CHAPTER 12

Malaria

The Interim Commission of WHO, recognizing the importance of malaria, decided that immediate action was necessary; it accordingly convened, early in 1947, an Expert Committee on Malaria to study and advise on this problem.

The general facts about the distribution and prevalence of malaria in the world at this time were known in detail for some areas, and roughly for almost all. Of the four varieties of the infection the two most important, due respectively to the parasites *Plasmodium vivax* (vivax malaria) and *P. falciparum* (falciparum malaria), were estimated to affect some 300 million persons yearly and to cause about three million annual deaths. Though principally a tropical disease, malaria has existed as far north as Archangel (64°N) and as far south as Córdoba in Argentina (32°S).

Despite the high figure of annual deaths, and though it is often a major cause of infant mortality, the importance of malaria consists mainly in the chronic invalidism it produces. It is insidious rather than dramatic in its effects except when, for reasons imperfectly understood until recently, an epidemic flares up, as in Ceylon in 1934-35. It leads to an increased number of deaths from other causes, impairs physical and mental development, and affects fertility and birth rates. It has serious repercussions on agriculture, commerce and industry. Wherever it exists, human progress is retarded or inhibited. The development of many potentially fertile areas of the world is barred by its presence; other areas, in which human activities have encouraged the breeding of the anopheline mosquitos that carry it, have been developed and later abandoned.

The epidemiology of the disease is determined partly by climate, which affects the breeding of mosquitos and the development in them of the malarial parasite. Nevertheless, in lands with similar climates malaria may behave in very different ways. There are regions, notably in the Pacific islands, where malaria does not exist simply because there are no anopheline mosquitos. Anophelines could in all probability establish themselves if introduced. There are also certain very efficient vectors which are known to be capable of establishing themselves if accidentally introduced into countries outside their present habitat, and of intensifying the transmission of malaria. The growth of international air traffic favours accidental dissemination of anophelines, a problem demanding vigilance.

Such was the problem, as seen in 1946. The old-established methods of control by minimizing mosquito breeding, and of alleviation or cure by the use mainly of quinine, had been by no means ineffective, but the potentialities of two new classes of antimalarial weapon, the insecticide DDT and synthetic antimalarial drugs, were great. The synthetic drugs had been used before and DDT during and after the Second World War, but their possibilities were as yet scarcely explored. The first report of the Expert Committee, in 1947, was devoted largely to suggestions for experiments in their use.

Although controlled experiments in the use of two new antimalarial drugs, chloroquine (aralen) and proguanil (paludrine) were proposed, the Committee placed its faith in the use of DDT against adult mosquitos as the main instrument for malaria control. The decision was made not only on grounds of efficiency, but also for economic reasons. Malaria, poverty, low population density and lack of development are inseparables in the rural tropics. The administration of antimalarial drugs, at least weekly, would demand organization that does not exist and could not be set up in most of the affected areas. Prevention of mosquito breeding by attacking the larval forms in water becomes more expensive per person the lower the human population density. In contrast, the use of DDT as a house spray, once or twice a year, demands a comparatively small, mobile organization, and its cost, which depends on the number of houses to be sprayed, remains about the same per head whatever the population density, except in rare circumstances.

Other chemicals, notably benzene hexachloride (BHC) and dieldrin, have been developed, supplementing, not replacing, DDT. Difficulties, foreseen and unforeseen, have had to be overcome, but WHO's original policy of relying on residual insecticides for world malaria control has never been superseded.

Besides reporting on the technical aspects of malaria control, the Expert Committee made recommendations on malaria policy which were adopted by the First World Health Asembly. Demonstration teams were to visit any malarious country requesting assistance. The basic composition of a team was a malariologist and an entomologist, with the addition of a sanitarian or a sanitary engineer. With a view to creating local malaria organizations, the Expert Committee recommended that governments should appoint nationals to understudy each member of the international team. At the same time, it was recommended that WHO should provide expert lecturers for existing schools of malariology, assist in setting up courses in malariology in regions not yet provided with such facilities, provide fellowships for individual training abroad, and circulate literature both on technical subjects and on the health education of the public.

