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A NOTE ON THE SORPTION OF INSECTICIDES ON TROPICAL SOILS

by

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The process of sorption of chlorinated hydrocarbon insecticides on tropical soils used in house construction and its effect on their residual contact action against adult mosquitos have been described in earlier papers (Hadaway & Barlow, 1952; Barlow & Hadaway, 1955, 1958a; 1958b), and summarized by Bertagna (1959). To recapitulate, solid particles of these insecticides deposited from aqueous suspensions of wettable powders, on the surface of chemically inert and relatively non-porous materials such as plywood, bamboo, glass and corrugated iron, persist for weeks or months, losses occurring in the laboratory largely by evaporation. There is a striking difference, however, on dried mud bricks or walls made from sorptive soils, and the solid particles are no longer visible after a few hours or days (see photographs, Hadaway & Barlow, 1952). At first the sorbed insecticide is concentrated in the surface layer of the soil and subsequently diffuses inwards until evenly distributed throughout the thickness of the brick or wall. This is a slow process and may take up to a year in bricks 1.2 cm thick, depending on the insecticide and environmental conditions. The rate of desorption is even slower, and it was shown that no losses of gamma-BHC to the atmosphere occurred until the insecticide was evenly distributed throughout the bricks.

Sorption of the chlorinated hydrocarbon insecticides is not followed by decomposition on the range of soils tested and they can be biologically active against mosquitos resting on the surface. In other words the sorbed insecticide can diffuse outwards on to the cuticle of insects in contact with the surface as well as inwards.

This process of sorption is considerably influenced in several ways by the relative humidity of the atmosphere. Firstly, the initial sorption of particulate insecticide proceeds more rapidly as atmospheric humidity decreases. Secondly, the rate of inward diffusion of the sorbed insecticide increases as humidity increases. Thirdly, the availability of a given concentration of sorbed insecticide to insects resting on the surface increases as humidity increases, and the change in biological activity with humidity is reversible. It was suggested that the mobility of the insecticide molecules sorbed on the soil particles is controlled by the amount of water vapour also sorbed, and this, in turn, depends upon atmospheric humidity. Our findings on the effect of humidity on dieldrin sorption by soils were confirmed by Gerolt (1961).

From the practical point of view sorption can be beneficial. Thus, it may prolong the persistency of an insecticide. It was shown chemically that loss of gamma-BHC at a dosage of $1g/m^2$ on glass plates was rapid and progressive, 50% being lost in the first week and none remained after 4 weeks, whereas under the same conditions none of the insecticide was lost, in 8 weeks, from bricks made from Uganda soil. Similarly, when 0-10 μ dieldrin suspensions were applied at a dosage of $1g/m^2$ there were losses by evaporation from glass plates of 50% in 24 weeks and 90% in 52 weeks, and from bamboo, palm leaf and wood of about 60% in 26 weeks, but substantially no loss from Uganda bricks in 48 weeks. Furthermore, a reservoir of insecticide within a dried mud wall is less subject to abrasion and general weathering than a surface deposit of particulate insecticide, and successive applications build up a concentration of insecticide in this reservoir.

On the other hand, there is a loss in effectiveness as particulate surface deposits are sorbed and as the concentration of insecticide in the surface layer decreases, and biological activity is dependent upon atmospheric humidity. The effect of humidity is, however, favourable in that biological activity is greatest in the wet season when mosquito populations are at their highest levels, and diffusion of the sorbed insecticide further into the wall is inhibited during the dry season.

The general conclusion from laboratory studies, from field trials in experimental huts (Davidson, 1953; Burnett, 1957; van Tiel, 1961), and from control schemes in Mexico (McNeel, 1958) and Taveta-Pare (Smith, 1962) is that a chlorinated hydrocarbon insecticide can give a satisfactory performance on sorptive dried mud walls provided that it has a sufficiently high intrinsic toxicity to the vector, that atmospheric humidity remains sufficiently high at least during the season when mosquitos are abundant, and that the vector rests on the surface for a sufficiently long period and is not irritated and stimulated to leave before acquiring a lethal dose. Dieldrin is the most effective of the chlorinated hydrocarbons tested on dried mud, while DDT generally gives poor results because of its low intrinsic toxicity and irritant action on mosquitos.

With the appearance in many parts of the world of strains of mosquitos resistant to chlorinated hydrocarbons, the World Health Organization initiated a collaborative scheme for the evaluation of new insecticidal compounds. This scheme includes the determination of the residual toxicity of new compounds on building materials both in the laboratory and in the field. Their persistence on tropical soils has been studied by the Tropical Pesticides Research Unit, Porton. The majority of compounds tested so far have been either carbamates or organo-phosphorus compounds.

Deposits of solid alkyl N-methylcarbamates from aqueous suspensions of wettable powder formulations were, in general, readily and rapidly sorbed by our standard soils, the sorption process at different humidities following the pattern outlined above for chlorinated hydrocarbons. All were rapidly sorbed on Uganda, Babati and Taveta soils, surface deposits usually disappearing within a few hours or days at 25°C. Most were also rapidly sorbed on the lesser sorptive Magugu soil, but surface deposits of compounds with high melting points (e.g. Sevin, and 6-chloro-3, 4-xylyl N-methylcarbamate) persisted for several weeks on bricks of this soil.

