THE USE OF INSECTICIDES AGAINST ADULT MOSQUITOES [1]

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There are two general methods in which insecticides are used against adult mosquitoes—by application of insecticidal residues on surfaces on which adult mosquitoes rest, and by direct application of insecticides to the insects by means of space sprays, mists, aerosols, or dusts.

Of the total tonnage of insecticides used in mosquito control on a global basis, a very high percentage is applied as residual sprays to control adult mosquitoes, aimed primarily at the control or eradication of malaria. DDT is the most commonly used insecticide for this purpose, followed by dieldrin and benzene hexachloride.

DDT is applied in most areas at a dosage rate of 200 mg. per sq. ft., although dosages ranging from 25 mg. to 260 mg. per sq. ft. have been used in some countries (Pal and Sharma, 1955) (Macdonald and Davidson, 1953). Water-wettable powders containing 75 percent DDT are generally the formulation of choice for residual house spraying with this insecticide. In some of the better homes where wettable powders may leave unsightly residues, water emulsions or kerosene solutions are employed. The finished spray is applied usually at the rate of 4 ml. per sq. ft. and the concentration is varied to give the desired dosage. Five percent suspensions, emulsions, or solutions give deposits of 200 mg. per sq. ft. and are the concentrations most commonly used. The frequency of applications ranges from 6 weeks with the lower dosages to once or twice annually with the higher ones, depending on a variety of such factors as vector species, climate, and type of construction treated.

Dieldrin is applied generally at dosage rates of 25 mg. or 50 mg. per sq. ft., using 0.625 or 1.25 percent suspensions prepared from 50 percent wettable powders. Frequency of application varies, but is usually once or twice annually.

BHC is applied at dosage rates ranging from approximately 10 mg. to 50 mg. of gamma isomer per sq. ft., with the greatest usage in the 20–25 mg. per sq. ft. range. Wettable powder formulations are used predominantly and frequency of application ranges from 6 weeks to 6 months.

Since the use of residual sprays for the control of malaria began, great improvements have been made in hand spraying equipment and insecticidal formulations. Present-day hand sprayers are specifically designed for sustained usage in house spraying under rugged field conditions and are a far cry from the flimsy units which were the only type of such equipment available in pre-DDT days. The constant strengthening and development of standardized sprayer specifications (WHO, 1956[a]) and testing techniques (Hall, 1955) for use by United States and international procurement agencies have been important factors in bringing about the improved sprayers.

Similarly, in the early days of house spraying for malaria control, serious difficulties were encountered with the water-wettable formulations of DDT purchased for use in overseas areas. These difficulties were due primarily to inadequate specifications. Again, research and development by United States and international agencies and industry have resulted in the development of standardized specifications (WHO, 1956[b]) (Pearce, *et al.*, ms.) for wettable powders which will give satisfactory performance in tropical areas if the specifications are adhered to properly during manufacture.

The two principal problems being encountered today on vector control programs employing the residual house spray-

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ing technique are insect resistance to insecticides and the sorption of insecticides by certain types of mud used in house construction in many parts of the world. Resistance is an extremely serious problem. Nine important vectors of malaria and *Aedes aegypti* are resistant to one or more of the insecticides usually used in residual house spraying. Fortunately, in most areas, these species are still susceptible to at least one residual type chlorinated hydrocarbon insecticide. However, in Greece, *Anopheles sacharovi* is resistant to DDT, dieldrin, and chlordane (Livadas, 1955), and in Lebanon the same species is resistant to DDT and dieldrin (Busvine, 1955). Much additional research on this problem is needed if the present advantage in this fight against disease vectors is to be maintained. In that respect, it might be mentioned that in laboratory tests by the Communicable Disease Center at Savannah, Georgia, malathion, parathion, EPN, and combinations of them with DDT, have shown considerable promise as possible substitute insecticides against anophelines resistant to chlorinated hydrocarbon insecticides.

The sorption of insecticides by mud walls is a phenomenon reported from numerous localities in many parts of the world. Contrary to earlier reports (Downs, *et al.*, 1951) that sorption was accompanied by chemical decomposition of the absorbed insecticides, Barlow and Hadaway (1955) have demonstrated rather clearly that the rapid disappearance of insecticidal residues from treated mud surfaces is a physical process of sorption. Bordas and Navarro (1955) later reported observations that the toxicity of dieldrin on mud surfaces in Mexico increased steadily as the relative humidity increased. Burnett (1956) in Africa also reported changes in mortalities of mosquitoes exposed to dieldrin on mud surfaces in relation to seasonal differences in rainfall. Barlow and Hadaway (1956) and Miles and Pearce (1957) have confirmed the fact that the sorption process is affected rather drastically by humidity. Low humidity rates increase the speed of penetration of the insecticide into the mud with consequent decreasing kills of insects. High humidity rates slow down the penetration of the insecticide into the mud, thereby prolonging the effectiveness of a treatment. If sorption has already taken place, high humidity rates cause the insecticide to move back toward the surface of the mud, with resultant increasing kills of insects. Barlow and Hadaway (1956) also found that the structure of the mud surface affected the sorption of insecticides. Paulini (1956) confirmed the physical nature of the sorption phenomenon and showed that the colloidal mineral fraction of mud is the component responsible for its sorptive power, the higher the content of mineral colloids the greater the sorptive power.

