, and are consequently too expensive to be excavated below the subsoil water level. It will not be out of place, if we note the fact that the tracts away from the river and also places which complain of scarcity of water and where *bils* and pits dry up much earlier, are not free from malaria, as it ought to be, if dampness alone was the cause of malaria. Most of the Jhenida subdivision and parts of the Magura subdivision, where people suffer from want of water and which are away from the big rivers and high lands, constitute the most malarious parts of the district.”

3. The view expressed in the above passage confirms the statement made by Babu Umesh Chandra Ghosh, B.L. (one time the Chairman of the Jessore Municipality, and Vice-Chairman of the District Board) in a pamphlet published in 1905, to the effect that—

“It may be pointed out that the unhealthiness of this district (Jessore) is not due to the humidity of the soil caused by the presence of the *bils*, but to the diseased condition of the rivers. Some of the rivers are half dead, while others are slowly dying. The districts of Bakarganj and Faridpur, which abound

* This is the exact opposite of what takes place in naturally higher areas such as the Punjab and Upper Burma.

with *bils* of various sizes, are not unhealthy. Pargana Telihati, which consists of more than 300 villages, is mostly covered with *bils*. If one looks at a map of the pargana he will see nothing but a vast sheet of water, dotted with elevated earthen mounds here and there, which are utilized for the purposes of human habitation. The people, though living in these *bil*-clogged villages, are robust and healthy. There can be no doubt that the existence of the *bils* is not the cause of the malaria which prevails in this district.

4. The fact that in Jessore malaria is most severe on land which is relatively high and in areas which are suffering from a lack of water rather than an excess, is in accord with many earlier observations in other parts of Bengal. For example, Dr. Jackson, when reporting in 1872 on the outbreak of epidemic fever in the eastern portion of Burdwan district, states that—

“It was more fatal in the higher and better drained than in the low lands.”

Dr. Wise, writing in the same year about the occurrence of severe malaria in the Manikganj subdivision of the Dacca district, remarks :—

“The causes which have rendered this subdivision the most unhealthy in the whole district are not, I think, difficult to indicate. It is the most northern, the most elevated, and the driest in the district. The rainfall is much less than at Dacca.”

The Sanitary Commissioner, reporting in 1877 on a severe outbreak of malaria in the Keshpur and Narangarh circles of Midnapur, observes that—

“These circles are well raised and comparatively dry, suffering as a rule rather from drought than excess of the moisture.”

The Civil Surgeon of Faridpur, commenting in 1884 on the prevalence of malaria in the thanas in the north-west of that district, adds that they—

“Are situated high above the level of the floods.”

And a year later, the Sanitary Commissioner quotes the Deputy Magistrate of Chuadanga subdivision of the Nadia district as remarking that—

“The prevalence of fever in his subdivision appeared to be due to deficient water-supply.”

5. The instances cited above suffice to show that, unlike other parts of India, possessed of widely different physical configuration and climate, the delta tracts of Bengal almost invariably show an increased prevalence of malarial infection whenever the amount of water, which ordinarily collects on the land surface during the wet season, is seriously diminished; whereas villages in the midst of large swamps or situated in badly drained low-lying areas liable to flooding during the rainy season often possess populations of superior physique, vitality and fecundity, and at the same time enjoy a comparative immunity from malaria. This fact has

frequently attracted attention. The Lieutenant-Governor of Bengal, in a note upon the Burdwan fever published in 1873, remarked—

“I am very much struck, in comparing the population returns with the map, to observe that the highest population almost exactly corresponds with the tract marked by Colonel Haig in the deepest colours as most in want of drainage and improvement, and with a similar tract in Midnapur, which has similarly suffered from flood, and the difficulty of carrying off the water, as I myself witnessed a few months ago. Colonel Haig gives a vivid, and, I may say, horrible description of the tract, as one in which there is absolutely no healthy flow of water whatever, and no escape—a hollow in which the water stagnates, and a mass of decaying vegetation festers in it; where noxious fumes exhale in the hot weather, while the damp of the raw cold weather, and extremes of temperature then prevailing render it still more unwholesome. Yet, in the reeking swamps, the human race seems to have multiplied to a greater extent than any where in India—perhaps in the world. It seems, as if it may be almost said, that we cannot have too much water in this country, and that, in such conditions in this climate, all sanitary science notwithstanding, the human race multiply till it is wasted by great calamities. As it is, Colonel Haig truly observes that up to this time there has been much less fever in these reeking swamps than in the higher parts of Burdwan and Hooghly where there is a sensible natural drainage.”

