WORLD-WIDE MOSQUITO CONTROL

SPECIES SANITATION AND NATURALISTIC METHODS OF CONTROL OF MOSQUITOES

by

Harold Farnsworth Gray, Gr. P.H.
Berkeley, California

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INTRODUCTION

Practically every medical man knows there are about 1700 species of mosquitoes, of which about 170 are **Anopheles** (malaria transmitters). Every one knows that mosquitoes breed in water, usually standing water, and that if we get rid of the water, or can kill the mosquito larvae in the water, we can eliminate mosquitoes. These are elementary statements, but beyond these ABC's there is a considerable body of techniques relating to just the usual methods of mosquito control by the processes of drainage, filling and pumping, and of larviciding by means of petroleum derivative oils, Paris green and pyrethrum extracts.

A certain amount of entomological knowledge, engineering skill and practical experience are necessary to effectively apply the foregoing methods. But there are many places in the world, especially in the tropics, where these usual methods of mosquito control are only partially applicable, or cannot be effectively used because of cost limitations, scarcity of equipment or materials, climatic conditions or other factors, and other methods, developed from our ecological study of mosquito species, may be more simple, less expensive and reasonably effective.

A number of such methods, because they are directed usually to making some minor change in the environment so that unfavorable instead of favorable natural conditions occur with relation to a particular mosquito species, are termed "naturalistic" methods of mosquito control.

You will note that I said "naturalistic" control methods are directed at a particular species of mosquitoes. This ties into another rather modern concept in mosquito control, that of "species sanitation." The idea of "species sanitation" was undoubtedly developed by Sir Malcolm Watson in Malaya, but the term, or its Dutch equivalent, was coined by Swellengrebel.

Let us limit our discussion of these two concepts principally to the control of malaria, in order to keep within a reasonable compass of time.

There are 170 species of **Anopheles** in the world, of which probably all are capable of transmitting malaria. But not more than about 47 species and subspecies are of any appreciable importance as malaria transmitters, and of these probably only about 20 or 25 species and sub-species are of great importance.

Years ago Watson discovered the very important fact that in any area where malaria is prevalent, usually only one, or at the most two or three species or subspecies of **Anopheles** are concerned in the transmission of the disease, and therefore if effective control methods are applied to this species the disease can be very greatly reduced in that area at minimum expense. For malaria control, the reduction of the very few (usually only one) vector species will produce good results, even though other Anophelines and Culicine mosquitoes still are abundant, in that area.

Of course in some areas, particularly tropical areas, concentration on the vector **Anopheles** for that area will not usually minimize the great numbers of pest (non-vector) mosquitoes, and there may also be a problem of other mosquito-transmitted diseases such as yellow fever, dengue or filariasis. But the vectors of these diseases are a few specific mosquito species, against which a particular form of species sanitation will be applicable, so that, for our illustrations, we will stick to malaria control.

Medical officers are concerned principally with the control of disease, where fore their interest will be served by species sanitation, a concept which is in accord with the military maxim of economy of effort.

SPECIES SANITATION

For illustrations of species sanitation let us take a few regions throughout the world and call attention to the principal malaria vectors there.

1. Many of you come from the Mississippi Valley, or the Southeastern states, where a single species of mosquito, **Anopheles quadrimaculatus,** is the effective vector of malaria. Successfully control this one species in that area, and malaria no longer will be endemic, though there are other **Anopheles** present which can, but seldom do, transmit the disease.

2. But in the Pacific Coast States, a mosquito which looks much like **Anopheles quadrimaculatus,** but has entirely different breeding habits, is the effective vector of malaria. This is **Anopheles maculipennis freeborni,** which breeds in shallow seepage water especially from irrigation, whereas **A. quadrimaculatus** is typically a pond or reservoir breeder. The control of malaria in the Pacific Coast Valleys almost entirely depends on the control of **A. maculipennis freeborni.** The control methods which are successful against **Anopheles quadrimaculatus** would fail against **Anopheles maculipennis freeborni,** and vice versa.

