been studied chiefly for the purpose of comparing them with dieldrin. However, these studies have also been an aid in developing antidotes. The study of aldrin was made for the specific purpose of studying the hazard of that compound in floor wax intended for ordinary household use.

Some insecticides give off an appreciable vapor when they are applied as a residual spray, thus acting concurrently as a space treatment. Extensive studies have been carried out on the possible hazard which chlordan may present when used in this way inside of dwellings.

# THE STATUS OF FLY RESISTANCE TO INSECTICIDES IN THE SAVANNAH AREA AND ITS IMPLICATIONS IN THE GENERAL PROBLEM OF FLY CONTROL

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The development of resistance to DDT by house flies was first reported in Italy in 1948. At least some of the numerous complaints concerning the lack of effective fly control with DDT in this country in 1947 and 1948 were undoubtedly due to fly resistance, although that fact was not generally recognized at the time. By the early spring of 1949, however, the existence of DDT-resistant strains of house flies in many localities of the United States had been recognized and proved by both laboratory and field tests. Studies were immediately begun by several research agencies to develop DDT substitutes and to study the possible development of resistance to these other potential fly insecticides.

The area in and around Savannah, Ga., is one of the locations where DDT and other halogenated hydrocarbon insecticides have been used for the longest continuous period of time. The Savannah laboratory of Technical Development Services began testing DDT for fly and mosquito control in this area in 1944, with numerous homes and some dairies being treated that year. The following year, 1945, the fly control studies were extended to include not only dairies, but also restaurants, abattoirs, food processing plants, garbage dump areas, and other similar fly foci. These studies were continued on about the same scale in 1946 and 1947, with chlordan also being used on several premises. The Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture also used some of the dairies near Savannah for fly control studies in 1945, 1946, and 1947.

A review of the work conducted in 1947 indicates that the results obtained with DDT that year, while still reasonably good, were not as striking as in previous years at the same location. As stated previously, these poorer results were quite likely attributable to the development of fly resistance, but it was not recognized as such at the time; and other reasons, notably poor sanitation, were considered the important causes of the reduced effectiveness.

During 1948, neither the Technical Development Services nor the U. S. Department of Agriculture conducted fly control field experiments with residual sprays in the Savannah area. However, the operators of the dairies and other establishments

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at which such work had been conducted in previous years, either applied DDT residual sprays themselves or contracted for such work with local pest control operators. In most of the instances, satisfactory control was not achieved. Those applying the sprays themselves repeated treatments every few weeks. Those employing commercial pest control operators complained bitterly about the lack of effective fly control, and forced the pest control operators to repeat treatments to such an extent that most of them abandoned the field of fly control around dairies and other locations of high fly breeding potential and attraction.

In the spring of 1949, laboratory tests with flies reared from eggs collected at dairies around Savannah revealed moderate to strong DDT resistance in the flies present at practically all of them. This was later verified by field tests with DDT, which failed to give satisfactory fly control at applied dosages of 200 milligrams per square foot. Methoxychlor and combinations of DDT and methoxychlor also failed to achieve satisfactory fly control. Lindane gave satisfactory results for only 2 to 3 weeks when applied at 25 milligrams per square foot, and for 4 to 8 weeks when used at 50 milligrams per square foot. Chlordan at 100 and 200 milligrams per square foot and dieldrin at 12.5 and 25 milligrams per square foot gave results which approached those obtained with DDT during the first few years of its usage. These chlordan and dieldrin treatments were applied in July and generally remained effective for the balance of the season.

Space spray tests conducted at the city dump in 1949 indicated that the house flies in the Savannah area were resistant to DDT space sprays as well as residual sprays. Dosages of DDT space sprays which produced 80 to 95 percent kill of blow flies gave only 11 to 20 percent kill of house flies. When chlordan or dieldrin space sprays were tested, both produced slightly higher levels of house fly kills than those of blow flies, a phenomenon previously encountered with DDT prior to the development of DDT resistance in house flies.

During 1950, fly control investigations by Technical Development Services included studies of space sprays, larvicides, and residual sprays at dairies and on rural premises. Because of the encouraging results obtained with dieldrin in 1949, a major portion of the work in 1950 was done with this insecticide. Other materials tested as residual sprays included toxaphene, chlordan, and pyrethrum with piperonyl butoxide. The spray tests included most of the newer chlorinated hydrocarbon insecticides, as well as pyrethrum, rotenone and lethanes. Dieldrin, chlordan, lindane, and benzene hexachloride were tested as larvicides.