In 1884 also, Dr. Ghosh, Deputy Sanitary Commissioner, when reporting on the health conditions of villages in the Bistupur thana of the Diamond Harbour subdivision of the 24-Parganas, observed that—

“These villages are all situated on the *bils* (cultivated, and known as the *bada*) in connection with the Kaurapukur *nala*, the huts are peeping out of a vast sheet of paddy fields, and almost every house has to be reached by means of a dug-out. Paddy cultivation, fishing and duck farming are their principal occupations. The people seem to be in perfect health, children fat and healthy, women strong and hard-working, very different from what is seen in a Bengal village. This proves what I have always maintained, that moisture *par se* is not the origin of malaria. There is too large a quantity of water here for it to be injurious Go to the south of the Khulna district and parts of Barisal, cultivated very largely with paddy, and there one cannot help being struck with the fine robust constitution of the people.”

6. This extraordinary immunity from fever often enjoyed by *bil* villages greatly impressed the medical men and other officers who investigated the Burdwan epidemic. Colonel Haig, R. E., reported that—

“No connexion has yet been traced between the intensity of the fever and proximity to stagnant marshes On the contrary, there are numerous facts which are absolutely irreconcilable with such a supposition. Some of the villages on the borders of the Dankuni *jolas* have been distinguished by comparative immunity from the fever, while it has raged in others which are quite free from swamps. The Collector reports that Chanditola and the neighbouring village at the south-west corner of these swamps have generally been considered “exceptionally healthy.”

And Mr. Grant, Magistrate of Howrah, remarked in the same connexion—

“I have only to say that everyone who has studied the subject must have been struck with the fact that the fever constantly (indeed very generally) avoids these horrible swamps.”

Babu Ramesh Chandra Mukharji reported also that—

“The villages situated in the approaches to, and in the very hearts of, the great marshes—the Rajpur *jhil*, the Kanderah *jola*, the Bura *jola* and the Panchla *jola*—have enjoyed comparative immunity from fever.”

And Dr. Sutherland observes that—

“The village of Jenkari is on the edge of a vast tract of swampy country and yet is healthy. Not a few examples of the same kind are to be found near.”

In other portions of the Burdwan Division the experience of Drs. French and Jackson afforded further confirmation of the view that villages in very swampy situations as a rule escaped a serious amount of fever. The former officer remarked that—

“Villages in the vicinity of large *jhils* suffered very little, if at all, from the fever.”

And the latter stated very definitely that—

“Villages on *bils* have not been more unhealthy than others, but quite the reverse, even when their sites are flooded in the rains.”

7. The condition of things described above is by no means exceptional. Lieutenant Colonel (now Sir Leonard) Rogers, I.M.S., as recently as 1909 called the attention of the Simla Malaria Conference to the fact that—

“In the 24-Parganas, the Sundarban area, which was practically flooded, was the most healthy part of the district.”

And Lieutenant-Colonel Fry, I.M.S., in his Second Report on Malaria, points out that villages in the Singur and Chauditola thanas of Serampur subdivision of Hooghly (an area in which the drainage is the described as being “very congested”) remain singularly free from malaria. The author of this note also has recently reported on the existence of a similar condition of things in the Howrah district and in the *bil* tracts of Madaripur and Dacca, which all enjoy a remarkable immunity from malaria in spite of numerous swamps and a general excess of surface water. Moreover, there is an exceedingly simple explanation of this apparent anomaly.

