

## THE MALARIA PROBLEM OF ASSAM\*

**I**N an address on the control of Malaria in Assam, delivered to the Assam Branch of the British Medical Association in January, 1930, I recorded the principal results of my researches, during the past four years, on Assam's malaria problem. From my researches I stated that *A. minimus* was practically the only carrier found among some 50,000 adults dissected belonging to twenty different species. I also recorded the results of my investigations on the bionomics of this species. I stated that in the selection of its breeding places, *A. minimus* in Nature avoids: (1) Contaminated water. By that I mean muddy or silty water; water with finely divided clay in suspension; water contaminated with the products of iron oxide bacteria; or water covered with a thick scum of surface algae. (2) Water which has a high velocity of current. (3) Water covered with dense shade.

I also recorded that the conditions which this dangerous species selects for breeding sites are: (1) Clear water. (2) Stagnant or slowly moving water. (3) Where a certain degree of sunlight reaches the water surface.

### MASONRY WELLS

To the types of breeding places of *A. minimus* which I have already recorded, I have now to add finding larvae of this species in a "pucca well." The "pucca" well in which *A. minimus* larvae were collected was about 20 feet deep, and was constructed entirely of reinforced stone concrete well-rings cemented together to prevent contamination of the water from percolation. The water level in the well was within six feet from the ground surface. This finding, at first, appeared to me to be exceptional, but the necessary condition demanded by *A. minimus* in the selection of breeding sites, viz., clear, uncontaminated, slowly moving or stagnant water, completely or partially exposed to sunlight, were fulfilled.

The main reason why *A. minimus* and other species of anopheline mosquitoes have not previously been found breeding in masonry-built wells fulfilling the above conditions in areas which I have investigated is doubtless due to the fact that these wells are usually treated daily with chlorogen, thereby eliminating the larval food supply. Further, mosquito larvae have little chance of surviving even in open unchlorinated pucca wells, as water is being more or less continually withdrawn by buckets from early morning to late in the evening. The well teeming with *A. minimus* larvae had, I found on investigation, been left unchlorinated and undisturbed for several weeks. *A. minimus* has now been eradicated from this well by eliminating the light factor, i.e., by providing a suitable cover. This finding in a masonry-built well clearly demonstrated to me that concrete inverts, unless properly graded and constructed, could also function as breeding places for *A. minimus*. As mosquito control by "pucca drains" was the principal anti-malaria measure adopted in a highly malarious site in Assam, I was interested to learn that many of these drains have also to be regularly oiled because anopheline mosquitoes are found breeding in these concrete inverts. An engineering friend, who has studied the anti-malaria measures which have been carried out in areas under my supervision, wrote to me that "open pucca drains with slopes flatter than 1 in 400 do not keep dry, as slight settlement and imperfect work cause pools to form. At 1 in 400

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they are fairly free from pools. Again, all pucca drains have to be cleaned regularly, as rubbish causes pools." It is obvious that, if concrete inverts are to fulfil the function intended, the factor underlying mosquito control by this means is to obtain high velocity of current by eliminating pockets, pools, obstruction from vegetation, and to provide a suitable gradient. In my opinion the gradient should not be less than 1 in 200.

### WATER TIDINESS

The removal of vegetation, i.e., the clean weeding of drains, streamlets, streams, pools and tanks has been repeatedly advocated in Assam and elsewhere as an anti-malaria measure. The principles underlying clean weeding or removal of debris which are of value in preventing mosquitoes breeding are: (1) increase of velocity of current through removing obstructions; (2) in certain types of soil there is increased water contamination from the direct action of the water on the denuded soil surface (silt or clay factor); and (3) in other cases and especially in pools and tanks the removal of vegetation diminishes the available shelter for larvae and increases the opportunities of larvivorous fish. But my own experience has been that *A. minimus* will breed freely in the small pockets and bays of clean-weeded, clear water, slowly running drains, streamlets or streams, also in clean-weeded pools or tanks if the degree of light, demanded by this species in its breeding areas, is sufficient. In high-lying hyperendemic malarious sites the slow flowing clear water in loops, pockets and pools of partially shaded or unshaded streams and streamlets affords prolific breeding places of *A. minimus*. These areas are frequently devoid of any vegetation (grass or weeds) near the water edge. It is apparent therefore that clean weeding as an anti-larval measure has decided limitations, especially as thorough oiling by a knapsack sprayer destroys vegetation. Further the decomposing vegetation is an excellent medium for retaining oil.