Seven teams were operating by the end of 1949, all in Asia—four in different provinces of India, one in Afghanistan, one in Pakistan, and one in Thailand. Preparations for an eighth, in Iran, were under way. Six of these teams were established with the co-operation of UNICEF, which supplied equipment, transport, insecticides and drugs, WHO supplying the professional staff; for the seventh, WHO itself provided the supplies. In the same year, WHO assumed technical charge of malaria control among Palestine refugees. Consultants and lecturers were appointed to several centres, and facilities for training WHO fellows were established at five institutions. Forty-seven experts had been designated in over thirty countries to furnish additional technical advice by correspondence.

Expansion of activities continued smoothly in 1950, by the end of which year nine demonstration teams were at work. Those previously established had expanded their areas of operation, and in India and Pakistan during 1950 the number of persons protected from malaria was increased fourfold. In the demonstration areas of Thailand and Pakistan, and in at least one area of India, there was evidence that the transmission of malaria had actually been interrupted.

At the request of the governments concerned, several teams were able to work on other health projects during the periods between transmission peaks, and after spraying operations were completed. These included a successful kala-azar survey and treatment programme in Pakistan, typhus control in Afghanistan, a small plague control operation in south-west Bengal, the preparation of plans for filariasis control in Calicut (Madras), and certain general assistance in sanitation and public health. More consultants were made available to assist governments and fifteen fellowships in malaria were awarded.

One of the outstanding events of 1950 was the Malaria Conference in Equatorial Africa, held at Kampala. Representatives of eighteen territories adopted a resolution recommending governments to control malaria by modern methods as soon as feasible, and to seek the co-operation of WHO in planning arrangements which, necessarily, would spread across national frontiers.

With the co-operation of UNICEF it was possible to undertake a total of twenty-two projects in 1951. The Afghanistan Government was able to take over full responsibility for two field projects, while the project in Thailand, started three years earlier with UNICEF help, led to a national five-year programme for the elimination of malaria as a major public-health problem in the country.

It was found necessary in some instances to modify the original demonstration methods. In certain areas of the world, for example, the Western Pacific Region, the reaction of the local vector of the disease to residual insecticides was not known, and had to be determined by experiment on a comparatively small scale. Doubts had been expressed whether those particular anophelines did in fact rest on the sprayed walls of houses for a long enough time after biting to pick up a lethal dose of insecticide. Pilot projects showed that the local vectors, *Anopheles leucosphyrus* in Sarawak and *A. minimus flavirostris* in the Philippines, could be attacked successfully by the usual method of spraying dwellings with residual insecticides.

In 1951 there occurred, through incidental circumstances, an event that marked a turning point in the history of WHO's policy in malaria control. Greece, which had converted its malaria-control programme (begun with assistance from the Rockefeller Foundation) into a nation-wide DDT spraying campaign since 1946, found difficulty in procuring the DDT necessary to maintain coverage over the whole area. It was decided, instead of reducing the dosage, to continue spraying, as warranted, with the required strength in some areas, but to discontinue it altogether in others. The results proved that discontinuance of spraying in such circumstances did not result in a startling recrudescence of malaria, but cases did occur. The local malaria service established a special organization of "epidemiological surveillance". This picked up cases easily enough, evidently before they infected enough mosquitos for the disease to become widespread again.

In 1953, this finding was discussed by the Expert Committee on Malaria and at an international conference for Asia, held at Bangkok. The Expert Committee advised that health administrations should give careful consideration to discontinuing residual spraying, with proper safeguards, after some years of malaria control.[1] The appearance of resistance to DDT in vector anophelines in several malarious areas made the discontinuance of spraying urgent and not merely desirable. It was also hoped that, with the prospect of spraying campaigns limited in time, governments would be more easily encouraged to establish nation-wide schemes and to co-operate with one another across land frontiers. Clearly, the larger the area under control, the safer discontinuance would be, and without co-ordination of programmes across frontiers countries which eradicated malaria from their own territories would remain exposed to the danger of their neighbours' malaria and would have to maintain active control at least on their borders.