8. Ross has shown that the prevalence of malaria in any locality bears a definite relation to the ratio borne by the number of anopheles mosquitoes present to the human population residing there. And he has also pointed out that malaria cannot exist unless the actual number of anopheles mosquitoes per head of the population exceeds a certain minimum. The number of anopheles mosquitoes occurring in any place is governed by the facilities which exist for their breeding, and although insects can only multiply where there is water, the character of the collections of water available for their breeding exerts an important influence upon the actual number produced. Observations have shown, in the first place, that small collections of water are relatively more favourable to the breeding of mosquitoes than large ones; and, in the second place, that it is only the edges as a rule, especially in the case of large collections of water which afford shelter to their larvæ. And, broadly speaking, it may be stated that the number of anopheles present in a

definite area is probably determined by the amount of water "edge" existing there. If the ratio of edge is low, the anopheles will be relatively few, and if it is high, it is certain that they will be exceedingly prevalent; and as the prevalence of anopheles mosquitoes varies with the amount of water edge, so also will the intensity of malaria tend to vary in the same way.

9. A little consideration will show that the amount of water edge in any area is not governed by the extent of water surface present there; for a large collection of water may have very much less of the dangerous edge than that provided by a number of smaller pools, which in the aggregate possess a very much smaller surface. If, for example, we take the case of a circular *bil* about one mile in diameter, we have, roughly speaking, three miles of edge, or in other words three miles of potential breeding places for mosquitoes. If this *bil* were to be drained absolutely dry, the three miles of dangerous edge would of course be abolished, and the *bil* would cease to be a danger from the point of view of malaria. But if we cannot entirely dry the *bil*, drainage may be a very risky measure, if it does not reduce the amount of water edge existing during the rainy season (the only period which we need bother about because it is the only season when malarial infection can be contracted). The attempt at drainage under these circumstances will not diminish malaria, but on the contrary it may lead to an actual increase of the disease. The reclaiming of La Chartereuse swamp near Bordeaux is a classical instance of this. Work was commenced in the summer of 1805 with the result that an appalling epidemic occurred causing 18,000 cases of pernicious malaria and 3,000 deaths. Similar results have been observed in England also. Dr. Paley, reporting to the Privy Council in 1860 on the subject of an epidemic of malaria at Peterborough, remarked—

"The first effect of the improved drainage of the large ten districts of our neighbourhood, especially those which were formerly constantly covered with water, like Whittlesea Mire, has been rather to increase the prevalence of ague."

The ten districts of England are now comparatively healthy, but, as is well known, they were specially reclaimed for wheat cultivation, and the requisite drying up of the soil was obtained by the use of pumps actuated by windmills, replaced in latter years by steam engines.

10. In the case of the delta tracts of Bengal, the configuration of the land surface, the heavy rainfall it experiences, and the character of the crops cultivated make it impossible to dry up the country during the wet season, and in these circumstances attempts at reducing the amount of water on the land surface are almost certain to be followed by an increased amount of water edge, an increased production of anopheles mosquitoes and an increased prevalence of malaria. This point can be easily made clear by means of the diagrams attached. Eastern Bengal and other areas subject to flooding are kept healthy, owing to the fact that in these areas all the hollows, pits, *dobas* and irregularities of the land surface, the edges of which would harbour mosquito larvæ if they contained a limited amount of water, are merged in the general inundation, levelled up so to speak, and thus rendered almost harmless; whereas in parts of the delta no longer subject to inundation the myriads of potential breeding places of this kind are no longer neutralized by flooding,

and as a result enormous numbers of anopheles mosquitoes are produced during the rainy season and malaria becomes proportionately prevalent and severe.

11. But, although partial drying up of delta areas may be exceedingly dangerous and suggested drainage schemes for the rural tracts of Bengal must only be adopted after the most careful enquiry and examination, there are alternatives which promise excellent results. These alternatives may be described briefly as (1) temporary flooding and (2) irrigation.

In Bengal, the accidental flooding of malarious areas has almost invariably led to a temporary amelioration of malaria. And it may be pointed out that this method of combating the disease was made use of over 2,000 years ago by Empedocles, who is recorded to have freed the city of Selenos of malaria by flooding the swamps which surrounded it with water brought in by means of canals and aqueducts. At a much later period also Lancisi made use of the same methods to reduce the prevalence of malaria in parts of Italy.