3. Some of you may be stationed in the Solomon Islands, or New Guinea or the Molucca Islands, or North Queensland. Here the principal vector of malaria is **Anopheles punctulatus,** which is also found in New Britain and New Hebrides, along with its sub-species, **A. punctulatus moluccensia.** The first species is usually limited in its breeding places to natural swamps, pools, and puddles of stagnant water. But its variety **moluccensis** is one of the most versatile breeders among Anophelines, and apparently will breed in almost any kind of water, fresh or brackish or salt, clean or dirty, running or stagnant, in natural collections or in artificial containers. Where you have **A. punctulatus moluccensis** to deal with, you have a formidable job on your hands, for you may have to attack and control

all water within a reasonable distance from your post. In controlling **A. punctulatus moluccensis** the idea of species sanitation is negatived more or less, as in controlling that species you probably must, of necessity, control practically all other species of mosquito in its area. However, practical experience with this species during this war may modify our views and perhaps bring about some simplifications in control of this species.

4. Probably the principal vector of malaria in the Philippine Islands, at least on Luzon, is **Anopheles minimus flavirostris,** a mosquito which breeds in running water in streams and ditches. The usual methods of mosquito control, directed againts standing water, fail completely to control malaria where this mosquito is the vector, as on Bataan Peninsula.

In 1898 when we first went to the Philippines, our Army medical officers had been taught to look upon marshes as malarious, and they regarded the lowlands, especially in the vicinity of Manila, for example, as extremely dangerous to troops. Actually there was a low incidence of malaria in and about Manila, where the dominant anopheline, **A. ludlowi,** is a poor vector under natural conditions; but the rigidly held idea that "marshes equal malaria" led to the stationing of troops as much as possible in the hill areas near running water. Malaria promptly became a scourge among troops and civilians so situated, while the disease remained at a low rate of incidence among troops and civilians quartered of necessity in the supposedly malarious lowlands. A report by Crosby and Whitmore in 1904, buried in the medical records of Fort Stotsenburg and long neglected, showed that the stream-breeding **Anopheles minimus flavirostris** of the hill areas was an important vector, in fact **the** vector, of malaria in Luzon. But it took twenty-one years (to 1925) for this information to be acted upon, even though Walker and Barber in 1914 had again showed that the stream-breeding **A. minimus flavirostris** was the dangerous vector. And in view of our recent heavy losses on Bataan Peninsula, due in large part to malaria, I can perhaps be pardoned a certain skepticism as to whether our available knowledge was adequately acted upon.

5. Many years before the relationship between **Anopheles** and malaria was known, the Italians had recognized that a mixture of salt water and fresh water on the marshes along the Italian coast resulted in intense malaria. An Italian engineer named Zendrini therefore in 1740 constructed control gates on the marshes near Viereggio to keep out the salt water from tides, with the result that these marshes and their vicinity have been healthy ever since. Zendrini's gates were still operating at last reports.

The reason for this we now know. Malaria in this part of Italy is transmitted by **Anopheles sacharovi** and **Anopheles maculipennis labranchiae,** which are brackish water breeders. When the salt water was excluded by Zendrini's gates, the conditions became unfavorable for these two vector species, and they were supplanted by fresh water **Anophelines,** such as **Anopheles maculipennis messeae** and **Anopheles maculipennis maculipennis,** which are not normally vectors of malaria in Italy, though they are usually vectors in Southern Russia.

6. As a final illustration we may mention Malaya, where Watson discovered that a selective attack against **Anopheles umbrosus** in the lowland swamp areas was necessary for malaria control, but that in the hill areas the species which must be controlled was the stream-breeding, sunlight-loving **Anopheles maculatus.**

The foregoing illustrations serve sufficiently to illustrate the fact that in any area the attack upon mosquitoes, for successful malaria control, must be made upon the principal vector species in that area. This means also that we must understand the ecology of this principal species, and use as control measures those which are effective against that particular species. This, for economy of effort, we would like to do at a minimum expenditure of labor and materials, and this can frequently be accomplished with a relatively minor change in environmental conditions, which will make the area unsuitable to the breeding of the vector species in that area. Let us therefore discuss some of these changes which we term "naturalistic methods."

