MALARIA, WITH REFERENCE TO

(1) THE DANGER OF IMPORTED ANOPHELINE INSECTS,

(2) AN UNUSUAL BREEDING GROUND.

BY

L. BOUSFIELD, M.A., M.D. (CANTAB.), M.R.C.S., L.R.C.P., D.P.H.

Medical Officer of Health, Khartoum and Omdurman.

I.

This article deals with the malarial problem in Khartoum, a town which is situated at the junction of the Blue and White Niles, and which has a hot and dry climate with a very small rainfall.

The Southern Sudan is highly malarious, while the Northern Sudan, until recent years, was not nearly so much infected; but the steadily increasing number of pump irrigated farms and the very high Nile of 1917 converted it into a very hot-bed of malaria in that year.

The natural sources of infection for Khartoum are—(1) River pools, (2) garden and household collections of water, (3) wells, (4) rain-water pools, (5) irrigated farms.

The rain, though very small in total aggregate, comes in a few heavy storms, which often flood streams and produce many pools which may last weeks.

Besides the five sources mentioned, there is a large traffic in steamers, native boats, and trains coming from highly malarious districts.

Before preventive measures were adopted there is abundant evidence that Khartoum was intensely malarious, but since steps, first inaugurated by Lieut.-Colonel ANDREW BALFOUR, C.M.G., while M.O.H., have been taken to deal with the problem, the town has been kept remarkably free from malaria, and a mosquito is rarely seen or heard.

The total population of Khartoum and Khartoum North is about 33,000, and the recorded malarial cases have been taken as follows:—

Oct. 1st to Sept. 30th.		Khartoum.		Khartoum N.		Total.		Approximate Incidence per 1000.
1911-1912	...	56	...	19	...	75	...	2.27
1912-1913	...	31	...	16	...	47	...	1.40
1913-1914	...	51	...	17	...	68	...	2.06
1914-1915	...	58	...	16	...	74	...	2.24
1915-1916	...	5	...	2	...	7	...	0.21
1916-1917	...	109	...	14	...	123	...	3.75
1917-1918	...	264	...	36	...	300	...	9.09

The records from 1911-1916 are highly satisfactory, while the increases for 1916 to 1918 were produced by—(1) the high Niles, especially that of September, 1917; (2) the great increase in native craft bringing in wood, due to the shortage and exorbitant price of coal.

The number of native boats now bringing wood into Khartoum is about forty-five to every one prior to the war.

These boats nearly always come from highly malarious districts, and journey slowly down or up the river to Khartoum, often tying up to the banks during the night.

Thus anophelines come on board to feed off the crew, and, when fully gorged, seek

the nearest shelter, which in most cases is the cargo, especially wood cargoes, where they remain undisturbed until unloading occurs.

The anti-malarial measures adopted are briefly given :—

(1) The towns are divided into areas, to which a man of the mosquito brigade is appointed.

He inspects weekly every house, garden, well, etc., in his district.

(2) Every adjacent farm is inspected weekly.

(3) All the river banks and pools are inspected weekly.

(4) Mosquito clearance stations have been formed on the Blue Nile, east and west of Khartoum, and every river craft has to call for inspection, the clearance of water and live mosquitoes, when possible by SO_2 gas, or cresyl, and an attempt is made to bolt mosquitoes from exposed cargoes by smoke producing machines.

(5) The prosecution or imposition of a fine in every instance when mosquito larvæ more than three or four days old are found in domestic utensils, etc., or in places where ordinary care would have prevented their occurrence.

The fine imposed usually corresponds to about 10s.

(6) Constant check inspections are made by the British Staff to see that the work is thoroughly done.

Except under such circumstances as a very high Nile or very extensive rains, Khartoum can be, and is, kept practically free from malaria, and, were it not for the imported infective insect, the records would be much more satisfactory, and it is to call further attention to the importance of such sources of infection, in places where active anti-malarial work is done, and where the success is to some degree nullified by the advent of such insects, that this article is written.

The more one studies the malarial problem the more one is forced to recognise that in combating the source of the disease the battle must not only be fought locally but must be extended to regions far beyond what has been, and often still is, regarded as sufficient, and when traffic from highly infected regions exists the imported imago has to be reckoned with.

The following facts are recorded dealing with imported mosquitoes :—

(1) The area of Khartoum and Khartoum North adjacent to the river is far less densely populated than that further away, and yet the former has supplied a far greater number of malarial cases than the latter.

For instance, between October 1st, 1916, and January 20th, 1917, there were ninety cases, believed to have been locally contracted, of which fifty-five occurred within 150 yards of the river bank amongst 2,900 inhabitants, while of these there is evidence that thirteen or more occurred from a flight of mosquitoes from a wood boat, and that of the remaining twenty-two it appears highly probable that six were contracted through infective mosquitoes brought in by trains. We have demonstrated on several occasions the presence of mosquitoes in incoming trains.

During the period under consideration the wind is blowing from the northern direction, thus causing Khartoum to be more affected than Khartoum North.