12. Besides these examples, we have evidence to show that the introduction of an added supply of water into specially unhealthy areas in Bengal has also led to an improvement in health.

Dr. Coats, when Sanitary Commissioner of Bengal, records the fact that—

“The admission of the Damudar water into the Kana Nadi in 1873-74 and 1875 was followed by an immediate and marked amelioration in health.”

And Dr. Dutt of Serampur, who visited this area in 1879, stated that—

“The letting in of the Damudar water was a most welcome relief, and that, but for it, parts of the country would have been entirely depopulated . . . It has been allowed to flow in 1878 and 1879, and the people say that the epidemic has disappeared since the last two years. These facts leave no doubt that the letting in of the Damudar water in the Kana Nadi and through it into the khals, drains and tanks, etc., in the interior of the subdivision, has led to this improvement.”

That this view was not merely imaginary is shown in a further report by Dr. Coats, wherein he remarked—

“At a recent visit, I myself found only two per cent. of the people suffering from the effect of former fevers, enlarged spleen and anæmia. The pathshalas were full of healthy boys, not one of whom had splenic enlargement, cultivation was going on actively, and people were eager to have increased water supply and drainage.”

13. In view of the reference to drainage in the above passage, it may be urged that villagers in Bengal often clamour for drainage and that several large scale drainage schemes that have been already carried out, notably the draining of the Dankuni *jolas*, the Howrah and Rajapur swamps, and the Magrahat Drainage Scheme appear to have been followed by excellent results. But what are the real facts? Colonel Haig, R.E., reporting on the Dankuni Drainage Scheme in 1878, five years after its completion, observed—

“In the first place, then, it may be remarked that experience has proved not merely that it is only in so far as irrigation can be combined with drainage that the full benefit of these schemes can be derived, but that for all practical

purposes the improvement is limited to the area for which irrigation is available Contrary to all expectation, the experience of the five years which have passed since the completion of the works has shown that in years of ordinary rainfall the sluices and drains are required much more for letting in water from the Hooghly for irrigation than for draining it off Thus in 1873, during 153 days from June to October in which there was a rainfall of 34 inches, the sluice-gates were never once opened for drainage, but were opened 15 days for admission of water. In 1874, with a rainfall in the same months of 41·48 inches, the sluices were not once worked for drainage, but during 13 days for irrigation. In 1875, the rainfall was 34·62 inches, and the sluices worked eight days for drainage and 15 days for irrigation. In 1876, with a rainfall of 46·71 inches the sluices were opened for drainage for eight days, and for irrigation for 26 days. In 1877 with 38 inches of rain, the number of days were 4 for drainage and 22 for irrigation. The capacity of the sluices is in fact determined, not with reference to the requirements of drainage at all, but to those of irrigation; it must be such as experience shows to be necessary to raise the level of water in the low grounds with the gradual growth of the plants, and this is probably in excess of what is required for drainage, though the point has yet to be determined by a year of excessive rain, which we have not had since the works were finished. The average rainfall in Hooghly of the five months referred to is given by the Meteorological Department at 50·72 inches. These are very curious facts, and show what an immense proportion of the heavy rainfall of Lower Bengal is consumed in the process of vegetation, the rice plant apparently requiring a great part of it, and the rest passing off chiefly by evaporation, for the subsoil drainage appears to be very small. It also appears from what has been said that some very important experience has been gained in this our first experiment in drainage on a large scale in India, as it is now found that it is sufficient if the discharging capacity of the drains is not above one-ninth of what was originally thought necessary."

The Magistrate of Howrah, also writing of the Howrah and Rajapur Scheme in the Annual Administration Report of 1897-98 remarks—

"All the drainage schemes have proved to be of immense benefit in reclaiming waste swamps and improving the other lands. They were originally intended for the drainage of the swamps, but they are now advantageously utilized in irrigating the lands, in years of drought and scanty rainfall, with fresh water from the Hooghly river."

More recently in 1905, the Commissioner of the Burdwan Division stated of these works—

"These schemes have proved very successful in reclaiming the extensive waste swampy lands west of Howrah and improving other lands. The surplus water is drained out by the channels and sluices in years of heavy rainfall; while in years of drought, water from the river is let in for cultivation and drinking purposes. The schemes have been of great benefit to the people of the neighbouring tracts, who can reap a good harvest in years of drought, as well as in years of heavy rainfall."