NATURALISTIC METHODS

1. Changing Saline Content of Breeding Water

One of the simplest methods of naturalistic control is to change the salt content of the breeding water. Many species of mosquitoes are limited in breeding to water of a certain salt content, and above or below that content they will not breed in appreciable numbers. Many examples can be given, but three will be presented.

(a) The brackish marshes at Durazzo, Albania, formerly bred millions of **Anopheles sacharovi**, a dangerous malaria vector. Hackett had this marsh enclosed on the shore side by a dyke, and installed automatic gates which would permit salt water from the Adriatic Sea to flow in at high tides, thus increasing the salt content above the tolerance for **A. sacharovi**, and so practically eliminating malaria in this area.

(b) Walch in Java eliminated the breeding of **Anopheles sundaicus** in the native food-fish (**Chanos** species, called "bandeng" by the natives) ponds along the coast by similarly increasing the salinity of the water in the ponds, but paradoxically the breeding of this same species in the coastal mangrove swamps at Malaya can be controlled by freshening the swamp water.

(c) I have previously referred to the control of **Anopheles sacharovi** and **Anopheles maculipennis labranchiae** at Viareggio in Italy by excluding salt water from the marshes. The Dutch have also found that when new polders are reclaimed from the sea, at first the dangerous vector **Anopheles maculipennis atroparvus** breeds profusely, but later, when the polders have become freshened, **atroparvus** is supplanted by the relatively harmless **Anopheles maculipennis messeae**, which appears to be able to overbreed **atroparvus** in fresh water.

2. Flushing

Some of the most dangerous tropical vectors of malaria breed in running water, for example **Anopheles maculatus** in Malaya, and **Anopheles minimus flavirostris** in Luzon or **Anopheles minimus** in India; or they are stream-bed pool breeders, such as **Anopheles culicifacies** in Ceylon.

The latter species can be controlled by channelizing the stream so as to eliminate the pools, and some workers have been quite ingenious in devising simple methods of making the stream itself do the work of channelizing the center of the stream bed while silting up the side pools. These stream-bed pool breeders can also be controlled by oiling, but at much greater ultimate cost.

But for the species actually breeding in running water the usual control methods are either inapplicable, ineffective or out of the question because of cost, and new methods had to be devised. K. B. Williamson at Cameron Highlands in Malaya is credited by Watson with having successfully developed in 1930-32 the method of automatically flushing streams to destroy the larvae of **Anopheles maculatus**, though both Le Prince at Panama and Ronald Ross at Ismalia are known to have used hand-controlled gates for flushing early in this century.

Flushing is performed by building a small dam (a few feet high) across the stream bed, and placing in it a device which will permit a large quantity of water to be stored above the dam, and then be discharged suddenly down stream. The control apparatus may be either a hand-operated sluice gate, or an automatic device such as a tipping bucket or a siphon.

In Malaya, thousands of natives have been taught to control malaria on their land by means of inexpensive hand-operated sluice gates, and many have also built control structures of the inexpensive tipping-bucket type. In Penang J. S. DeVillers has successfully developed an automatic siphon for the flushing device, and this idea has been extended by G. Macdonald in Ceylon to a standard concrete siphon fabricated in sections at a central plant and quickly and easily assembled where required.

In practice, the action of the sluice, either automatic or hand-operated, causes a large quantity of water to flow suddenly down the stream bed, flushing all mosquito larvae and pupae out, and killing many if not most of them, either by bruising them by dashing against the sides and bottom of the stream, or by the dynamic effect of the water in disrupting their bodies. Not only are the larvae cleared out of the stream bed for distances of from several hundred yards up to a mile or more below the dam (depending upon the slope of the stream bed and the volume of the flush), but the fluctuations in water level in the ponded reach above the dam also tends to discourage mosquito breeding, and probably most of the few larvae to be found above the dam will be either left stranded on the sides, or swept out with the flush.

