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INSECTICIDES USED AND DOSAGES, FACTOR DIMINISHING RESIDUAL EFFECT; BIO ASSAY TESTS

by

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1. The fastest and most reliable method of interrupting the transmission of malaria is by attacking the anopheline vector in its adult stage. This attack takes advantage of the habits of the female Anopheles. It can be achieved by the systematic application of residual insecticides on a total coverage basis in human and, if necessary, animal dwellings. The use of this method depends on three facts:

(a) Most of the anopheline vectors rest for some time during each gonotrophic cycle[1] on the walls and other internal surfaces of houses or other shelters in which they feed. Some vector species feed in the open, but nevertheless rest for a time inside human dwellings.

(b) The female Anopheles which feeds on a carrier of malaria parasites is able to transmit the infection to the next human victim only after the appearance of infective forms of the parasite in the salivary glands of the mosquito. This takes usually about 10-14 days in the tropics and longer in temperate areas. During this period, the female Anopheles will pass through a number of gonotrophic cycles and will consequently feed several times and also enter and rest in the premises.

(c) Residual insecticides maintain their contact toxicity to mosquitos for a longer or shorter time depending on the properties of the insecticide itself and on the type of sprayed surface. Constant toxicity can be maintained by applying them in adequate dosages and spraying cycles.

(1) The gonotrophic cycle of a mosquito is the interval between each bloodmeal and the subsequent egg-laying (shortly after which the mosquito feeds again). It extends over a period of two, three or more days depending on the species and on environmental conditions.

In consequence, any Anopheles which feeds on man and in the course of its life comes, even for a short period, in contact with the interior surface of human houses or other shelters, is subject to a degree of toxic action of the applied insecticide. The probability of this contact depends on the preferential habits of each species of Anopheles. Naturally, those that are most attracted into human habitations will be most frequently exposed to the toxic deposit on the walls and other interior surfaces.

In some exceptional circumstances (where a vector rests outside after feeding, and where it is confined to very limited and accessible breeding places) the attack can be carried out against the larva.(1)

Three insecticides belonging to the group of chlorinated hydrocarbons are commonly used for residual spraying: these are DDT, BHC and Dieldrin.

The technical product resulting from their chemical industrial processing cannot be used as such for spraying. To do so it has first to be formulated. Formulations employed in malaria campaigns are rarely solutions, sometimes emulsions and most frequently water dispersible powders.

(a) Solutions:

The usual solvents utilized are the hydrocarbons. The chief members of the series used for insecticide sprays are: kerosene, solvent naphtha, white spirit and other fractions of petroleum cracking. Those solvents have the advantage of being easily available, but their major inconvenience is inflammability.

Concentrated solutions can be prepared with adequate solvents. Solutions containing 35 % of DDT are possible with cyclohexanone or benzene, such solutions can be diluted on the spot with kerosene, solvent naphtha, etc.

(b) Emulsions:

An emulsion consists of two immiscible liquids, one of which is broken up into globules (dispersed phase) and dispersed as such in the other liquid (continuous phase). Commercial emulsions contain an emulsifying agent which gives stability to the system and prevents globules coalescing together and the emulsion "breaking". Emulsifiable concentrates can be prepared for further dilution with water to the desired concentration. They may consist of a solution containing from 10 to 35 % of the insecticide and from 3 to 10 % of emulsifying agents. Before spraying these concentrates are diluted with various proportions of water to obtain the desired concentrations.

(1) Report on Malaria Eradication, by the Director General WHO. E/ICEF/386, 21 July 1959.

Example of emulsion:		
	DDT	5 parts
	Solvent naphtha	20 "
	Linseed fatty oil	7 "
	Ammonia (0.940 sp.gr.)	3 "
	Water	65 "
		100 parts

Emulsions present the advantage of availability at lower price than solutions, but they are inflammable (in the form of concentrates) due to the solvent, they need excellent storage conditions to prevent breaking and, last but not least, they are bulky which like solutions, involves increase of transport costs.

(c) Suspensions of water-dispersible powders:

Chlorinated insecticides in this form are compounded with a diluent clay but in the later stage of preparation various wetting, suspending and anticaking agents are added. Commercially available concentrates contain today up to 50 and 75% of the technical product; that is under a relatively small volume a high amount of active material. This implies advantages for transport and storage. Other advantages are cheapness (in comparison with solutions or emulsions), reduced hazard of toxicity to human and essentially greater persistency on sprayed surfaces particularly on sorptive ones. For these reasons wettable powder formulations are most widely utilized in malaria eradication campaigns.

2. Choice, dosage and frequency of application

The choice of the insecticide, its dosage and spraying cycle are conditioned by three main groups of factors: biological, physico-chemical and local.

(a) Biological factors:

The duration and type of the transmission season depends on the complex interplay of many factors as appears in the following known formula (P.F. Russell):

$(X + Y + Z)$ p^{nbec} = malaria endemicity and epidemicity in this formula.(1)

X = the human carrier	b = bionomics
Y = the mosquito vector	e = environment
Z = the human victim	c = control
p = the plasmodium	t = treatment
i = immunity	

(1) P.F. Russel, Malaria, Basic principles briefly stated, Blackwell, Oxford, 1952, p. 95.-

The role of the mosquito vector implies consideration of its vectorial capacity in connexion with its ecology, biting habits and reaction to insecticides (base line susceptibility level, irritance, etc.).

Toxicity to humans and animals should not be a limiting factor in operations and thus preference ought to be given to insecticides, presenting less risk of hazard.