The Expert Committee, at its 1953 meeting, reaffirmed its belief in the feasibility of WHO's original aim of "eliminating malaria from the world as a public-health problem". In 1954, the XIV Pan American Sanitary Conference gave special attention to the concept of actual eradication of malaria by intense co-ordinated antimalaria work. Eradication, previously regarded as an ideal in favourable circumstances, had now become a matter of urgency through the need for breaking the cycle of transmission before the anticipated development of insecticide resistance in the vectors. Aware of the increasing danger of resistance in anophelines; considering the good results achieved in many parts of the world (and, indeed, the almost complete absence of setbacks in the early stages of residual insecticide spraying campaigns); noting, too, the encouraging Greek experience after the discontinuation of spraying, the Executive Board brought these considerations to the notice of the Eighth World Health Assembly in 1955. As a result, the Health Assembly decided "that the World Health Organization should take the initiative, provide technical advice, and encourage research and co-ordination of resources in the implementation of a programme having as its ultimate objective the world-wide eradication of malaria." The same resolution authorized the Director-General to obtain financial contributions and to establish a Malaria Eradication Special Account.

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1954, **80**

In pursuance of the Assembly's resolution a five-year plan was drafted; consultants were sent to assist countries and to assess the degree of insecticide resistance in vector anophelines where reported; a research programme was suggested to several institutes whereby insecticide resistance would be induced in laboratory colonies of anophelines so that the factors that produce resistance might be determined; "operational" research in pilot projects in the field was redoubled; established international teams in twenty-one countries intensified their work; new projects were started in Indonesia and North Borneo; consultants visited many countries, notably those of the Eastern Mediterranean and European Regions, to obtain their co-operation in an inter-regional programme of malaria eradication, the details of which were later discussed at a conference in Athens in 1956.

The Athens Conference, attended by representatives from France (Algeria), Greece, Iran, Israel, Italy, Morocco, Portugal, Turkey, Yugoslavia (and many other countries less intimately concerned geographically), endorsed as advisable and feasible the policy of an internationally co-ordinated campaign for eradication.[1] Later, experts from Egypt, Iran, Iraq, Lebanon, Pakistan, Saudi Arabia and Syria attended an advisory meeting with the Expert Committee. During the same year the policy was endorsed at regional conferences held in Cambodia, Borneo, Viet Nam and Kenya, and at meetings for countries in the Region of the Americas. The number of WHO malaria field projects rose to thirty-four, including two in additional countries—Ethiopia and Sudan.

In 1956 the Ninth World Health Assembly endorsed and re-emphasized the policy of eradication. The Tenth World Health Assembly's resolution was concerned particularly with the stimulation of inter-country arrangements with a view to minimizing the danger of importation of sources of infection, and the suggestion that all governments should supply information not less frequently than once a year on the development of their programmes.

The present policies of malaria eradication, now accepted generally, have been developed from the following epidemiological and public-health considerations.

Malaria eradication means the ending of the transmission of malaria and the elimination of the reservoir of infective cases in a campaign limited in time. This must be distinguished clearly from two other concepts. *Malaria*

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1957, **132**

control, until recently the sole aim of campaigns in most countries, implies the reduction of the disease until it is no longer a major public-health problem. Control must be maintained by continuous active work, and the programme is therefore unending. *Vector eradication* means the total elimination of all members of the species concerned, so that they do not breed when the programme is ended. It is therefore a project limited in time. It is feasible, and has been achieved, in some places, but is not practicable everywhere. *Malaria eradication* is the application of the same principle, not to the mosquito but to the malaria parasite, and has been shown already to be applicable in many countries. As generally used, the term does not imply that vector eradication is necessarily to be achieved too. *Falciparum* and *vivax* malaria die out in infected individuals within three years; the aim of eradication is to break the cycle of transmission for three years, so that thereafter antimosquito measures can be discontinued, leaving the vector anophelines in existence but without the possibility of becoming infected—a state known as anophelism without malaria.