And exactly the same thing may be said of the Magrahat Drainage Scheme, which has also successfully combined the functions of irrigation with that of surface water control.

14. All the above schemes, it may be observed, although applied to *bil* areas and spoken of as "drainage schemes," are, strictly speaking, schemes for irrigation. And it is owing to this fact that they have not led to an increase of malaria in their vicinity. For although the introduction of irrigation into dry countries like the

Punjab and upper Burma is often followed by an extraordinary increase of epidemic malaria, in swampy low-lying deltas it has a contrary effect, as is shown by the history of irrigation in the deltas of the Kavari and Godavari in Madras.

In 1809, Tanjore suffered from severe epidemic malaria which followed upon scarcity of water owing to the decay of the irrigation system of the delta originally organized some 1,600 years ago in connexion with the *Grand Anicut*. Before the trouble was finally remedied, Tanjore had lost 25 per cent. of its population; but very shortly after a plentiful supply of water for flush irrigation was secured by the projects of Sir Arthur Cotton, Tanjore became a prosperous and comparatively healthy district once more. And the history of Godavari is very similar, for that delta district was fast passing into a state of decay, depopulation and bankruptcy when Sir Arthur Cotton designed the irrigation of the delta. And as recently as 1872 and 1873 this area suffered from epidemic malaria. The irrigation system of the Godavari delta was finally completed in 1891, and the Gazetteer of the Godavari district contains following reference to the present health conditions in the district:—

“The fact remains that the delta taluks (unlike irrigated areas in some places in this Presidency, the valley of the Tungabhadra for example) are not greatly subject to malaria, and are, in fact, the part of the district in which it is least prevalent.”

15. A consideration of the facts brought forward in the preceding paragraphs leads to the conclusion that in the delta tracts of Bengal it is necessary to approach the question of the drainage of rural areas with the greatest circumspection. This is all the more necessary, because of the frequent demand for the drainage of *bils* on the ground that the carrying out of projects of this kind will not only bring new land under cultivation but greatly reduce prevalence of malaria. As regards the pecuniary advantage likely to accrue to the owners of the land that may be reclaimed by such measures, there is no question, as I showed in a previous note, that it may in some cases be enormous. But I confess that I fail to see in what manner the drainage of many of these swamps can possibly benefit the health of communities in their neighbourhood that may be suffering severely from malaria. In this connexion I would once more call attention to the view, expressed in a previous report upon a scheme for the drainage of the Arool Bil, that this scheme can in no sense be considered a sanitary measure. Formerly the scheme proposed was for the removal of water only. It has been considerably modified however and regulators and sluices provided, so that the depth of water can be controlled. Regulation and control of surface water is more desirable than mere drainage, which, while perhaps benefiting a small area of perennial swamp, does so at the expense of the elevated land in its vicinity. But where drainage schemes can be combined with irrigation much lasting good may be expected.

APPENDIX V.

Flooding or Covering by Water as a Method of Anti-malarial Sanitation.

The article on malaria in Hirsch's Handbook of Geographical and Historical Pathology, when discussing the effect of floods upon the prevalence of the disease, remarks upon :—

“The fact that, *when the water is high and the ground completely covered by it*, the endemic or epidemic disappears, fresh cases of the disease appearing only after the water has run off and the surface of the country has been laid bare. Classical examples of this are furnished by the malarious regions periodically inundated on the banks of the Nile, Indus, Euphrates, Ganges, Senegal, Niger, Mississippi and other rivers, where the endemic always begins after the waters have begun to subside. There is another illustration of the fact in those rice-fields in India which are always under water, and, as Annesley remarks, are the least dangerous to health. Experience also in Turkey (Sandwith), in Sardinia (Morris), at several places in the Southern States of the Union (Nott), in England (Royston) and elsewhere, proves that the complete flooding of marshy ground, and the filling up of standing pools, ditches, and the like causes the endemic to disappear as certainly as if they had been dried up.”