Obviously this general device can be used successfully and extensively in many tropical areas. Watson and others report that it is used widely in Malaya, and its use in India is being rapidly increased. When we get back to the Philippines, we should use this method very extensively wherever applicable.

I quote the following from pages 4, 5 and 6 of a pamphlet published in May, 1942 by the Ross Institute of Tropical Hygiene (London School of Hygiene and Tropical Medicine), entitled "Some Emergency Anti-Malarial Measures," and written by Sir Malcolm Watson.

"On the western side of South India the malarial season is the pre-monsoon period, when the rivers are running at a slow speed, and are not flushed by rain storms. Once the monsoon breaks there is no need for any mosquito control of the streams. On a number of estates which I visited I saw a very simple way of sluicing the streams. It consisted of an earth dam with one or more oil drums, the ends of which had been removed, to form openings through the dam for releasing the flush. The upper end of the oil drum was closed by a sheet of wood until the dam was full. Then the wood was removed by hand and the stream was flushed. On one estate there were 60 of these dams across various streams, the largest of which was about 20 feet wide. The dams were operated in succession, beginning at the top. The fall in the malaria as the result of this simple procedure was remarkable indeed. The largest of these dams cost three rupees for labour. When the monsoon broke all the dams were swept away, but to replace them at the end of the rains cost only 60 rupees. Except for the wages of the two or three men who operated the sluices this was practically the whole cost of the control of malaria on this estate for the year. Nothing would have been gained by erecting concrete dams; they would have been merely so many obstructions during the torrential rains of the Western Ghats.

"In South India I also saw many simple sluices made of wood, where the gate was lifted by hand out of the slit which held it. These, too, were in earth dams, which were washed away when the floods came. The sluice gate was saved by being tethered to the bank by a wire. It is important that the sluices are water-tight, otherwise in drought not enough water is collected to flush the stream. It is also important that the flush should not exceed the amount of water in normal wet weather. If it does the banks of the stream are eroded. The quantity of water released depends on the size of the openings in the dam and capacity of the reservoir.

"There were also very effective concrete dams, which flushed rocky streams 20 feet wide for fully a mile. The length flushed depended on the nature of the stream bed. Where the gradient was flat, and the bed full of large boulders, the flush was effective for a short distance. The sites of the dams should be the end of the flatter portions of the stream bed. In this position the dams will hold the maximum amount of water, and so will be most effective. Where, after flushing, larvae are found lower down in a stream it indicates that another dam should be erected. Before building permanent dams it might be wiser in some places to begin with temporary earth dams. These would be a guide to the best sites for the dams, to the required capacity of the dams, and the results likely to be obtained by sluicing. At one place where the river had an unusual number of obstructions and the desired results were not obtained, a special procedure was adopted. The gate was opened, and the dam half emptied. Then the gate was closed, the dam oiled, and after a short time the gate was reopened and the oiled water rushed down. This was effective in removing larvae which previously managed to maintain themselves in this very rough stream bed.

"In Assam, in Northern India, Mr. Lloyd, a tea planter, was, if my memory is correct, the first to use sluicing. He erected a series of dams in a ravine about

40 feet wide. The openings were controlled by sluices. What was a dangerous valley from the many seepages in its bed was effectively controlled by the dams and the sluicing.

"Many new dams are now being erected in Northern India, in which an automatic sluice is incorporated in the concrete, like those designed by Dr. McDonald for Ceylon. But instead of a flush of 475 gallons per minute from each syphon, some sluices are designed to deliver four times this quantity of water. They have to be constructed on the site, as the various pieces are too large to be cast at a central spot, as in Ceylon. But despite this want of mass production, they cost much less than a battery of the Ceylon type which would deliver the same amount of water. Another difference, as the result of the experience in Ceylon, is the incorporation of a hand-operated sluice gate in the dam, as well as the automatic syphon. This allows the debris and silt, which has collected in the dam, to be scoured out during heavy rains. It will probably be wise to incorporate a hand-operated sluice in all dams, along with automatic syphons; so that if in a partial drought there was not enough water in the dam to operate the automatic sluices often enough, the stream might still be kept harmless by opening the hand sluices."

