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The Chief of the Malaria Section has the honour to communicate hereunder the following note:

RESIDUAL INSECTICIDES AND MOSQUITO CONTROL

by

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The introduction of house-spraying with residual contact insecticides changed the whole outlook on mosquito control. For these new materials to be used successfully and economically, however, they must be applied in such a form that they are readily available to the mosquitos which settle in the houses; widespread, unintelligent use may result merely in kills too low to prevent the transmission of the malaria parasites and may be a factor in the development in mosquitos of resistance to the insecticides. Much of our work has been devoted, therefore, to a study of the various factors influencing the effectiveness of insecticides applied to building materials.

Our investigations show that the primary factor determining the initial and residual toxicity of a contact insecticide to an insect such as a mosquito which may settle on the treated surface for only a relatively brief period is the physical state of the deposit. The most efficient treatment is one which produces a readily available surface deposit, which can be picked up by a mosquito settling on the treated surface and which is retained when the mosquito leaves. The availability of the deposit depends largely on the type of formulation and the nature of the material to which it is applied. It is not wise, therefore, to make a general recommendation as to the best insecticide, dosage and frequency of application; each situation should be considered separately.

Solutions and emulsions have two disadvantages. Firstly, they are absorbed by porous materials, and the penetration of insecticide with the solvent into the material treated may result in a great loss and waste of insecticide and a surface deposit of low efficiency. Secondly, sooner or later, depending on the volatility of the solvent, crystallization of the insecticide occurs and this is often accompanied by a marked loss in toxicity. The crystalline form of the deposit depends on the properties of the solvent employed, on the nature of the surface sprayed, and on the prevailing climatic conditions. On some woods and fibrous materials crystals of DDT and dieldrin may take the form of needles projecting from the surface, and these are readily available for pick-up so that they are highly effective, but frequently the crystals are large and recumbent and comparatively ineffective. It has been found possible, however, to modify crystal growth by the inclusion in the solution of the optimum amount of an additive. For example, the addition of 0.5 per cent. by weight of a coumarone resin to a 5 per cent. solution of DDT or dieldrin in kerosene results in the production of projecting bunches of small crystals which are more effective biologically than the larger recumbent crystals obtained from a simple kerosene solution.

Wettable powders are found to be the most efficient formulations for general use, and especially for application to porous materials. On non-porous materials there is some loss in efficiency because the wetting agent solution tends to stick the insecticide particles to the surface, but on a porous material the insecticide particles are filtered off at the surface and are more readily available for pick-up. Wettable powders containing 50 per cent. insecticide appear to be the most efficient; with lower proportions of insecticide the greater bulk of the inert constituent tends to mask the insecticide, while at higher proportions there is a tendency for the insecticide particles to aggregate during storage. The particle size of the insecticide in a wettable powder is of considerable importance for we find an inverse relationship between particle size and toxicity. Particles of 10 microns and less are picked up and retained by mosquitos very much more readily than larger particles. It must be remembered, however, that evaporation of a volatile insecticide is most rapid from small particles. In addition to their greater biological efficiency, small particles are desirable from the practical application point of view; the risk of blockage of nozzles is less, and they remain in suspension longer than large particles which tend to settle and remain in the bottom of a sprayer especially when there is no agitating mechanism. An additional advantage of wettable powders, of course, is that the particle size of the insecticide can be pre-determined during manufacture and commercial products can be standardized to meet the required specification.

