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INSECTICIDES FOR THE CONTROL OF INSECT-BORNE DISEASES[1]

by RICHARD W. FAY
Technical Development Laboratories
Communicable Disease Center
Public Health Service
Savannah, Ga.

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The gradual build-up of knowledge has made man the dominant vertebrate species on this earth. The increase of medical knowledge has permitted man to increase his survival rates, and at the same time the accumulation of technical knowledge has enabled him to conquer distances. The latter, together with the social complexities of modern civilization, has made nations more dependent upon one another. These changes have emphasized other phases in the survival struggle among which are the securing of enough food and the conquest of transmissible diseases on a world-wide basis. In these phases of survival, man has met worthy opponents in the lower forms of life: the insects, the bacteria, and the various disease organisms: bacteria, protozoa, rickettsia, and viruses.

Man's advantage over these animals lies in the ability to learn by experience and experiment. The lower forms of life are favored by high biotic potentials and variability within a species. The high biotic potentials necessitate high mortality levels to bring a species under control. High mortalities in turn select variants of the species which differ in some manner so as to overcome the control measures involved. A seesaw battle has resulted, with temporary gains for man with new control methods or for the lower forms through the appearance of resistant strains.

The fluctuations in control of disease vectors are well illustrated with the common housefly, *Musca domestica* the house fly, and a closely related species, *Musca sorbens*. The first two flies are of worldwide disease significance, important as transmitters of enteric diseases such as typhoid, bacillary and amoeba dysenteries, diarrhea, and Asiatic cholera. The last species, *M. sorbens*, shows a seasonal prevalence closely correlated with the epidemics of acute ophthalmia in North Africa. The habits of the adult flies in collecting around the eyes and on the faces of children lend support to disease transmission by the species.

The discovery and use of residual insecticides such as DDT, methoxychlor, chlordane, and dieldrin gave man a decided advantage in the control picture, but with the widespread and continued use of these chemicals, variant strains of resistant houseflies appeared and the utility of the chemicals diminished. The occurrence of resistance was aligned closely with the intensity of use, especially where a single insecticide was chosen for a widespread campaign. Resistance extended to the various types of formulation and to the different application techniques, although there were minor differences in mortality influenced by the intensity of the insect's exposure to the chemicals.

In addition to resistance, changes in the biological balance have in certain instances given the flies a temporary advantage in that more extensive populations appeared after chemical applications. This phenomenon was shown in pit privy treatments with dieldrin residues. Housefly production in the treated privies increased markedly over that in untreated privies. Experiments have demonstrated that the populations of the soldier fly, *Hermetia illucens*, in the privy contents were eliminated by dieldrin treatments. The larvae of this species normally convert the privy contents to a semisolid to liquid consistency and with their elimination the privy contents became semisolid to solid, a consistency which proved more favorable to housefly breeding (1).

Chemical control of houseflies has moved on to the organophosphorus compounds. Here a good many new compounds were available at about the same time, so that no one compound has received the over all application as did DDT or dieldrin. Within the last four years, however, variant housefly strains resistant to Bayer 21/199, Diazinon, parathion, and malathion have appeared in field populations of Denmark, Switzerland, Italy and the U. S. A. Many of these strains are resistant to specific compounds and the pattern of cross resistance to the organophosphorus group has not been clearly defined as yet. Treatments such as impregnated cords, poison baits, and larvicides as well as residual deposits have been used with the organophosphorus compounds. In many cases these measures are more transitory in their effects on the fly populations and the loss of the usefulness of all the organophosphorus compounds may be forestalled if they are wisely applied.

The control of housefly-borne diseases through insecticide measures stands at present somewhat in favor of man, but it behooves us to be looking for new means of control. These means may involve new lethal chemical groups or possibly more subtle means of chemical control such as growth regulators, antimetabolites, or sterilizing agents.