3. Fouling and Stagnating

One of the things that is noticeable about most species of **Anopheles** is their preference for comparatively clean water. The most important exception presently in mind is **Anopheles punctulatus moluccensis** in New Britain and New Hebrides, and perhaps elsewhere, which will breed in foul water. It therefore is possible to discourage the breeding of most species of **Anopheles** by purposely fouling their available water with rotting vegetation or other organic matter, such as sewage, garbage or other wastes. True, this may make possible an increased breeding of certain Culicine species, and result in much discomfort, but where other methods are either not available, or too costly to apply, or are ineffective, there seems to be no reason why the method of deliberately fouling the breeding water should not be used effectively. Native labor could be used to cut large quantities of vegetation and pack it into breeding waters, to ferment and foul the water.

Where there is a shortage of anti-larval oil, such as Diesel oil, or of larvicides such as Paris green or pyrethrum, the method of fouling certainly ought to be used as a substitute method, and in addition I feel that it ought to be tried out extensively in the tropics as an anti-anopheles control method, even if you also treat the fouled pools with oil from time to time to minimize the breeding of pest mosquitoes of the Culicine group.

I will here quote certain pertinent remarks by Sir Malcolm Watson regarding the use of oil. They are quoted from a paper entitled "Some Points in the Technique of the Prevention of Malaria," and published in 1938 in the Journal of the Ceylon Branch of the British Medical Association. Watson is quoted for the reason that he was the originator of successful malaria control in the Far Eastern tropics (Klang and Port Swettenham in Malaya in 1901), and has had the longest and most successful experience of any living man in the effective control of malaria in the tropics.

"This was the discovery of a perfect anti-malarial mixture. It proved of incalculable value to Malaya. I am thinking in terms of tens of thousands of lives and hundreds of thousands of pounds. Its use rapidly spread all over the Peninsula, and today there is, I believe, a far greater amount of oil used per head of the population in Malaya than in any other part of the tropical world. Government in Malaya uses it extensively, and encourages its use by carrying oil on the railway at the lowest rates, as some other Governments are also doing at the suggestion of the Ross Institute. One of the great advantages of oil is that within a few days, every larva in an area can be destroyed, a large number of adults returning to lay their eggs also are destroyed, and those that do not alight on the oil have to travel outside the oiled area, at least half a mile from a house before they find congenial and clean breeding places. It means that if a female of a species is laying her eggs every three days, she has to travel backwards and forwards several miles in the ten days before the parasites have developed to the state of being sporozoites in her salivary glands. Only when this stage is reached can she infect when she bites. Obviously every mile she has to travel reduces her chance of getting in a bite that can infect. In practice, when oiling has been properly done on a weekly round, malaria drops very rapidly, and within less than three months only relapses are found on an estate, and not so many of them. Spleen rates, admission rates and death rates fall with an almost startling rapidity even on the most intensely malarial places. These results are to be seen not only in Malaya, but also in India and Africa. The area usually oiled is half-a-mile round the inhabited area; it is possible that in very special conditions, a somewhat larger protective area is required, but these are very special conditions.

"Any oil or mixture of oils will not give this result. We soon found that what is sold as 'crude oil,' or 'fuel oil,' or 'diesel oil' varies greatly in composition in different parts of the world; and that many of these oils do not make satisfactory anti-malarial mixtures. Some would not kill larvae, some would not kill grass, some would not spread, some required admixture with uneconomical amounts of kerosene, and some were quite useless.

"I would like to give a warning against using home made mixtures of old engine oils. These vary in composition and some are useless. It may well prove to be false economy to use oils which have not been tested to see if they are effective larvicides.

"The Health Officers of one Government, who could draw large supplies of used aeroplane oil for anti-malarial purposes, found even this so unreliable that each sample had to be tested before it could be used, and owing to the results being so variable they gave up using the aeroplane oil."

4. **Shading and Clearing**

There are perhaps a dozen or more of these naturalistic methods of mosquito control, but I shall select only one more for discussion. For the other methods, those especially interested can find descriptions in the book on "Mosquito Control" published in 1940 by Professor W. B. Herms and myself.