Anophelism without malaria is known to exist in many formerly malarious countries in which no specific antimalarial campaign has been undertaken—England and parts of continental Europe are examples. But in the tropics, too, e.g., eastern India, there are malaria-free districts, despite the presence of one or more notorious vector species, and the proximity of malaria areas. This condition, however, is not necessarily stable.

Eradication might have remained an exceptional aim if events had not made it a preferable one to mere control. In particular, as already stated, the fear has arisen that the permanent maintenance of control by means of the residual insecticides might prove to be impossible, owing to the development in the vector mosquitos of resistance to the effects of these. Besides this, an eradication campaign calls for the provision of special finance for a limited time only, a necessity more easily understood by the local people and their legislative representatives than indefinitely continued expenditure on malaria control.

A malaria eradication programme is a development of normal malaria control, but differs radically from mere control in a number of ways, apart from those already mentioned. The standard of its execution must be perfect, and must be checked by constant surveillance of the population for fresh cases. The source of any case must be investigated, and spread from that source prevented. As the campaign approaches its goal, the detection of residual foci of transmission becomes more important. This may be difficult as many foci are likely to display themselves only through the movement of residents, to appear as malaria cases in areas supposedly cleared of the disease. The source of the infection must be sought, and may turn out to be overlooked hamlets or possibly a group of regular migrants.

Whatever the mechanism of an eradication campaign, its task is accomplished when the evidence of surveillance and a methodical search for cases indicate that transmission is completely ended and that the number of potentially infective carriers is reduced, if not to zero at least to an insignificant level. The active campaign is then discontinued, but it is the essence of a successful eradication campaign that it must include a surveillance organization efficient enough to recognize reintroduction at the earliest possible moment. It is to be assumed that the apparent elimination may not be perfect, and that immigrants or infected mosquitos from outside the country may reintroduce the disease. While anopheline vectors exist, this may happen at any time. The most likely source is an immigrant or a person with long-standing symptomless infection, who will therefore not be detected as a case but will infect a certain number of anophelines. The appearance of even one such case must be the signal for an immediate intensive search for other cases, and also for a temporary and local antimosquito campaign. The number of secondary cases arising from this source will be fairly small, but being non-immunes they will become highly infective to mosquitos. Malaria is then transmitted with increasing frequency until an obvious epidemic results.

The speed with which an epidemic may result from the reintroduction of malaria into a malaria-free area depends on temperature and the characteristics of the local vector mosquito. Theoretically, infection due to *P. falciparum* could reach 100 per cent. in less than two months after the appearance of the secondary cases, and *vivax* infection in not much over a month.

Deliberate eradication has been accomplished, and is standing the test of time, in several formerly malarious countries, notably in the Mediterranean areas and the Americas. Its general feasibility, however, has been the subject of argument and confusion: in some countries routine campaigns with residual insecticides achieve excellent results, while in others similar campaigns (carried out with equal efficiency) diminish the numbers of the vector mosquitos, but not the incidence of malaria. For example, Ceylon and African territories differ radically in the pictures they present of malaria and its amenability to control.

The distinction between apparently irreconcilable conditions has been explained by a minute study of the epidemiology, in particular of the characteristics of different species of anopheles. Such epidemiological principles now govern the strategy of malaria eradication.

A process of sexual development, requiring twelve days in optimum climatic conditions, takes place in the mosquito, which in order to transmit malaria must bite at least two humans at not less than twelve days' interval. This being so, several individual characteristics of different vector species are of great importance. The longevity of the mosquito, its appetite for man as compared with its appetite for lower animals, and the frequency with which it feeds are the most important. Two extreme examples will illustrate this. The natural mortality of *Anopheles gambiae*, the principal vector in tropical Africa, is about 10 per cent. per day. This mosquito feeds only on man, and bites usually every other day. One of the most important vectors in India and Ceylon, *A. culicifacies*, has a daily mortality of 22 per cent. Moreover, it feeds on lower animals in preference to man. The chance that *A. gambiae* will take a single human feed in its lifetime can be calculated to be 136 times as great as the chance that *A. culicifacies* will do so. Their respective chances of taking two bites within the interval necessary to transmit malaria are very much more divergent.