More recently, Deadrick in his text-book on “The Study of Malaria” (1910) gives the following example of the effect of floods upon malaria :—

“The primary effect of the submerging of land, while the water is high, is to diminish malaria. A remarkable example which illustrates this occurred in Holland in 1748. The Dutch allowed the land, for defensive purposes, to become overflowed. Peace being concluded during the middle of the summer, the inundation was caused to subside, whereupon a serious outbreak of malaria occurred. The epidemic was not successfully combated until the land was again submerged and kept so until the advent of winter. The effect upon malaria of inundations is almost yearly observed in the valleys of the Nile, of the Mississippi, and of other large streams.”

Many other authorities also have called attention to very similar facts. For example, Davidson states that :—

“In some marshy countries, a heavy rainfall diminishes the prevalence of fever by covering the marshy ground with a protective sheet of water. Thus in the Netherlands, it has often been remarked that rainy years are healthy years, while hot and dry seasons are feverish.”

Scheübe, speaking of conditions affecting malaria prevalence, remarks that :—

“Very heavy rain has a deterrent influence on naturally damp soil . . . At the height of the rainy season . . . in Deli in Sumatra (Martin) and New Guinea (Schellong), the minimum number of cases of illness is notified ”

And he explains this by observing that :—

“A thorough soaking of the soil is deleterious to the development of the mosquito ”

Craig also records that :—

“ In many regions, however, where abundant rains occur, malaria is rare, even though the anophelines are present. This is explained by the fact that in such regions the rains are so heavy and continued that the breeding places of mosquitoes are washed out and ova and larvæ do not have a chance to develop, or that no infected individuals are resident in the locality. In the former instance an unusually heavy rainfall may act as a protection against malaria.”

Manson too has observed the same thing and explains it in the following passage :—

“ In some places, particularly in those that are low lying, flat, and swampy, fevers of first invasion disappear almost entirely when the country becomes flooded . . . In some places much rain will scour out the mosquito pools, in other places it will just fill them . . . The key to the explanation of the varying relation of malaria to rainfall is to be found in the influence of the latter on the local mosquito pools.”

2. The passages quoted above show that it has long been recognized that the flooding of a country may exert a beneficial influence upon malaria. And authorities like the late Professor Angelo Celli and Professor Julius Mannaberg have always regarded flooding or “ covering by water ” as useful measures for the control of the disease. The former author refers in his classical monograph on “ Malaria according to the New Researches ” to this method of combating malaria in the following words :—

“ Covering can, so to speak, also be made with water. If a stratum of water be made to cover a malarious site, so long as the water remains at a constant level there will be brought about a relative improvement . . . This submersion in certain cases is only relatively beneficial, and its real value will have to be tested in the light of the new theory regarding the origin and propagation of malaria by means of mosquitoes. Thus perhaps will be explained what seems to be a paradox, namely, that the suppression of an epidemic of aquatic origin is brought about by the presence of water.”

And in Nothnagel's Encyclopædia of Medicine, the latter writer, when discussing the prevention of malaria, remarks that :—

“ In swamps, where drainage was impossible, a regular level was aimed at, especially during the summer months, by the regulation of the incoming and outgoing water, and by the building of dams since it was not the surface covered with water but that which was alternately under water and exposed to evaporation, which was dangerous.”

Adding that :—

“ Exceptionally during severe epidemic radical measures were undertaken, as for instance, the copious flooding of malarial foci. This was first put into practice by Empedocles, later by Lancisi.”

Some investigations by Lieutenant-Colonel Hodgson and King, I.M.S., serve to throw a new light upon the rationale of phenomena of the kind referred to and enable us to understand why “ floating or covering by water ” may be a most useful measure of anti-malarial sanitation. The following passage is extracted from

Lieutenant-Colonel Hodgson's note in the Proceedings of the Lucknow Sanitary Conference, 1914 :—

“ Taking the mosquito in its larval existence, we found that the optimum temperature for anopheles lay between 68°—78°F. Temperatures above 80°F. became more and more unsuitable, while temperatures of 95° to 104°F. were rapidly fatal. In nature, during the monsoon at Delhi in August, and in Madras in November, we found the surface of pools to vary from 73°F. to 104°F., the difference being due to the following important facts :—