The sources of infection might be neglected breeding places in pools, gardens, houses or steamers and boats; but for ten months in the year mosquitoes are practically never seen, yet all these sources are present all the year round, except that the steamers and boats, though running all the year round, are more numerous with the high Nile, and are found only to harbour anophelines to any degree during the period when breeding places exist in large numbers outside the controlled area.

(2) During the period just mentioned river craft are often found, when passing through the clearance stations, to harbour considerable numbers of anophelines.

They are very rarely found to be breeding on board, though *Culex* and *Stegomyia* frequently do so.

The anophelines are nearly always females, and undoubtedly come on board for human blood, and not to breed.

Except in holds and cabins, which can be closed and fumigated, the problem of how to deal with them efficiently, and at a reasonable cost, is very difficult; at present we try to bolt them with smoke outside the town.

The map shews that cases tend to collect round unloading stations, which are marked X.

(3) Many times it has been found that a few mosquitoes appear in a house near the river bank, which has been free from them for months, and this has almost invariably coincided with the advent and tying up of a steamer or native boat opposite to the house, while no local neglected breeding places could be found on most thorough examination.

For instance, on March 14th, 1918, two very large barges, laden with wood, arrived opposite the Burri Water Works, having come from the White Nile, which was at that period teeming with mosquitoes.

Prior to this, for some considerable time very few mosquitoes had been noticed at the waterworks, but immediately after unloading was commenced mosquitoes appeared in considerable numbers.

The Chief Engineer's servants' quarters are immediately opposite the unloading place, and in their bedroom we found—

On March 16th, 18 female anophelines ;

“ “ 17th, 7 “ “

“ “ 18th, 5 “ “

and after this date only one every few days, and within ten days all had disappeared.

In the adjacent houses very few could be found.

We have found wire mosquito flappers the best method of killing off such mosquitoes, and during the winter of 1917, and early in 1918, two men were employed daily to visit all servants' rooms and the latrines along the front ; by this means large numbers were killed off.

Curiously, in the latrines, quite ninety per cent. were male culices, the female culex being seldom found, and the anopheline but rarely.

This observation has been often corroborated locally, and the love of the male culex for the latrine bucket appears to strongly indicate that the male culex loves feeding off human excreta if he gets the opportunity.

(4) The mosquitoes known to breed locally are *Pyretophorus costalis*, *Culex fatigans* and *Stegomyia fasciata*.

Species, which do not breed locally, have been found in houses near the river banks and in incoming trains :—

(a) *Teniorhynchus*.

(b) *Cellia pharænsis*.

(c) A very large, dark coloured culex, unidentified at present, but known to be a marsh breeder.

(5) One very instructive example of malaria caused by anophelines from a wood boat is now recorded. (*Vide* Plan I.)

On December 22nd, 1916, malaria began to appear amongst the soldiers of the Military Works Department and the Sirdar's escort.

Ten cases appeared between December 22nd and January 2nd, and then the outbreak abruptly stopped.

This area is inspected weekly, and a very careful check inspection failed to shew any neglected breeding place.

About the same time two small epidemics occurred amongst the British troops and the Egyptian battalion at Said Pasha Barracks.

Ten British soldiers developed the disease between December 19th and January 3rd, and then the disease claimed no more victims, while eight cases occurred at Said Pasha Barracks between December 22nd and December 30th, and then no more cases appeared.

Careful inspection revealed no missed breeding grounds, and Said Pasha Barracks lies surrounded by desert.

No pools were found to have larvæ more than two or three days old, and the farm on the other side of the river was found to be free.

It appeared possible that these three little outbreaks were connected, and investigation elicited the following facts :—

On December 7th a nuggar, loaded with wood, having evaded the Mosquito Clearance Station, arrived opposite the Military Works Department, and was unloaded by the soldiers between 2 p.m. and 6 p.m. on that day.

The wood had come from a highly malarious place on the Blue Nile.

Now the only bodies of men living near this unloading station are:—(1) The Military Works Department; (2) Sirdar's escort: and both were infected.

The civil public works department buildings are immediately opposite the unloading station, but are unoccupied at night, except for two watchmen, one of whom went down with malaria.

Pools, owing to the falling Nile, had commenced to form late in November opposite the Burri Waterworks, a little E.N.E. of the British barracks, but were kept under supervision.

On December 9th thirteen pools were found to be heavily infested with anopheline larvæ two to three days old.

On following up the history of this wood boat we found it had tied up on the evening of December 6th opposite to these pools, and had remained there until the morning to pass through the bridge.

At this date the wind was blowing from the N.E., and there can be no doubt some mosquitoes flew on shore, some laying eggs in these pools and causing the cases of malaria, namely, two at the Burri Waterworks, ten at the British barracks, all occurring in the N.E. portion, and that some flew on to Said Pasha Barracks across the desert, some 1,000 yards distant, but only infected two rooms (*Vide* Plan I.), these, except for one, being the nearest to the British barracks.

It will be noted that the first occupied room, *A*, was unaffected, though 95–100 men sleep here, and the reason was because the N.E. windows, facing direct to the wind, were kept closed, while the windows of *B*, being sheltered from the direct effects of the wind by the projecting room *A*, were left open.

