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The Secretary of the Expert Committee on Malaria has the honour to communicate hereunder the following note:

EXPERIENCE WITH RESIDUAL SPRAYING OF INSECTICIDES IN THE CONTROL OF A. LEUCOSPHYRUS-CARRIED MALARIA IN SARAWAK

by

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A. leucosphyrus was until recently one of the few anophelines about which there was no proof that it could be controlled by residual insecticides. Moreover, its elusive behaviour, added to the semi-nomadic habits of many tribes in the interior of Borneo, made it doubtful whether A. leucosphyrus-carried malaria could be controlled there by means of residual insecticides. In order to elucidate this problem, a malaria pilot project, supported jointly by the Government and WHO, was set up in July 1952 in Sarawak, British Borneo. In addition, a general malaria survey of the country was started to ascertain the distribution and extent of the malaria problem.

Sarawak is on the north-west coast of the Island of Borneo and forms a coastal strip some 450 miles long, varying from 40 to 120 miles in depth, with a total area of some 47,000 square miles. The country can be divided, from a geographical as well as a geological point of view, into coastal alluvian plains, hilly country and, finally, the mountainous areas of the interior. As will be shown later, the coastal plains have little importance from the malaria point of view; it is in the hilly country and in the mountains of the interior that malaria is to be found.

Sarawak, which is almost on the Equator, has a humid and hot climate. The annual rainfall varies from 100" to 200". Kuching, in the southern part of Sarawak, has an annual rainfall of 158", whereas Marudi, the centre of our experimental area in northern Sarawak, has 108" per year. Monthly variations are small, although the Kuching records show that the months with least rainfall are June, July and August. Precipitation increases in September, to reach its maximum in January. In the case of Marudi, there is hardly any variation in rainfall through the year, although July and August tend again to have the least. Mean maximum/minimum temperature in Kuching, based on many years' observations, is 80°F. approximately, seasonal fluctuations being again of little importance. Relative humidity is high, the average monthly record at 8 a.m. in Kuching being always above 70%, readings below 60% at any time of day being rare. Climatic conditions are thus favourable for malaria transmission throughout the year.

The population of Sarawak, according to the 1947 census, which is the last available, is 546,385. The country is inhabited by a great variety of racial and cultural groups, among which the Iban or Sea Dayak is the largest one. Chinese are numerically the second racial group, followed by Malays, Land Dayaks and other smaller groups such as Kayan and Kenyah, but the Chinese are, from the point of view of trade and economic development, the most important group in the Colony of Sarawak.

From the point of view of malaria, the surveys carried out by the WHO team show that racial groups have a very definite significance: Chinese, for instance, were invariably found suffering from malaria much less than the Dayaks living in their immediate neighbourhood. Thus, mode of living, occupation and customs have a definite bearing on malaria rates in Sarawak.

The Dayaks and related tribes in the hilly and mountainous interior live basically on rice agriculture. Areas for cultivation on the mountain slopes are cleared by cutting and burning the forest. Cattle, buffalos and horses are practically unknown both in the interior of Sarawak and in most places in the centre of Borneo, so that all the work is done by the people themselves, and since under such primitive cultivation the land yields little, the people have to move every year to fresh area to cut the forest and plant their rice. The result is a scattered, thin, semi-nomadic population living in the so-called "long houses" near the rivers, and in small farm buildings on the slopes of the mountains, and it is among this population that endemic and hyperendemic malaria is to be found.

A long house is a whole village under a single roof and this communal building lasts usually for 10 to 15 years until the villagers move to another place along the river. The long houses are solid structures made usually of hard wood, sometimes with bamboo flooring and thatched roofing. The rice farm buildings are flimsy wooden shelters intended to last for one year only, and, like the long houses, are built on poles rising above the ground.

As can be expected, the position of the villages, i.e. the long houses, can only with difficulty be plotted on maps and there is practically no information regarding the position or number of farms belonging to each village; an important part of our malaria control project in North Sarawak was to locate the scattered farms where the people spend many months and where spraying with residual insecticides is as necessary as in the long houses.

Communications in the interior are difficult; there are practically no roads and the local way of travelling is by dug-out canoes and other rivercraft. In Northern Sarawak most of the villages and farms can be reached by water, but in the south of the country, with a relatively higher population density, the villages are often reached by foot.