While the knowledge gained on the nature of the sorption phenomenon is increasing steadily and will undoubtedly aid in surmounting this problem, the fact remains that it still is a serious problem to be overcome if malaria eradication is to be practicable in large areas of the world. Some of the best industrial and governmental research laboratories in the world are now working on this problem, and it can be hoped that a practical solution to it will be forthcoming.

In addition to indoor spraying for mosquito vectors of disease, residual sprays may be used outdoors also to control adult mosquitoes. Bidlingmayer and Schoof (1956) found that residual treatment to the outside, lower portions of houses and to the shrubbery, grass and other vegetation within a radius of approximately 100 feet of the dwelling gave significant reduction in daytime annoyance from salt-marsh mosquitoes for periods of 1 to 9 weeks. Applications were made with 1.25 percent emulsions at the rate of 5 to 10 lbs. of DDT per acre. BHC (1.3 lb. gamma isomer per acre), dieldrin (4 lbs. per acre), and lindane (1.5 lb. per acre) were relatively ineffective. In later studies (CDC, 1957), Diazinon and malathion at 2 lbs. per acre were also found ineffective. Variations in the duration of effectiveness of the DDT treatments were attributed to mosquito potential, more frequent treat-

ments being required whenever weather conditions permitted excessive mosquito production.

Space spraying for adult mosquito control is an operation of old standing. It also is an activity which has developed tremendously since the old days of "Quick, Henry, the Flit." From that lowly start of occasional household spraying with a relatively standard pyrethrum formulation in a simple hand atomizing type of sprayer, the use of space sprays for the control of adult mosquitoes has become a highly organized, almost nation-wide operation involving a complex combination of equipment, techniques, and materials. It represents the principal use of insecticides by many of the organized mosquito abatement districts and is the only method used by an even greater number of communities which attempt to reduce adult mosquito annoyance without the benefit of an established mosquito abatement organization. In addition to these relatively large-scale outdoor space spraying activities, there is an even more widespread use of indoor space sprays by individuals for the control of adult mosquitoes. In 1955, the annual civilian spending for insecticides for household use in the United States approached $75,000,000—largely through such retail channels as drug stores and grocery stores (NPCA 1956). Almost any large retail store dealing in general household items in this country and a large percentage of gasoline service stations carry in stock a wide variety of insecticidal formulations for adult mosquito control in homes—sprays, aerosol bombs, smoke or fog generators, and so forth—not to mention repellents.

The most casual review of the literature will show that an extremely wide variety of insecticides, dosages, and formulations have been used in outdoor space spraying operations for adult mosquito control, as well as in equipment and methods for applying them. DDT has been and still is the most commonly used insecticide for this purpose. In areas where some species have become resistant to DDT, practically every other recently developed chlorinated hydrocarbon insecticide has been used to some extent (Ginsburg, 1956), including chlordane, toxaphene, DDD, dieldrin, BHC, lindane, heptachlor, and aldrin. Pyrethrum, allethrin, lethane and thanite have been used alone or in combination with the chlorinated hydrocarbons. As multi-resistant strains of mosquitoes have appeared, particularly in California and Florida, attention has shifted to the organophosphorus compounds, of which malathion is the one most commonly used.

There are almost as many dosages and formulations used in outdoor space spraying as there are operating units or agencies employing this method of adult mosquito control. There are no such things as standard formulations or dosage rates. They vary according to species of mosquitoes, geographical area, type of application employed, weather conditions, and the opinions of the individual operators. DDT is used most commonly as a 5 percent solution in fuel oil, applied at approximately 0.5 lb. per acre. The other chlorinated hydrocarbons are also used generally in some type of fuel oil solutions at dosages ranging from 0.1 to 0.5 lb. per acre. Malathion likewise is used at dosage rates of 0.1 to 0.5 lb. per acre.