A further conception must be explained, that of the reproduction rate of malaria, which is the number of fresh cases to which each existing case gives rise in the prevailing circumstances. If this rate is more than one, malaria will increase until the community is saturated with it, and will remain at this level. If it is less than one, malaria will decrease and eventually die out. If *A. gambiae* is the local vector, the reproduction rate is maintained above one if each case infects no more than one mosquito. If the vector is *A. culicifacies*, attracted more to lower animals than to man, 800 mosquitos must be infected by each human case to maintain the reproduction rate of malaria at one.

These calculations provide a complete explanation of the difference between malaria carried by the two mosquitos. With *A. gambiae* as the carrier, malaria saturates the community, and is stable from year to year and decade to decade. With *A. culicifacies* as carrier, the maintenance of malaria depends on the existence of a large mosquito population. Any antimosquito measure may be sufficient to reduce the local reproduction rate to below one. On the other hand, if breeding increases in a malaria-free area an epidemic is the first result. Such malaria is in fact unstable.

A. gambiae and *A. funestus*, the vectors in tropical Africa, typically produce stable malaria. *A. gambiae*, in particular, has every quality required for the successful transmission of malaria. A strong, long-lived mosquito, which bites man in preference to any other animal (except at the extremes of its geographical range), it takes large blood meals and is likely to acquire infection from minimally infective humans; its eclectic breeding habits make antilarval campaigns against it difficult; it tends not to rest for a lethal length of contact on insecticide-treated surfaces; in several areas it has developed a practically complete resistance to the effects of some insecticides. It has been exterminated by very thorough antilarval campaigns from two areas, Brazil and Egypt, which it invaded outside its normal habitat. This is one of the striking contributions made to international health by the Rockefeller Foundation in assisting country services. However, its extermination in Africa south of the Sahara and north of the Union of South Africa is probably impossible. Malaria eradication in the area in which *A. gambiae* is the carrier is a problem of much greater difficulty than anywhere else in the world, with the possible exception of New Guinea. *A. gambiae* has been the subject of a WHO monograph.[1] Its biology and other characteristics are at present the subject of intensive research.

There are other vectors of a stable type of malaria: *A. minimus* in Assam, *A. fluviatilis* in South India, *A. sacharovi* and *A. labranchiae* in the Mediterranean zone. In their presence, anophelism without malaria never occurs naturally.

The malaria policy described above has had an indispensable counterpart in the technical field: detailed working-out of methods and terminology.

It was essential that malariologists of different countries should speak exactly the same technical language. Considerable confusion in the terminology of malaria still existed in the nineteen-forties, extending even to the zoological names of the different species of parasite. A WHO committee undertook

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[1] HOLSTEIN, M. H. (1952) *Biology of Anopheles gambiae*, Geneva (*World Health Organization: Monograph Series* No. 9)

the task of drafting a standard terminology, of which English and French versions were published in due course.[1]

Another WHO committee assisted research into the properties and uses of the new synthetic antimalarial drugs, and collated the results in a monograph published in 1955.[2]

It is still accepted that chemotherapy and chemoprophylaxis can play a most important part in malaria control and eradication. Antimalarial drugs are available in the event of an epidemic resulting from failure of control with residual insecticides. Some of the new drugs appear to exert a prophylactic action if given only once a month. Even that is a difficult administrative task, though strikingly good results were achieved in Morocco by giving a very high proportion of the population monthly doses of chloroquine, amodiaquine, or pyrimethamine. In Brazil chloroquine was administered by mixing appropriate amounts of it with common salt. Subsequently WHO sponsored further controlled experiments in this technique. An important discovery, with regard to mass drug prophylaxis, was that pyrimethamine is secreted in human milk in sufficient concentration to be effective as a prophylactic for child as well as mother. Finally the last stage of an eradication campaign, epidemiological surveillance, depends on the rapid and efficient treatment of all discovered cases.