This last method is the matter of clearing areas in which mosquitoes breed. In many anti-mosquito campaigns one of the measures used has been the clearing of dense vegetation in jungles, swamps and along stream beds. Sometimes this was done merely to permit easy access for the application of other control measures, such as drainage or oiling; in other cases it was done to facilitate the drying up of wet areas; and in other cases it was just done because somebody else had done it elsewhere.

Against some species of **Anopheles,** such as **A. umbrosus,** which is a shade-loving species, clearing is a useful procedure, though usually relatively expensive. But against such sunlight-loving species as **Anopheles minimus** in India, or **Anopheles maculatus** in Malaya, and probably against **Anopheles pseudopunctipennis** in Argentina, clearing is not only useless, it is highly dangerous. The British found this out years ago in Malaya. When they began work in the hill regions, they cleared the small streams, following out their customary procedures in the coastal lowlands. But when they did this the malaria became epidemic in severe form, as they thus made possible the great proliferation of **Anopheles maculatus,** which thrives best in sunlight. Now they leave as much shade as possible along the streams, and in India, against **Anopheles minimus** they plant hedges of **lantana, dharanta** and other bushes along their streams, ditches and drains so as to effectively shade the water surface. In some cases they have made mats of split bamboo or other materials and covered the water surface with these mats.

Rather obviously, therefore, clearing should not be adopted where there is any danger that a sunlight-loving vector **Anopheles** would be encouraged to increase its breeding, and furthermore, clearing may be interdicted by military conditions requiring maximum concealment. But shading, if carefully done, may not interfere with military concealment, and may be very helpful as a deterrent to the breeding of certain dangerous vector **Anopheles** in a particular area. But be sure you know what species are present, what species is the primary malarial vector, and what its breeding preferences are with respect to shade or sunlight, before you change the landscape.

I quote again from Watson, in an article entitled "Prevention of Malaria in

India," published June 8, 1940 in "Nature."

"For example, on many estates in India, as in Delhi, much malaria has been 'man-made.' Over wide areas of both northern and southern India, the malaria is entirely due to man interfering with Nature by his clearing away jungle from streams and exposing them to the sunshine, and by his draining swamps. For by doing so he has driven out the jungle-loving or harmless species and permitted the breeding of dangerous species—**A. minimus** in the north, **A. fluviatilis** or **A. culicifacies** at different elevations in the south. Intermittent flushing will wreck the home of even the fastest stream-breeding malaria-carrier in the world; it is much used in India. Streams are flushed by hand-operated openings in simple earth dams; by automatic tippers, costing a shilling or less, of a design that would rejoice the heart of Mr. Heath Robinson; or by more elaborate things of concrete and iron. In other places, if man holds his hand, Nature will cover up her wounds with secondary jungle, but often she is too slow and we must replant appropriate shade. So we see the strange sight of hundreds of acres of little squares of almost stagnant water growing rice in the sunshine, and down the center of the rice fields a stream densely shaded by a hedge; it may be of the lovely shoe flower (Hibiscus), the wild rhododendron (Melastoma), the notorious Lantana or other plants. The center stream alone was the danger. The hedge has made it harmless, and an intense source of malaria has been eliminated. There are 2,000 miles of these dense hedges now, and 4,000 miles will be effective by the end of the year."

5. Pole or Faggot Drains

There will probably occur a number of situations at or in the vicinity of stations which will be occupied for considerable periods of time (perhaps for the duration of the war) and where sub-surface drainage would be a very helpful **Anopheles** control method. However, neither vitrified clay tile, or concrete drain tile, or perforated corrugated metal pipe, or even gravel or crushed rock, may be available to construct such drains.

Under these conditions it is possible to construct sub-surface drains which will work effectively for years, using native materials which are readily available at the site. The best are bamboo poles laid in the trench in such a manner that the longitudinal interstices between the poles forms the channel through which the water can flow. Three, six, or ten poles, tied at intervals of about two feet, can be used in the bottom of the trench, and covered with a few inches thickness of any coarse twigs, small brush, etc., to prevent packing of dirt into the spaces between the poles.