Of the materials commonly used in house construction in tropical countries, dried mud presents the greatest and most interesting problem. Solid particles of insecticides in deposits from wettable powders are rapidly removed from the surface of what we term an "active" mud by adsorption; molecules of insecticide are concentrated on the mud surface (mainly interior), a high gradient is set up between the mud and the solid particles in contact with it, and insecticide diffuses into the mud until no solid particles remain on the surface. At this stage DDT and dieldrin are concentrated close to the treated surface, but in the adsorbed state are not effective against mosquitos settling on the surface. The rate at which this initial adsorption process takes place depends on the volatility of the insecticide and its particle size. As an example of the rate of adsorption, 10 micron particles of DDT are removed from the surface of an active mud at 25°C in a few days. After the initial rapid adsorption, DDT and dieldrin diffuse further into the mud as they are desorbed from the initial site and adsorbed again on active surfaces deeper inside the mud, and we have recovered unchanged DDT at a depth of more than 1 cm 12 months after its application to the surface of active mud bricks. Diffusion of more volatile insecticides, such as aldrin and the gamma isomer of benzene hexachloride, is more rapid but losses in the opposite direction by evaporation to the outside also increase and sufficient vapour may be released from the mud to exert a fumigant effect on mosquitos resting on the surface.

The adsorptive properties of soils from different localities vary considerably; in general, red lateritic soils are the most active. There may be considerable local variation as is shown by samples of soil from the Taveta area of Kenya; those from some areas are very active while others from nearby localities are relatively inactive. This has obvious implications in a large-scale malaria control programme.

We do not suggest that these laboratory findings indicate that the application of residual insecticides to mud walls is not worthwhile. In the laboratory it is necessary to standardize materials as far as possible and to have a reasonably flat and smooth test surface, and for this reason our soil samples are sieved before being made into mud bricks. In practice, soils are never "purified" to this extent, and in fact materials such as sand or gravel, straw or dung, are often added, and we would expect the deposit falling on this extraneous material at the surface of a wall to have its normal persistence. Thus, although the loss in toxicity of DDT and dieldrin wettable powders due to adsorption by an active mud is so rapid and striking under laboratory conditions, it may not be so marked in the field. Nevertheless, adsorption may well explain the loss in efficiency of mud wall deposits after a few weeks or months and the necessity to re-apply insecticide more frequently than would be expected.

Our attempts to prevent or inhibit the adsorption of insecticide by the inclusion of various chemicals in the wettable powder suspension have been unsuccessful, although it has been shown that the presence of a surface coating such as a limewash or distemper, which prevents contact between the insecticide particles and the active mud, does slow down the adsorption process considerably. On the other hand, we suggest that adsorption of a volatile insecticide which can exert a fumigant action is beneficial. Rapid adsorption of solid particles from the surface and the production of a "reservoir" of insecticide within the wall from which vapour is released at a reduced rate increases the effective life of a volatile insecticide. This may well explain the longer than expected residual action of gamma-BHC in mud houses.

The dosage of insecticide applied must provide adequate coverage of the surfaces with sufficient deposit to maintain a source of readily available insecticide. The effective dosage of a given insecticide will vary, therefore, with different formulations on different types of material, and will depend on particle size and losses by absorption and adsorption. It may be mentioned here, however, that we consider present field dosages of 0.1 to 0.2 g per m^2 are insufficient in mud houses for full advantage to be taken of the rapid adsorption of gamma-BHC and its subsequent release at a reduced rate. A new wettable powder containing 50 per cent. gamma-BHC should be a more suitable formulation for the application of higher dosages than the earlier ones containing only 6.5 per cent. of the gamma isomer.

Finally, with regard to the contact insecticide of choice, dieldrin has obvious advantages over DDT. Although it has a higher vapour pressure, it is sufficiently persistent to have a long residual action under most conditions. It is generally much more toxic than DDT to adult mosquitos, and as the lethal dose decreases the physical state of the insecticide becomes less critical. Furthermore, whereas mosquitos are quickly irritated by contact with DDT and may be stimulated to leave a treated surface before acquiring a lethal dose, they are not irritated, at least to the same extent, by contact with dieldrin. However, a highly toxic, quick acting, insecticide such as gamma-BHC which can act as a fumigant must have a role to play in mosquito control, especially in mud houses. Additional advantages of a fumigant are compensation for uneven applications, and continued action even when covered by soot deposits from fires.