The use of insecticides for controlling the mosquito vectors of disease has resulted in spectacular gains, particularly in human malaria reduction. Here the insect is essential to the transmission of the disease and represents the only host other than man. DDT was initially so effective against the larval and adult mosquitoes that species eradication on a nationwide basis was attempted in several areas. Virtual elimination of certain species, such as *Anopheles darlingi* and *Anopheles albimanus*, was obtained in some areas. Ecological differences in other species or the appearance of insecticide resistance in some species has changed the control picture to one of malaria eradication rather than mosquito eradication. DDT, dieldrin, and to a lesser extent BHC were the insecticides of choice for malaria control programs and still remain so for most cases. However, both DDT- and dieldrin-resistant strains have appeared in several species of anopheline vectors of malaria. With the exception of *A. albimanus* and *A. sacharovi* the resistance has been to only one of these insecticides, so that the other could be utilized in the control programs. With the two species mentioned, however, the use of other types of insecticides, possibly malathion or Diazinon, is under investigation, and the doors are opening to other types of residual insecticides.

In the control of urban yellow fever through *Aedes aegypti* eradication, DDT has been the insecticide of choice. The occurrence of DDT-resistant larvae and adults in various countries of Central and South America has produced a shift to other insecticides such as BHC, dieldrin, and malathion. The resistance to these compounds has not appeared in the species.

In the control of encephalitis, the use of DDT larvicides against the mosquito vector *Culex tarsalis* went out with resistant strains in the western U. S. A. In certain areas where *C. tarsalis* control with BHC, toxaphene, aldrin or dieldrin larvicides was found no longer practical, parathion, EPN, or malathion larvicides were employed. More recently malathion-resistant strains have appeared in limited areas of California.

Culex quinquefasciatus (*fatigans*), a major transmitter of filariasis, has shown resistance to DDT and BHC larvicides. DDT residual treatments for adult control in homes have not been satisfactory in many areas. Laboratory tests have indicated certain strains to have high percentages of dieldrin-resistant adults, but residual applications of BHC and dieldrin have appeared satisfactory in field control operations where DDT residues fail.

In personal protection, considerable strides have been made in repellents for skin and clothing applications. Diethyltoluamide and chlorodiethylbenzamide are very effective new compounds.

The development of granular formulations of various toxicants has represented a considerable gain in the accomplishment of practical control in many areas where vegetation prevented adequate distribution of other types of mosquito larvicide for

[1] From the Communicable Disease Center, Bureau of State Services, Public Health Service, U. S. Department of Health, Education and Welfare, Savannah, Ga.

mulations. The development of fog and dust formulations and of dispensing equipment has added considerably to the control of adult mosquitoes, particularly in emergency conditions.

In the application of the organophosphorus compounds to housefly control, many formulation adaptations have been made taking advantages of habit or response patterns of the insects. Examples are the use of attractant materials in poison baits, the use of sugar-insecticide residual bait sprays, and the use of insecticide impregnated cords or strips in fly-resting localities. These types of modified formulations have not been as fully employed in mosquito control as in fly control, and a closer examination of mosquito response may evolve new control applications in the future.

Turning to the use of insecticides in other diptera-borne diseases, larvicide applications with DDT have proved very effective against the black flies, *Simulium* spp., in campaigns against onchocercasis in Central America and Africa. The DDT as an emulsion, suspension, or oil solution is introduced into watercourses and eliminates *Simulium* larvae over distances of several miles. Although other insecticides have been evaluated, DDT remains the best choice. In certain circumstances DDT dust or oil solutions have been applied against the adult flies with good results.

In campaigns against leishmaniasis and pappataci fever through the control of various species of sand flies, DDT residual applications to the walls of houses, to animal shelters, and even outside applications on selected resting places have been very effective. BHC residual deposits also have shown good results with similar types of application. No resistance has been demonstrated in the species of black flies or sand flies, and in these cases man has made definite progress in disease control.

In the campaigns against sleeping sickness, applications of dieldrin and of DDT have proved feasible against *Glossina palpalis*, a species of tsetse fly restricted largely to the vegetation along water courses. Against the savannah woodland species and the forest dwelling species of tsetse flies, however, insecticide applications have proved uneconomical unless the infested area can be restricted by other means. Here the extent of the infested territory, the nature of the vegetation, and the necessity for aerial applications have limited the use of insecticides rather than any resistance in the insects themselves.