Little was known about malaria in Sarawak before the commencement of the WHO pilot project in 1952, with the exception of the extreme north of the country where field surveys had been made. The malaria map of Sarawak was thus virtually blank. Since 1952 malariometric surveys and entomological observations have been carried out in the five Divisions of Sarawak. It was known, prior to our work, that in British North Borneo and other parts of the island A. leucosphyrus was the main malaria vector. McArthur (1947) showed that A. maculatus, in spite of the reputation it had acquired in Malaya, was harmless in Borneo and that it was in fact A. leucosphyrus which was responsible for malaria transmission in the interior, although it had hardly been suspected as a vector before. Our studies in Sarawak have shown that in Sarawak also it is A. leucosphyrus which is the main malaria vector. Colless (1953), WHO consultant, was able to prove that the vector in our study area in the north of Sarawak was A. leucosphyrus Dönitz 1901, and not A. leucosphyrus balabacensis, as in British North Borneo. Although taxonomic differences between these two varieties of A. leucosphyrus are small, their behaviour as vectors may be different, as will be shown later.

For the trial of residual insecticides, a large area in the Baram district in Northern Borneo was selected. The whole valley of the Baram river and its tributaries from immediately above the confluence of the Tinjar river up to the headwaters was taken as a DDT experimental area, leaving only four villages on the Baram near the confluence as a gammexane area, intended to be used mainly for entomological observations. The valley of the Tinjar, which is parallel to the Baram, was used as check area.

The Baram DDT area covers approximately 1,800 square miles and the gammexane area about 160 square miles; the Tinjar check area used as control throughout our work is approximately 1,000 square miles. Both the Baram and Tinjar rivers are navigable up to the headwaters; in fact, all the villages and most of the farms can be reached by water. The Baram can be followed for 190 miles across our DDT area. The last village on the headwaters is 650 ft. above sea level, and though some of the rice farms and other villages along the tributaries may be a little higher, practically all the population in the DDT and gammexane areas, as well as in the Tinjar check area, is found less than 1,000 ft. above sea level.

The population living along these rivers belong to the Kayan and Kenyah tribes, the latter being split into various sub-groups. They are typical of the interior people and the study area itself is considered also a typical example of hilly and mountainous country in the interior of Borneo. Our DDT area in Upper Baram has, according to our own census, 5,622 inhabitants and the gammexane area 772, whereas the Tinjar control area has a population of 1,735. These are relatively small figures but, though we would have liked to have had a larger sample, the scattered population of Sarawak and the lack of communications make it difficult for a small team to supervise a project on a larger scale.

Entomological studies carried out in the test area before the introduction of residual insecticides and in the check area up to date have shown that the main house-haunting anopheline is A. leucosphyrus Dönitz. A. barbirostris is also found in long houses and farms, and of less importance are A. montanus, letifer, kochi, tesselatus, barbumbrosus, maculatus, albotaeniatus, umbrosus, and separatus. A total number of 9,143 anophelines have been dissected up to date, including 5,912 A. leucosphyrus and 1,041 A. barbirostris. Gland dissections were made throughout our work and 30 A. leucosphyrus or 0.58% were found infected, and 3 A. barbirostris or 0.29% also showed gland infection. All the other anophelines yielded negative results for human malaria sporozoites.

It should be noted that the sporozoite rate for A. leucosphyrus in our study area is lower than the sporozoite rate found for A. leucosphyrus in British North Borneo but, as we pointed out earlier, we are dealing with A. leucosphyrus Dönitz, whereas the findings in North Borneo applied to A. leucosphyrus balabacensis. We may add here that the spleen and parasite rates in our Baram study area and in general in Sarawak are definitely lower than the corresponding rates found previously in British North Borneo. Infant parasite rates are also low and it seems likely that A. leucosphyrus Dönitz is a less efficient vector than A. leucosphyrus balabacensis.

Night mosquito captures have been made at various times in different places in the test area, prior to DDT and gammexane, and systematic monthly captures have been carried out in the check area since December 1953. It is too early to know if there is any variation in the mosquito density throughout the year or in the sporozoite rate, although the results so far obtained show that the numbers caught in human dwellings remain fairly constant and that gland infections are found every month. Our captures have been made systematically throughout the night. A summary of the results obtained in our capture station in the check area is as follows:-

Time	8-10 p.m.	10-12 p.m.	12-2 a.m.	2-4 a.m.	4-6 a.m.	Grand total
Total anophelines captured	329	945	1,360	1,070	782	4,486
Anophelines per man-hour	3.2	9.3	13.3	10.5	7.7	8.8

As can be seen, anophelines, of which A. leucosphyrus form the bulk of the captures, tend to visit human dwellings late in the night and seem to have their peak activity between midnight and 2 a.m. Care was taken in our observations to study the height above the floor at which anopheline mosquitos were caught during the night. The following results were obtained in our check area:-

Height above floor	Up to 3 feet	3 to 5 feet	Above 5 feet	Grand total
Total anophelines captured	2,185	1,355	946	4,486
Percentage distribution	48.7	30.2	21.1	100

It will be noticed that the majority of mosquitos were caught on the walls up to 5 feet and that not many rested above that level. Systematic captures made in the DDT area before spraying yielded results similar to those summarized above (Colless, 1953). It must be kept in mind here that the long houses in which all these captures were made are built on poles and that therefore the floors are several feet above the ground.