In most tea estates in Assam it is routine custom to clean out ditches and drains periodically from the point of view of tea cultivation. The principle underlying cleaning drains is obviously to prevent water logging, or in other words to increase soil aeration by facilitating run-off. The result of these cleaning efforts, unfortunately, has been in many cases to broaden water channels unnecessarily, and thereby to reduce the velocity of current also to increase the difficulty of providing biological control of malaria by dense shade.

### SHADE

Where feasible, water channels on malariogenic terrain should be narrowed and deepened as this increases the velocity of current and facilitates covering by dense shade. Dense shade, of course, prevents vegetation from growing in the bed or on the banks of a drain or streamlet and hence obviates the necessity of cleaning these channels, thereby also eliminating the recurring expenditure associated therewith. During the past eighteen months I have been investigating the degree of shade essential to eliminate *A. minimus* from proved breeding places. I find that durantha (the thorny privet hedge) and eupatorium give excellent dense shade over narrow channels and have, so far, from my investigations, fulfilled requirements, but my recommendation to shade clear-water broad channels with trees such as *Cassia nodosa* or *Cassia javanica*, unfortunately limits itself only to certain types of breeding places. *Cassia* trees although they give dense shade are deciduous and hence will not fulfil the function intended over breeding areas which are malariogenic during the period of the year when the leaves have been shed. *Cassia* trees shed their leaves in March, April, and early May, hence these trees are only suitable for shading breeding areas which function as *A. minimus* resorts, during the monsoon season. In hyperendemic sites where malaria is being transmitted after

the night temperatures rise above 60°F. in March and April, it is essential, where feasible, to provide dense evergreen shade over water-courses which are selected by *A. minimus* as breeding sites during this period of the year. For this purpose I am at present carrying out experiments with trees which will give dense shade throughout the entire Assam malaria season. The jak-fruit tree (*Artocarpus integrifolia*) appears to be highly suitable for this purpose.

### SWAMP VEGETATION

A clear distinction must be drawn between the planting of swamp vegetation and allowing a swamp to revert naturally to jungle. I have watched swamps in the process of reverting to jungle over a number of years, and during these years they have remained a deadly danger to all who lived near them. In parts of the swamp there is shade enough to retard the growth of larvae; but the shade was by no means uniform, and open spaces teeming with *A. minimus* existed. In the course of many years, the probability is that the whole swamp would be shaded over; but we cannot afford to wait this time.

The vegetation I am now planting consists of several swamp plants, which are not the end-product of reversion to jungle, but an intermediate stage. They propagate themselves rapidly when introduced, and as we know from practical experience soon blot out the sunlight and *A. minimus*, which requires sunlight.

In these hyperendemic sites the principle underlying absolute shade are also being applied; that is filling in functionless man-made drains, man-made clear-water tanks, and borrow-pits.

### TEMPERATURE

I have previously stated (*Ind. Journ. Med. Research*, 1930) that during the period of the year (December, January, and February) when the night temperatures drop below 60°F. the feeding stimulus of anopheline mosquitoes and especially of *A. minimus* is inhibited.

With a view to reducing expenditure on larvicides I stopped all anti-larval measures on fifteen gardens under my supervision during the past season when the night temperatures had dropped below 60°F., but carried on, as usual, all anti-larval measures on three tea estates in the same district, so that the effect on the incidence of malaria could be compared on controlled and uncontrolled areas during the ensuing transmission period. Fifteen of the uncontrolled gardens included three hyperendemic sites, while two of the controlled areas were also hyperendemic sites. The results, so far, have shown that, if dangerous breeding areas are efficiently controlled by anti-larval measures during the period of the year, when the night temperatures rise above 60°F., it appears to be unnecessary to apply anti-larval measures during the non-transmission period of the year. Further investigation, however, is required to confirm this opinion.