Because of their possible danger to man, it was vitally important to ensure that residual insecticides could be used without danger on a mass scale, by operators of low education. In 1953 a monograph was published outlining the hazards to man from the use of toxic insecticides.[3] In 1956 a study group recommended protection measures for workers applying insecticides of the chlorinated hydrocarbon and organo-phosphorus groups.

The various reports of the Expert Committee on Insecticides deal with specifications for the chemical, physical and biological characteristics, dosages and keeping qualities of insecticides and their formulations, and for the design, construction, reliability and efficiency of spraying apparatus. These have

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[1] COVELL, G., RUSSELL, P. F. & SWELLENGREBEL, N. H. (1953) *Malaria terminology*, Geneva (*World Health Organization: Monograph Series* No. 13); VAUCEL, M., ROUBAUD, E. & GALLIARD, H. (1954) *Terminologie du Paludisme*, Geneva (*World Health Organization: Monograph Series* No. 25)

[2] COVELL, G. et al. (1955) *Chemotherapy of malaria*, Geneva (*World Health Organization: Monograph Series* No. 27)

[3] BARNES, J. M. (1953) *Toxic hazards of certain pesticides to man*, Geneva (*World Health Organization: Monograph Series* No. 16)

been useful in ensuring the efficiency of campaigns in the field. For example, in the early days of residual spraying, difficulties arose in different campaigns because of the poor suspensibility of water-dispersible powders.

The effectiveness of a residual insecticide depends on mosquitos resting on the sprayed surface for an adequate length of time. Certain malaria vectors tend by nature not to rest indoors, and others (by genetic selection or acquired behaviour) soon cease to rest on sprayed walls. The Athens Conference therefore recommended that in some Mediterranean areas, where malaria is carried by such elusive vectors as *A. sergenti*, spraying should be extended to external resting places as discovered by careful field research, and in other circumstances that larvicidal campaigns, with the old weapons of oil and Paris green, might have to supplement the effects of residual spraying.

The most serious problem of malaria control since the foundation of WHO has been the development by anophelines of resistance to residual insecticides. The Expert Committee on Malaria, in 1950, though no examples of anopheline resistance had then been reported, anticipated its appearance at some time as other (culicine) mosquitos and houseflies were known to develop resistance. The Committee recommended the collaboration of insect physiologists and organic chemists in research on the matter.

Anopheline resistance was reported in 1951, first in Greece, where *A. sacharovi* was found resting unharmed on DDT-sprayed surfaces, and later in the United States of America, where *A. quadrimaculatus* was believed to have developed some degree of resistance after prolonged use of DDT against its larvae. In 1953, the Expert Committee, referring to this development, noted that in many large areas there was no apparent development of resistance in malaria vectors, despite the continued use of residual insecticide for periods of up to nine years. The Committee also noted that laboratory efforts to produce resistance in anophelines had been very much less successful than in the case of the housefly.

The 1956 Athens Conference, already referred to, noted that certain anopheline vectors in Greece, Indonesia and Saudi Arabia were developing resistance. But it was most concerned at receiving information that the vector *A. gambiae* in northern Nigeria had developed some degree of tolerance to DDT after less than two years of a spraying campaign. WHO issued a series of information circulars on the resistance problem, to keep workers abreast of developments.

Residual insecticides fall into two main chemical groups, chlorinated hydrocarbons and organic phosphorus compounds. The latter, with one or two partial exceptions, are not yet free enough from risk to human life for general use. The well known insecticides are chlorinated hydrocarbons, DDT, BHC, dieldrin and chlordane being the chief examples.[1] These fall into two groups as far as resistance is concerned. One type of resistance involves BHC, dieldrin and chlordane and related compounds; the other involves DDT and its analogues but not BHC, dieldrin, etc. With the exception of *A. sacharovi* and possibly one other species, no mosquito yet has developed resistance to both groups. The fact that resistance is generally restricted to one group offers a possible solution to local problems of resistance by using an insecticide of the other group, even though this means certain administrative difficulties. It is also possible that development of organic phosphorus compounds will later add to the insecticide armoury.