During World War II, epidemic typhus was controlled with remarkable results through the use of DDT powder which was dusted inside clothing of persons infested with human body lice, *Pediculus humanus corporis*. Successful campaigns against epidemic typhus were carried on all over the world during the period from 1945 to 1950. Lice were considered as a non-resistant species on the basis of early selection experiments. During the Korean War, however, in 1950-51 DDT resistant strains were encountered first in Korea and later in Japan. Since that time resistant strains have appeared throughout the world, even on Mexican laborers entering this country. Populations resistant to gamma-BHC and even to pyrethrins have been recorded. In view of these indications of resistance to these insecticides, the possible use of malathion dusts is under investigation.

Although halogenated hydrocarbon insecticides are apparently failing to control the cat flea, *Ctenocephalides felis*, and the dog flea, *C. canis*, in many localities, no problems have been encountered in campaigns against the oriental rat flea, *Xenopsylla cheopis*. This vector of bubonic plague and of murine typhus remains susceptible to treatment with DDT dusts.

Finally, in the case of American trypanosomiasis (Chagas' disease) in South America, the hemipteran carriers *Triatoma* spp. and *Rhodnius* spp. were not satisfactorily controlled by DDT, but residual applications of dieldrin and BHC have proved effective.

In considering the entire picture of insecticides as applied to the control of insect-borne diseases we find that although insecticide resistance has appeared in a good many important vector species, there are no species which are resistant to all of the really effective compounds. Thus man is reducing the incidence of the insect-borne diseases.

Man's requirements in our complex modern society have made nations more dependent upon one another. Movement of goods and people between the various countries is increasing annually. Faster transport has also emphasized the fact that disease has little regard for political boundaries. The recent movement of Asiatic flu across the world is a clear example. In a recent committee meeting of the WHO, a prominent Egyptian scientist pointed out that he had visited several areas endemic for jungle yellow fever in Central and South America and yet returned to his own country before the incubation period of the virus had elapsed and symptoms of disease could have appeared. With present day air travel, it is theoretically possible for a female anopheline mosquito to bite a malaria victim in any part of the world and reach you even before the malaria sporozoites have reached her salivary glands.

These points illustrate that communicable diseases anywhere are important to everybody. Insect vectors of disease can be attacked at the source, or quarantine measures can be applied. The use of insecticides in quarantine measures will be increasingly important as specific diseases are eliminated in various geographical areas. Quarantine measures are likewise important in preventing the spread of resistant strains of insect vectors of disease. Here, however, we are faced with an extremely difficult problem, for although we have insecticides to control any given resistant strain of insects, there remains a need for a single easily applied insecticide that is effective against all the strains of resistant insect vectors of disease. We cannot close our eyes to the fact that such formulations are not available at present, and the problem requires detailed investigations in the immediate future.

As the effects of reduced incidence of various diseases through insect control are demonstrated, the general public becomes more aware of the importance of insects in its daily life. An increased demand for various insecticides for domestic use can be forecast as a probable result. The lengthening of life expectancy and the reduction of infant mortality rates may well lead to markedly increased populations and higher food requirements. Here again these factors should produce greater markets for insecticides in agricultural applications.

Discussion

From the Floor: Earlier in Dr. Fay's discussion, he made a reference to the possible use of growth regulators to control insects, and I wondered if he has any information on products for experimental work that has been done.

Dr. Fay: We have not worked directly with growth regulating hormones, but we are interested in them since there is a possibility of using them in the future. In the recent article in *Life* magazine the immediate possibility of this type of approach was overemphasized, but the theories do have considerable promise. I think the most promising thing lies in the fact that these materials which investigators have isolated can be applied to the outside of the test insects and produce the effect. With the identification of the active ingredients there is a possibility for direct synthesis, and topical application would be more practical than materials which were active only when injected. We are watching the progress in this field rather closely.

REFERENCE

(1) Kilpatrick, J. W. and Schoof, H. W.: "Interrelationship of Water and *Hermetia illucens* Breeding to *Musca domestica* Production in Human Excrement." (In manuscript)

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