- (1) The *coolest* pools were very small pools lying amongst grass.
- (2) The edge of a pool in the day time is cooler than the centre.
- (3) The surface layer is often 3° or 4° hotter than the water 4 or 5 inches down at midday.
- (4) The water lying at the shallow edge, round grass stems, is the coolest part of a pool.
- (5) When the average temperature of pools had risen to 90° or even 100°, falling rain both at Delhi and Madras was found to be 73° to 77°F., during the monsoon.
- (6) The river at Delhi even after long drought never rose above 87°F. at midday.
- (7) Well-water varied from 80°F. to 82°F.
- (8) The sea at Madras in the monsoon was 80°F.
- (9) Small hoof marks in grass might contain water 90°F. cooler than a large pool 6 inches away, particularly during hot dry weather.

“ An anopheles mosquito lays her eggs in that type of pool which is coolest at the time. The struggle for existence rapidly increases above 80°F. and temperatures such as 104°F. are fatal to every single larva in less than 18 hours, though this is a temperature at which some pools have been found in nature. In the Terai in October water varied from 65°F. to 78°F. on the two days we examined it, and anopheles were breeding in millions. The great destroyer of mosquito larvæ is nature and her principal means is raising the temperature of the water.”

3. It will be seen from these observations that small collections of water and those possessing a large ratio of weedy edge are far more dangerous than large water surfaces, because they invariably possess a lower temperature much more suitable for mosquito larvæ than the high temperature to which large collections of water speedily become raised. This fact helps to explain the beneficial effect of flooding upon the prevalence of malaria. When water is admitted in large amount to the surface of a low-lying country, all the small pools are converted into large ones; on the one hand the ratio of dangerous edge is greatly reduced and on the other hand the temperature of the water is speedily raised with the result that the output of anopheles mosquitoes is restricted. And when this measure can be adopted with advantage from the point of view of agriculture also, as it may in countries where the population is largely dependent upon wet crops, a doubly beneficial result may be expected.

4. In regard to the use of flooding as well as in the case of other antimalarial measures specially directed against mosquitoes, there is another point which requires consideration. This is the fact that, broadly speaking, it is in the rainy season only that measures of this kind are required. Moreover, it is only at this time of the year that they can prove effective. An examination of the monthly curve of admissions from malaria will show that the disease usually begins to show an increase in the month of July or August, reaches its maximum in September or October and speedily declines

in November. If we compare this sickness curve with the curve of mosquito prevalence, we shall find a remarkable correspondence between them. That is to say, the increase of malarial fever always shows a correlation with the increase of anopheles mosquitoes, and a speedy decline of the disease always follow a great reduction of the number of anopheles. Once this point is grasped, it will be seen that anti-malarial measures directed against mosquitoes to be effective must be carried out during that period of the year when anopheles are active in transmitting infection, and at other times efforts directed against mosquitoes will be fruitless. Hence we have to consider the condition of land surfaces and the existence of mosquito-breeding places, especially small collection of water, during the monsoon months, and we must concentrate our effort upon reducing the output of insects at this period. In a low-lying country, such as Bengal, where the land surface has very little fall and where there is a heavy rainfall it is an exceedingly difficult task to diminish the output of mosquitoes by drainage. On the other hand, provided we can obtain a sufficient supply of water there should be no great difficulty in converting the dangerous small pools into collections of water sufficiently large as to cease to be a danger. This is the measure that I propose should be adopted experimentally in consultation with the Irrigation Department in all areas in which conditions will allow. And for this purpose I have obtained a list of irrigation sluices. I am informed that in the past very little use has been made of these sluices to provide a supply of water, but in consultation with the Irrigation Department I am hopeful that steps may be taken to utilise them during the present year. I have already arranged for an examination of the spleen indices of the villages served by these sluices. And it will be possible by watching the results of letting in water during the flood season to carry out a series of useful experiments at a comparatively small cost. In addition to this, I am hopeful of being able in the early future to make proposals for the carrying out of one or more larger scale experiments on the lines just indicated.