(b) Physico-chemical factors to be considered are of two types:

(i) Those related to the insecticide: volatility, reaction to sorption and particle size which condition the persistency of the insecticide;

(ii) Those related to the type of surfaces: proportion of sorptive and non-sorptive surfaces. BHC, for instance, is the most volatile of the three insecticides and has the shortest residual effect on non-sorptive surfaces. DDT and Dieldrin have a much more prolonged residual action since their volatility is low. On the other hand, the sorption of the insecticide into certain walls may greatly decrease the residual action of DDT and Dieldrin, while sometimes sorption may prolong the intrinsically short action of BHC. Moreover the influence of humidity on the effectiveness varies with each insecticide. The type of the insecticide formulation has some influence on the particle size of the relevant insecticides; this is turn has a bearing on the availability of the insecticide to the mosquito.

(c) Local and economic factors:

Amongst them first consideration should be given to the type of houses or huts (size and number of openings - doors and windows -) heating or cooking system with a proper device for the elimination of smoke which may otherwise cause soot or tar deposits on the insecticide layer; nature of their wall surfaces (masonry and concrete or plaster, mud, grass - thatched roofs -, bamboo, etc.) by which differentiation can be made between sorptive and non-sorptive materials;

permanent or temporary types of structures: migratory movements of population, nomadism involving the use of tents. Building of new houses - trends and proportion - Facilities for transport and storage have a decisive bearing on the costing and could not be overlooked.
types of roads: paved or dust which may produce masking deposits on the insecticide.

local customs of replastering, repapering, limewashing, cleaning, etc. in relation with religious or social reasons.
reaction of the local population with regard to spraying of furniture - staining or splashing by residual deposits -

In malaria campaigns and most essentially in malaria eradication campaigns a fundamental factor for the frequency of application of residual insecticides is the speed and extent of reduction of the area of "protective surface" (that is the surface that can still kill mosquitos) in relation to the total resting surface. It is therefore essential to ensure as complete a coverage as possible of all actual or potential shelters of mosquitos and in dosages that will kill it. The previously mentioned factors all have an influence both on the choice, on the dosage and frequence of applications. The Expert Committee on Malaria had them present when at its Sixth Session it recommended the following dosages:(1)

DDT	2.0 g/m^2	6-12 months
BHC-gamma	0.4 g/m^2	6 months
Dieldrin	0.6 g/m^2	6 months up to a considerably longer period.

3. Organo-phosphorus Insecticides

The wide-spread extension of resistance to chlorinated insecticides in a number of insects has stimulated research to discover new groups of insecticides. Much attention has been given to the group of organo-phosphorus insecticides. Since the pioneer work of Gerhard Schrader in Germany (1952) many types of toxic organo-phosphorus compounds of diverse structures have been investigated. Few, however, have the combination of desirable properties needed for vector control programmes:

(a) high density of insects

(b) stability and prolonged residual action

(c) low mammalian toxicity, and

(d) availability at reasonable cost.

The compounds satisfying more or less these requirements and used for residual spraying include such products as Diazinon, malathion, chlorthion, etc.

(1) Expert Committee on Malaria, Sixth Report, WHO Geneva, 1957, Techn. Rep. Ser. 123

Only a limited number of organo-phosphorus insecticides have been investigated so far in the field with regard to their potential effectiveness against anopheline mosquitos.

From preliminary trials conducted in El Salvador by ICA, CDC, PAHO and the Department of Health, El Salvador and in Greece by the WHO Insecticide Field Testing Team (I.F.T.T.), it seems that the following conclusions can be drawn:

(a) On alkaline surfaces (limewashed, lime plastered): chemical decomposition of organo-phosphorus compounds is to be expected: the fact has been demonstrated with malathion, diazinon and Bayten.

(b) On sorptive surfaces: organo-phosphorus compounds are more or less heavily sorbed and consequently inactivated due to either further chemical decomposition or strong physical retention; this is substantially different from the behaviour of chlorinated insecticides on such surfaces.

(c) On non-sorptive surfaces: a much longer residual effect could be expected (up to various months) as has been shown in semi-field trials and in El Salvador project.

(d) Due to these factors and to the specific high volatility of organo-phosphorus compounds fairly high dosages (1 or 2 g/m^2) should be applied to ensure long enough a residual effect.

The necessity to spray with fairly high dosages of organo-phosphorus compounds raises obviously the question of toxicity to mammals and therefore serious safety precautions must be taken to protect operators, personnel and the local population from toxicity hazard. The observations made so far in the two above quoted projects indicate that if proper safety precautions are taken the toxicity to mammals should not be a serious obstacle to the use of organo-phosphorus insecticides in case of necessity.

Let us say also in addition to atropine which is classically utilized for treatment of organo-phosphate poisoning by counteracting the accumulation of acetyl-choline, we have now, with PAM (pyridine-2-aldoxime methiodide) another powerful drug to protect or restore the activity of cholin[illegible]

4. Bioassay of residual deposits on wall surfaces

The following is extracted from the Tenth Report of the Expert Committee on Insecticides, Geneva, September 1959:

"The Committee wishes to stress the primary object of the bioassay test, namely to determine the time when an insecticide deposit on a given surface has lost its potency. The method is not a measure of the continued effectiveness for vector control

of an application of insecticide in an area, even though samples of the vector species may be used as a tool in the bioassay tests.

It is designed to provide information which may assist in:

(i) comparing the residual action of different insedticides or insecticide formulations;

(ii) deciding the appropriate insecticide dosage and spacing of spraying cycles for effective vector control; and

(iii)ascertaining whether or not the spraying has been carried out satisfactorily. The method will not measure the amount of insecticide remaining om the wall nor will it, by itself, measure the overall rate of kill of vectors being obtained during the campaign, since this can be assessed only by other entomological measurements in the area. It is not suitable for measuring the susceptibility or resistance of a population."