The windows of room *C*, facing N.E., were also kept closed, but there is a large arched opening between rooms *B* and *C*, allowing mosquitoes to pass freely from one to the other.

Room *B* developed five cases, four being near the most north-easterly window, while room *C* only developed three cases.

Rooms *D* and *E* were not affected, proving the well-known tendency of the mosquito to seek the nearest occupied dwelling.

In all these epidemics the malignant tertian parasite was present.

It seems probable that farther on in the town five other cases were caused by stray mosquitoes from this source, as they cropped up singly at this period and no local breedings out could be discovered; and, further, if due to a local breed out, the cases would have been more numerous and grouped together.

Six cases of malaria occurred in the railway employees' quarters during these four months, and these were almost certainly due to infective anophelines brought in trains.

II.

"An unusual and, it is believed hitherto unrecorded, type of breeding place of the anopheline mosquito (probably Pyrethrophorus costalis)."

The inundation around Khartoum, caused by the Nile flood of 1917, was very extensive, and totalled many square miles.

Tuti Island was largely flooded, and would have been almost completely submerged but for ramparts thrown up to keep the flood from the pump cultivated area.

The south-easterly portion of this island consists of large sand dunes with extensive intervening hollows. (*Vide* Plan II.)

The Nile reached 16'83 on September 22nd, and again on September 27th, from which date a very rapid fall took place for some weeks, but by the end of November the river level was being maintained fairly stationary.

The rapid fall drained off the large lakes that had been formed between the sand dunes and many of the pools, while we were able to deal with those remaining so as to render them harmless.

However, the amount of water sucked up and contained by the sand dunes must have been very considerable.

As the river fell large sand and mud banks appeared, but, except in one place, they all rapidly hardened on the surface, leaving scattered pools here and there.

At this one spot a large mud flat formed, some 150 yards long by some 30 yards broad.

Now the silt brought down by the Blue Nile in flood is very fine, and remains in suspension in the water for a very long time, and thus produces such a fertile plain as that of Egypt.

This mud flat was formed by this fine silt, and was of the consistency of thick pea soup.

It was not connected with any pool, there was no visible water, though the surface glistened in the sun.

On entering it one's feet went through without appreciable resistance until one was above one's knees in mud.

On taking up the fluid in a vessel it remained as fluid, and for a very long time.

Plan II. shews a rough section and plan of this flat.

The place was not examined for mosquito breeding, as it was concluded it was not a suitable breeding place; but on November 24th, 1917, one of the mosquito brigade men, while examining the pools on the island, tried to take a short cut by wading through this mud flat.

As he floundered through his dipper happened to enter the mud, and by force of habit he looked at the contents, and was surprised to find an anopheline larva five to six days old.

He carefully cleared the dipper and took other specimens, and found several more larvæ of different ages.

Mr. MURRAY, the Chief Sanitary Inspector, after confirming their presence, reported it to me, as the condition seemed a very difficult one to deal with.

I visited the place, and anopheline larvæ of various ages were found in considerable numbers, and this was confirmed later on, in the presence of Major R. G. ARCHIBALD, D.S.O., of the Wellcome Tropical Research Laboratories, and Mr. H. KING, the Government Entomologist.

On November 29th anopheline pupæ were found in fair numbers.

The question arose how one was to deal with this breeding ground, as both larvacide and oil tended gradually to spread on the surface and then slowly moved down towards the river, as the mud flat very gradually shelved in this direction. The perpetual and continuous spraying of oil or larvacide would soon have run into a very large sum at war prices; besides our stock would not have allowed of such a procedure.

Consequently I had a trench dug round the whole periphery, just outside of the mud flat, so as to try and intercept the water flow, and in doing this we came across the secret of the mud flat.

After digging through some ten inches of earth we came to a sand stratum, and some two feet below this a rocky stratum, which passed out from the island towards the river and is apparently restricted to this site.

In the deeper portion of the sand water gushed out like a spring the whole length of the canal adjacent to the island, and was undoubtedly fed and maintained by the vast amount of water still being given up by the sand dunes and island.

Elsewhere, there being no rocky stratum, the water took a deeper level, enabling the sand or mud to consolidate on the top and form banks.

It appears probable that the rocky stratum has a slight slope from the periphery to the centre, thus forming a shallow basin and allowing the water to escape but slowly to the river.

Major E. E. AUSTEN, of the British Museum, kindly wrote to me about this, and from his letter I understand such a breeding site has not before been described.

AND AN UNUSUAL BREEDING GROUND.

After digging the trench and intercepting the waterflow, and leading it off direct the river, the flat fairly rapidly consolidated and dried up.

I regret we cannot definitely say whether anophelines bred out from this site, but they could pupate, it appears probable that the adult insect could emerge from the pupæ case. No attempts were made to breed out insects from larvæ or pupæ taken, but *Pyretophorus costalis* is the only anopheline which has been found to breed locally.

PLAN I.

PLAN II.