### SOIL COMPOSITION

The relationship between soil composition and the breeding of *A. minimus* has been of great interest to me during my researches. The importance of certain types of soil which cause water contamination and hence become free from *A. minimus* is clearly brought out in low-lying land in Assam. In studying drains, streams, and streamlets on high-lying land it is interesting to note that many of these channels which have dried up during the cold dry weather run silty during the first few showers of the North-West monsoon and then clear during the remainder of the rainy season. The silt in these channels is obviously mainly due to atmospheric action, during the cold dry weather, which causes soil disintegration. As

soon as the gross products of disintegration have been washed away the water in these channels again runs clear and forms ideal breeding places for *A. minimus*. On low-lying cultivated land the finely divided products of soil disintegration, which have been in the past and which in this changing universe continue to be carried down from high-lying to low-lying land, are easily stirred up by rainfall and are inimical to the breeding habits of *A. minimus*. During the cold dry weather of 1929-30 I carried out a series of experiments on a drain, about fifty yards in length, on low-lying land, which *A. minimus* had selected as a cold dry-weather resort, because the undisturbed water had become clear. The silt was stirred up in the centre of the drain by three of my establishment for two hours daily over a period of one week. This had apparently no effect on the number of larvae which could be caught in the clear-water pockets at the edges. These pockets were unaffected as the silt did not reach them, but when the pockets and grassy edges of the drain were stirred up for two hours daily over a period of a week it became extremely difficult to find a single *A. minimus* larva. The degree of silt, also of water contamination generally necessary to eliminate *A. minimus* requires further investigation as experience has shown me that *A. minimus* is sometimes compelled during the cold dry weather to accept types of breeding places which are avoided during the rainy season when there is a great increase in the number of more suitable breeding places.

### RICE FIELDS

An extensive cold weather breeding area, formed by seepage from a plateau adjacent to a tea estate where the spleen-rate, in garden-born children, has never in my experience been over 6 per cent. has also been of great interest to me. This area is free from *A. minimus* during the period of the year when the soil is stilled and when under rice cultivation. As soon as the rice crop is reaped, in November and early December, the undisturbed exposed seepages teem with *A. minimus* larvae. Water contamination from silt during the rainy season and probably the shade of the thickly planted rice after the monsoon season appear to be the factors in keeping this area free from *A. minimus* until the rice crop is out.

Many of the swamps in Assam when cleared are harmless owing to their soil composition (silt or clay factors); but exposed clear-water swamps are invariably highly malariogenic. The danger of these swamps is in many cases further increased when railway embankments or bund roads cross them and retard the flow of the natural waters and so increase the bearing areas. Instead of the usual bund and narrow bridge or culvert, screw bridges or suspension bridges are much more satisfactory. Such bridges cause the minimum interference with nature, and facilitate the replanting of the swamp with aquatic vegetation that will ultimately completely eliminate sunlight and *A. minimus*.

Again in Assam there are thousands of acres of swamp where, owing to the composition of the soil, rice can be safely cultivated. But in other places, swamps are so deep, and of so little value for growing rice, that it is questionable whether it would not be better to abandon them, and move the people back a safe distance, which need not be far, as was shown by Watson's observations on flat land jungle in Malaya, and Christopher's on the Andaman Islands. Both these observers found that malaria was absent, or nearly so, in villages or estate cooly lines which were over half a mile from the breeding places of *A. umbrosus* and *A. ludlowi* respectively. Even if further research fails to show us more efficient methods of controlling anopheles than we now possess, we have always the above as a method to fall back on.

## EFFECT OF MALARIA ON LABOUR

Investigation has shown me that malaria in Assam is the disease which is mainly responsible for reducing the efficiency of, also for depleting, tea garden labour forces. Experience has also taught me that it is the highly malarious tea estates which are mainly compelled to recruit labour. There are many tea estates in this Province which are practically free from malaria and which have not recruited labour for over twenty years owing to the natural increase in the population. I have been informed that annually over £500,000 is spent by the tea industry on recruiting labour to tea estates in Assam from other Provinces in India. Much of this annual recurring expenditure will doubtless in due course be saved by the tea industry when the malariogenic factors in each area are carefully investigated and appropriate anti-malaria measures applied.

### SUMMARY

*A. minimus*, which is the main vector of malaria in Assam, was found breeding in a masonry-built well. This finding, at first, appeared to be exceptional but the necessary conditions demanded by *A. minimus* in the selection of breeding sites were fulfilled.

This finding also shows that *A. minimus* will breed in concrete inverts if these are not properly graded and constructed, i.e., mosquito control by concrete inverts is dependent on velocity of current. In the case of masonry-built wells the light factor has to be eliminated by providing suitable covering.

In certain highly malarious sites it is essential, if *A. minimus* is to be eliminated, to shade malariogenic water by trees which will give dense shade throughout the entire Assam Malaria Season.