If bamboo is not available, then any green wood poles (saplings) of two or three inches diameter will do. And even if no poles are available, the bottom of the trench can be filled for a depth of one or two feet with cut brush, and a fairly useful drain obtained.

Conclusion

In this somewhat sketchy manner I have tried to give you some idea of a few of the newer concepts in the field of malaria control by anti-anopheles methods.

We are not going to be able to carry on successful military operations in tropical areas unless we use intelligently and effectively the various **Anopheles** control measures which are applicable to the conditions in a particular area. Do not be deceived—drugs are not effective as malaria control agents. For the reason that he has had the longest and most successful experience of any man in controlling malaria in tropical countries, I quote Sir Malcolm Watson again on this point:

"I want to stress that while drugs can cure malaria, no drug so far known can prevent infection. While there are hundreds of places in which malaria has been abolished by the destruction of mosquitoes, there is no example of a place in the tropics being freed from malaria by the means of drugs alone. The use of quinine can never result in the abolition of malaria, or even make any material reduction in the liability to infection in a malarious locality. Extensive experiments with the new drugs atebrin and plasmoquin have led to the same conclusions."

This does not mean that Watson denies the applicability of anti-malaria drugs in malaria control. Here again his experience is probably the longest and most complete of all living men. I quote from his Finlayson Memorial Lecture at Glasgow in 1934:

"From no place, however, were results reported from quinine comparable with those obtained by attacking the mosquito, as at Klang, Ismalia and Panama. In Malaya, where we were faced with the most intense malaria, and could afford to neglect no measure which could be of any help, however slight, prevention by quinine was given a trial, not merely for a time, but the drug was used on a large scale for many years, after we had defined its value and its limitation. Our first efforts with the drug in 1904-1905 were definitely encouraging, but in 1906 when larger numbers of non-immune labourers arrived in the country, it was found necessary to raise the daily dose to 10 grains for adults, but even this did not prevent them becoming infected, and dying at a rate which caused grave anxiety. The conclusions I reached then were described in the first edition of my **Prevention of Malaria.** 'The true action of quinine appears to be to assist the human host in working out for himself the resistant power which will ultimately free him from the disease. It acts either by attenuating the virus within the host, or by increasing the resisting power of the host in some unknown way, or possibly by both. Without quinine in many cases, especially in very unhealthy spots, the human host would die before he had acquired his resistant powers. We thus see that, if quinine in sufficient doses be given, the man will gradually overcome the parasites, and apparently suffer little from them; but at the same time we see that during this period he is capable of infecting others. The man is for a time a "malarial carrier" not unlike the typhoid carrier.'

"There is, in my opinion, no antagonism and no competition between the various methods of preventing malaria. The wise sanitarian will use those which give him the maximum benefit for the minimum expenditure. In all campaigns anti-malarial drugs have a place. In tropical regions where malaria is intense drugs must be used to cure rather than with the idea that they will prevent infection; indeed, without drugs little headway might be made with other methods, and valuable lives might be lost in many campaigns."

There is no question but what under combat conditions in the tropical regions we will have to rely partly on the use of drugs to control the manifestations of malaria infection in personnel, and partly on a direct attack on adult anophelines in tents and barracks, either by hand catching or by pyrethrum sprys. But as the supply of quinine is quite limited, and much of our former sources of pyrethrum cut off, we should endeavor to make their use unnecessary as rapidly as possible, and this can only be done by means of anti-anopheles measures wherever possible. And in using anti-anopheles measures, we should use to the greatest extent possible the newer naturalistic methods which are effectively applicable to the vector **Anopheles** in the particular area of operations, rather than try to depend, unimaginatively, upon only the dependable old methods of drainage and oiling. Oil also is short and not easily available in many areas. But we are not short on brains, or versatility or constructive imagination or adaptability, and these qualities, with any reasonable quota of technical information should see a resourceful medical officer through some mighty tough spots in this war.