The sorbed carbamates were either stable on all of the standard soils or decomposed only very slowly (TPRU/Porton/Report No. 239). The most unstable compound was 2-isopropoxyphenyl N-methylcarbamate, and this had a half life of 21 days on Uganda soil, 33 days on Babati soil and negligible decomposition on

Taveta soil. The sorbed carbamates are, therefore, potentially biologically active, and bioassays have shown that they are indeed active. Typically, the particulate surface deposits from wettable powder formulations are highly toxic to A. stephensi, then there is a marked reduction in effectiveness during the first week or so as the initial sorption process is completed, followed by a more gradual loss in effectiveness over succeeding weeks as inward diffusion of the sorbed insecticide proceeds and the concentration in the surface layers decreases. This prolonged toxicity is more easily demonstrated while the atmospheric humidity remains high. At any time a reduction in humidity will result in a decrease in the activity of the sorbed insecticide. The residual toxicity of a wettable powder formulation of 3-isopropylphenyl N-methylcarbamate has been recorded by Hadaway & Barlow (1962), and more detailed investigations of the effect of humidity on the toxicity of known concentrations of this compound in soils and of other carbamates are described in TPRU/Porton/Report No. 242.

It is concluded that an alkyl N-methylcarbamate can be expected to give a satisfactory performance as a residual insecticide on mud walls provided that its intrinsic toxicity to the vector is high and atmospheric humidity remains high. The most promising compounds from the laboratory tests with A. stephensi would appear to be 3-isopropylphenyl N-methylcarbamate and 6-chloro-3, 4-xylyl N-methylcarbamate. The latter is less toxic intrinsically to A. stephensi and would be less effective on highly sorptive soils, but is physical properties allow it to persist as an effective surface deposit on the lesser sorptive soils for several weeks. Sevin shows a similar persistence on the lesser sorptive soils but it has a low contact toxicity to A. stephensi: Schoof et al. (1962) found it effective against A. quadrimaculatus.

Many of the organo-phosphorus compounds tested are liquids, and a greater or lesser part of the dosage applied as an aqueous suspension of a wettable powder formulation, depending upon the properties of the constituents, penetrates into a porous material. Even shortly after spraying on to dried soil bricks, surface deposits of these insecticides are frequently low and show low toxicity to mosquitos resting on the surface. Those organo-phosphorus compounds that are solids, for example Penchlorphos[1] and dicapthon, are rapidly sorbed on the standard soils and the sorption process again follows the pattern previously described for chlorinated hydrocarbons and carbamates. However, whereas the latter compounds are stable in the soils, the organo-phosphorus compounds tested are, in general, not and decomposition proceeds concurrently with or subsequent to sorption.

The rates of decomposition of a number of organo-phosphorus compounds in soils are given in TPRU/Porton/Report No. 239. Dichlorvos (DDVP) and related vinyl phosphates, phosphoramidothioates and phosphoramidates decompose rapidly. Many substituted phenylphosphates, phosphorothionates and phosphonates also decompose fairly rapidly. The most stable of the compounds tested are fenthion (Baytex) and the related compound Bayer 37342, 0,0-dimethyl 0-(3,5-dimethyl-4-methylthiophenyl) phosphorothionate. Fenthion was lost from Uganda soil at the rate of about 24% in 56 days at 25°C and 80% R.H., extrapolation giving a half-life of about three years. Under the same conditions the half-life of Bayer 37342 on Uganda soil was 72 days. Loss was slower from the other soils, percentage losses at 56 days being 10, 20 and 24% in Taveta, Magugu and Babati soils respectively. Sumithion, 0,0-dimethyl 0-(3-methyl-4-nitrophenyl) phosphorothionate, had a half-life at 25°C and 80% R.H. of 10, 28 and 42 days on Uganda, Magugu and Babati soils respectively. Rates of decomposition of malathion varied with soil type over a wide range, but generally this insecticide gave poor results on dried soils. Residual toxicities of fenthion and malathion on dried mud bricks were recorded by Hadaway & Barlow (1963).

It is concluded, therefore, that the majority of the organo-phosphorus compounds tested would not be expected to give an adequate performance as residual insecticides on mud walls. From laboratory tests, fenthion and Sumithion would appear to be the most promising to date.

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[1] Other designations for this compound include: ronnel, Trolene.

Field trials with some of these compounds in experimental huts lined entirely with dried mud have tended to confirm the laboratory findings (Smith & Hocking, 1962a, 1962b, 1962c). The most effective insecticide against naturally entering _A. gambiae_ was 3-isopropylphenyl N-methylcarbamate, over-all mortalities during the first and second months after treatment being 96% and 74% respectively. With fenthion the over-all mortality exceeded 75% for only three to four weeks, while malathion, Sumithion and 2-isopropoxyphenyl N-methylcarbamate were relatively ineffective. On the other hand, in experimental huts with mud walls and grass thatch roofs, these insecticides all performed satisfactorily and over-all mortalities of _A. gambiae_ exceeded 75% for several months. The effectiveness of deposits in this type of hut is clearly related to the residual toxicity of the deposits on the roofing material and to the resting habits of the mosquitos.

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