Since 1954, there has been much laboratory research on the nature of insecticide resistance. The dieldrin resistance in *A. gambiae* and the DDT resistance in *A. sundaicus* are associated with a single Mendelian factor, either a gene allele or an inversion of a length of chromosome, which in natural circumstances occurs rarely. When such a species is subjected to an insecticide campaign, individuals possessing this factor survive and eventually breed a new resistant population.

Research at the Ross Institute, London, proved that the dieldrin-BHC resistant factor in *A. gambiae* is intermediate in expression between dominant and recessive. The fully resistant mosquito tolerates about 800 times the normal lethal dose of insecticide, and the heterozygous hybrid of resistant and susceptible parentage tolerates 50 times the normal dose. In *A. sundaicus*, on the other hand, the resistant factor is recessive, and only the offspring of parents both possessing it will show enhanced resistance. Thus the breeding up of a new resistant community of *A. sundaicus* must be very much slower than in the case of *A. gambiae*.

A practical method of testing for resistance in any community of anophelines evolved from this laboratory research work. If mosquitos of the species under investigation are subjected to a certain predetermined dosage of insecticide, then even a single survivor proves the factor of resistance to

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[1] *Wld Hlth Org. techn. Rep. Ser.* 1954, **80**

TUBERCULOSIS

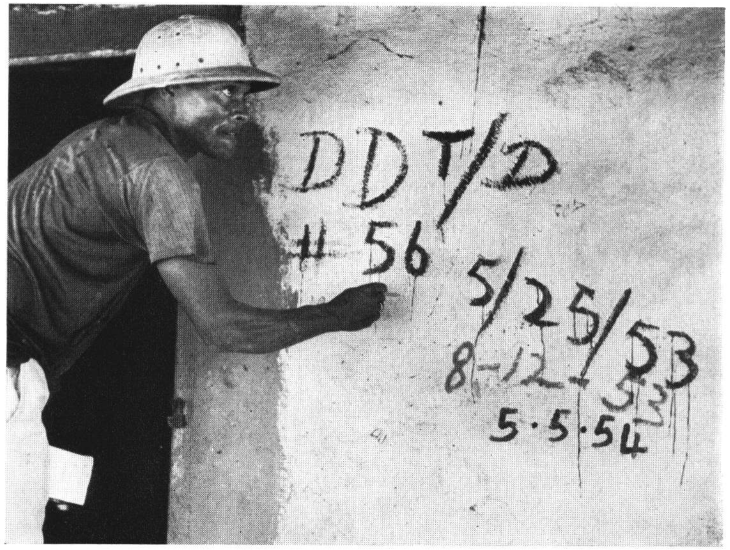
BCG vaccination in Viet Nam

X-ray examination at a tuberculosis centre in India

French Cameroons: preparing dieldrin spray

Iraq: spraying the inside of Kurdish tents

AGAINST MALARIA



Liberia: recording the date after spraying a house

Iraq: water in which mosquitos breed is examined to find the type of mosquito larva.

YAWS

A yaws control team in a Fijian village

be present. Laboratory experiment may then determine whether the factor is intermediate or recessive. If it is recessive, spraying at normal doses can proceed, and malaria eradication should be possible before the community becomes excessively resistant. If it is intermediate, spraying at normal dosages is useless, and by demonstrating this the test saves wasted effort and expenditure.

WHO now issues prepared testing outfits, the insecticide concentration of which has to be varied for different malaria-vector areas, to help field workers determine the presence or absence of resistance. The distribution of dieldrin-resistant *A. gambiae* in Africa is being mapped at present with the aid of these outfits.

The use of insecticide against the larval stage of the mosquito is believed to have hastened the development of resistance in adults, since such applications commonly cover an extensive area of mosquito population, particularly in aerial spraying. However, resistance does not appear to have occurred either in Sardinia or in Cyprus, where local conditions demanded the extensive use of larvicidal methods. Nevertheless, as an interim safeguard, WHO has recommended that the residual insecticides be used as little as possible for larvicidal work.