We would also like to emphasize the fact that the figures given above refer to mosquitos caught resting on the walls before and after taking their blood meal, and this shows that if captures are made throughout the night good numbers of A. leucosphyrus can be obtained and that this species definitely rests on the walls after entering human dwellings or before leaving them.

After making a general survey of all the study area, DDT and gammexane spraying operations were started early in 1953, both insecticides being used in the form of wettable powder. DDT was applied at the rate of 2 grams per square metre every six months and gammexane at the rate of 0.10 grams of gamma isomer per square metre every three months.

All the inside walls and partitions in human dwellings were sprayed as far up as could be reached with the equipment employed (Lofstrand 250-AP sprayers and 6503 nozzles). The fact that a certain number of anophelines were caught above 5 feet decided us to spray as high up as possible, usually up to 10 feet. Mosquitos had also been found resting under the platforms of the long houses and it was decided also to spray the supporting poles and the under-surface of the platforms. All human habitations, i.e. long houses plus rice farm buildings, were regularly sprayed. As can be expected, reaching the scattered farms was the most difficult and time-consuming part of the spraying operations, but it was felt that since people live there a good part of the year, the spraying of the farms was necessary.

The dates on which the spraying was carried out were as follows:-

1st DDT spraying	January/February 1953
2nd DDT spraying	August 1953
3rd DDT spraying	March 1954

A general pre-operational survey for the Baram DDT area was carried out in November/December 1952 and the first post-operational survey was done in November 1953, i.e. approximately 8 months after the first DDT spraying. In the Tinjar check area surveys were done in March and August 1953 and February 1954. The results obtained in children from 2 to 9 years of age were as follows:-

	DDT test area		Check area		
	Date of survey:		Date of survey:		
	Nov/Dec.1952 (pre-operational)	Nov.1953 (1st post-operational)	March 1953	August 1953	February 1954
No. of children examined	390	272	72	76	147
Enlarged spleens	202	89	20	28	49
Spleen rate (%)	51.8	32.7	27.8	38.9	33.3
Average enlarged spleen	1.7	1.8	1.5	1.9	1.8
No. of bloods examined	202	134	33	48	67
Positive bloods	72	11	6	12	16
Parasite rate (%)	35.6	12.4	18.2	25.0	23.9

As can be seen, 8 months of DDT produced a very marked drop in the spleen and parasite rates, whereas in the check area the malaria level was hardly changed. It will be noticed that the surveys were not carried out at the same time of the year. There is a gap of 2/3 months between the demonstration area and check area surveys, but this was inevitable due to the shortage of personnel in the project and the difficulties of communication. We think, however, that this has not had much influence on the results obtained. Figures for the gammexane area are not included here but, though the sample is small, the general trend observed is the same as in the DDT area.

Blood films were taken every month from babies under one year of age, for transmission or infant parasite rate. A summary of the results is given below:-

	No. of bloods examined	Number positive	Per cent positive
Infants born before DDT spraying	303	34	11.2
Infants born after DDT spraying	324	1	0.3

The conclusion to be drawn from these results is that, as only one positive blood film was found in a child born after the first spraying, with that exception malaria transmission has been successfully interrupted in the DDT area. This, coupled with the results of spleen and parasite surveys, seems to indicate that, in spite of the elusive reputation of A. leucosphyrus and in spite of the difficulties of dealing with a scattered semi-nomadic population, malaria can be controlled in the interior of Sarawak by DDT residual spraying.

We would like to add here, before concluding, a note of caution regarding the possibilities of a malaria campaign throughout the country. Our experience has shown that the spraying of long houses is relatively easy, but that to reach the scattered rice farms is a much more difficult task. The only infection we detected in infants after DDT spraying was in a family living in an unprotected rice farm, the location of which was unknown to our spraying squads. If this was overlooked with all the supervision available in a pilot project, and having the full co-operation of the local inhabitants, it can be easily understood that in a nation-wide campaign when DDT spraying becomes routine, a good number of far-away farms are likely to be overlooked. It can also be deduced from the above that if the spraying of the scattered farms presents many difficulties, the attack on breeding places in their neighbourhood as a means of malaria control is altogether impracticable.

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