The equipment for applying outdoor space sprays also varies greatly from small portable ground units to helicopter and C-47 aircraft units specially designed for the purpose. Here again, the type of equipment and method of application vary according to terrain, weather, size of area, type of area, mosquito species, and the whims of the individual operators. New variations of existing equipment are constantly being developed by many individuals to meet their own specific needs. Equipment which gives superior performance under one set of field conditions may be inferior to other equipment under other conditions. Each operator must carefully evaluate the conditions under which use is planned and select his equipment, insecticide and formulation to meet those particular needs.

A specialized use of insecticides to control adult mosquitoes is in the disinfesta-

tion of aircraft used in international traffic. The quarantine regulations of most countries of the world require that aircraft entering their countries be disinfested. Health authorities have always been most interested in avoiding the importation of exotic mosquito vectors of disease. With the attainment of malaria eradication in large areas of the world and the growing development of resistant species of malaria vectors, interest in aircraft disinfestation may be expected to increase in the future. Aerosols of DDT and pyrethrins are the most widely accepted method of aircraft disinfestation now used throughout the world. These are not completely satisfactory, however, and improved methods are needed. Some promising research is now in progress at the Communicable Disease Center laboratory at Savannah, Georgia, involving the possible use of insecticidal vapors or short-lived residuals applied with insecticidal vapors.

While insecticides for the control of adult mosquitoes have their place in most mosquito control programs, they are, at best, a temporary expedient. Part of every operating program should be directed toward more permanent solutions to the problem. We have such problems as resistance and sorption of insecticides by mud walls only because we have large numbers of mosquitoes to create such control problems. No species has ever developed resistance to an absence of breeding places. The elimination of mosquito breeding sources should be foremost on the list of control methods employed.

References

BARLOW, F. and HADAWAY, A. B. 1955. Studies on aqueous suspensions of insecticides. Part V. The sorption of insecticides by soils. Bull. Ent. Res. 46(3):547–559.

BARLOW, F. and HADAWAY, A. B. 1956. Effect of changes in humidity on the toxicity and distribution of insecticides sorbed by some dried soils. Nature 178:1299–1300.

BIDLINGMAYER, W. L. and SCHOOF, H. F. 1956. Outdoor residual treatments of premises for control of salt-marsh mosquitoes. Mosq. News 16 (1):17–19.

BORDAS, E. and NAVARRO, L. 1955. Studies on the vapour toxicity, repellency, the residual activity of DDT, chlordane, lindane and dieldrin. WHO/Mal./125.

BURNETT, G. 1956. Variation in mortality with differences in humidity among mosquitoes exposed to BHC, dieldrin and DDT. Nature 177(4510):663–664.

BUSVINE, JAMES R. 1955. Report on a visit to Lebanon and Greece regarding insecticide resistance of *Anopheles sacharovi*. WHO mimeographed Malaria Section Series, October 1955.

COMMUNICABLE DISEASE CENTER. 1957. 1957 Report from the Communicable Disease Center, Public Health Pesticides. Pest Control 25(3): 9–32.

DOWNS, W. G., BORDAS, E. and NAVARRO, L. 1951. Duration of action of residual DDT deposits on adobe surfaces. Science 114(2958): 259–262.

GINSBURG, JOSEPH M. 1956. A survey of insecticides used in country-wide mosquito control in 1955. Mosq. News 16(2):137–138.

HALL, LAWRENCE B. 1955. Suggested techniques, equipment, and standards for the testing of hand insecticide-spraying equipment. Bull. Wld. Hlth. Org. 12(3):371–400.

LIVADAS, GREGORY. 1955. Resistance of anophelines to chlorinated insecticides in Greece. Mosq. News 15(2):67–71.

MACDONALD, G. and DAVIDSON, G. 1953. Dose and cycle of insecticide applications in the control of malaria. Bull. Wld. Hlth. Org. 9(6):785–812.

MILES, JAMES W. and PEARCE, G. W. 1957. A rapid method for the measurement of the rate of sorption of DDT by mud surfaces. Science 126(3265):169–170.

NATIONAL PEST CONTROL ASSOCIATION, INC. 1956. 1955 Sales of products of interest to pest control operators. Technical Release No. 18–56.

PAL, RAJINDAR and SHARMA, M. I. D. 1955. Malaria control by the use of insecticides. Indian J. Malariol. 9(4):385–401.

PAULINI, ERNEST. 1956. Adsorção do DDT Pelo Barro. Revista Brasileira de Malariologia e Doencas Tropicais. Publicações Avulsas No. 6.

PEARCE, GEORGE W., GOODEN, E. L. and JOHNSON, DONALD R. Specifications for water dispersible DDT powder for use in malaria control programs. In manuscript.

WORLD HEALTH ORGANIZATION. 1956[a]. Sixth report of expert Committee on insecticides. Technical report No. 110.

WORLD HEALTH ORGANIZATION. 1956[b]. Specifications for pesticides.