Nowhere has insecticide resistance appeared immediately on the commencement of a spraying campaign, for the resistance factor is always rare in a natural mosquito population.

Another problem involving genetics is that of the differentiation of anopheles species by methods other than external differences. Some thirty years ago, *A. maculipennis* in Europe exhibited confusing vagaries of behaviour. It maintained intense malaria in most of southern Italy, but none in a few areas in the same zone; it was easily colonized in Holland and northern Italy, but not in Sicily; in some areas it frequented stables, in others bedrooms. Eventually it was differentiated into several sub-species by characteristics of adults or eggs which could be perceived by the naked eye or with the microscope. *A. gambiae* exhibits similar differences in behaviour which it would be more satisfactory to explain in terms of actual biologically specific types, but except for the separation of *A. melas* as a different species (by perceptible differences in the eggs) it has not been possible to do this so far. WHO is stimulating and co-ordinating research into possible differences, mainly by the microscopic study of chromosomes.

Another possible cause of ineffectiveness in efficiently applied residual insecticide is sorption of chlorinated hydrocarbons by certain types of mud used in building. A non-volatile residual insecticide applied to such a surface becomes inactive in a month or less, instead of six months or more. No reason has yet been advanced to explain why some muds should be "active" in this way. It is not difficult to make a rough and ready test of the activity of a specimen of mud, but more accurate tests must be biological—the exposure of mosquitos, at intervals of a month or two, to surfaces of the mud under test which have been treated with insecticide.

DDT and dieldrin become inactive soon after their application on active mud surfaces, particularly during periods of low humidity. However, an increase in the relative humidity may have the effect of renewing the biological effectiveness of the deposit to some extent. BHC, on the other hand, volatilizes slowly even after sorption, and actually retains its action longer on an active mud surface.

Enough has already been said of the qualities of *A. gambiae* to make it plain that the control or eradication of the malaria carried by this mosquito —i.e., the type prevalent throughout tropical Africa, south of the Sahara and north of the Union of South Africa—is a task in a category of its own. Theory suggests that this should be so, and in practice available evidence shows that three years of residual spraying by techniques which would have been successful elsewhere have not succeeded in preventing new cases of malaria. A possible exception is in high altitude malarious areas.

The *A. gambiae*-carried malaria of Africa is undoubtedly the most serious obstacle to the achievement of world eradication. It was considered by a small meeting of experts at Geneva in 1957. Admitting the comparative failure of insecticidal campaigns, the experts sought to appraise this from two angles: essential inadequacy of the method in the particular circumstances, or failure of efficiency in carrying it out.

They concluded that the explanation lay partly in inefficiency, both of men and of apparatus, and that in the particular circumstances an efficiency of almost a hundred per cent. was essential to the adequacy of standard methods. Even if this level of efficiency in carrying out the method is assumed, no general statement can be made as to the results to be expected from any one standard technique throughout the area: there must be, for each locality, adequate, accurate and reliable preliminary evaluation in pilot testing zones.

When, on the results of pilot testing, the method of control for the district is chosen and work commences, the two most important factors for ensuring success are constant checking of apparatus and close supervision of personnel at all levels. Elsewhere in the world, malaria eradication is being tackled with confidence if not without difficulties. WHO's Special Account for Malaria Eradication is intended to help in such instances.

As more and more countries achieve malaria eradication without vector extermination, the continued existence of malaria in other countries will become of increasing international importance: while the parasite exists, no country with potential vectors can forget the possibility of its importation.

Economic gains have been seen in practice to follow malaria eradication. However, another observed result is rapid growth of population, and responsible writers have expressed the fear that food supplies may not increase in proportion. While endemic malaria is itself one of the great causes of low agricultural productivity, it is realized that this danger cannot be ignored, and, therefore, a malaria-eradication campaign should be seen as part of a general programe of development and social advance.