The results obtained in 1950, insofar as house fly control is concerned, were most disappointing. In residual spray tests at dairies, toxaphene and pyrethrum with piperonyl butoxide failed to achieve satisfactory house fly control. Chlordan at 100 milligrams per square foot failed to bring the fly population down within satisfactory control limits. A subsequent treatment with chlordan at 200 milligrams per square foot at these same dairies was relatively ineffective. Dieldrin at 25 milligrams per square foot gave much poorer results than in 1949, less than 2 weeks effective control being obtained at some of the treated dairies. Laboratory tests with flies reared from eggs collected at the dairies treated with chlordan and dieldrin indicated that the flies were moderately to strongly resistant to the respective insecticide with which each dairy had been treated. Adult flies trapped at the chlordan-treated dairies and exposed in wall cages on surfaces at another dairy which had been treated with dieldrin at 50 milligrams per square foot appeared to be highly resistant to dieldrin also.

In general, the results of larviciding tests at dairies with chlordan, lindane, and dieldrin indicated that relatively satisfactory fly control could be achieved with approximately weekly applications of these materials on the manure piles, stable litter, and other fly breeding areas on the premises, providing the degree of sanitation practiced by the dairy was reasonably good. In the presence of poor sanitation, semiweekly larvicidal treatments did not keep the flies under control, although in most cases the fly populations were noticeably suppressed.

At one dairy, which is situated just outside the city limits of Savannah and where the sanitation was very poor, weekly larvicidal applications of dieldrin at the rate of 25 milligrams per square foot failed to produce satisfactory fly control. After 4 weeks of such treatments, the frequency of application was increased to two treatments weekly. After the seventh larvicidal treatment, the adult fly population began to increase, and by the end of 2 months from the time of the first treatment, during which a total of 12 larvicidal applications had been made, the grill index for this dairy exceeded 1,000. An over-all application of dieldrin at the rate of 50 milligrams per square foot was



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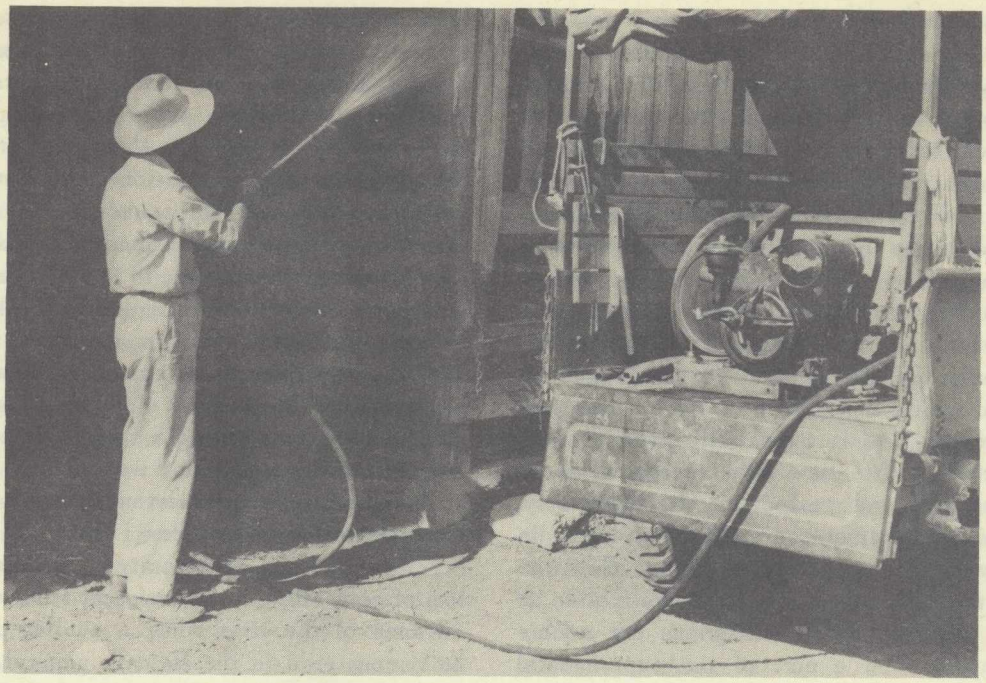

Test spraying was conducted on dairy barns in the Savannah area to determine fly resistance to various insecticidal formulations.

then applied to the inside surfaces of all of the buildings on the premises, except the feed and milk rooms, with proper precautions being taken to prevent any contamination of the milk as a result of the spraying. While some flies were killed by the spraying operation and there was some reduction in the grill index during the week following this residual spray application, it was not possible by visual observation to detect any reduction in the fly population. Four days after treatment, flies were observed resting on the treated surfaces at night with no apparent ill effect. Two weeks after treatment, the grill index exceeded that prior to treatment.

Adult flies trapped at this dairy were exposed in laboratory tests to residual deposits of DDT, dieldrin, chlordan, heptachlor, lindane, and some other new potential insecticides which are still in the developmental stage. None produced sufficient mortality to indicate that they might give effective control of this particular strain of flies. Space spray tests at this dairy indicated that these flies were resistant also to space sprays of DDT, dieldrin, aldrin, chlordan, lindane, and technical benzene hexachloride. The lethanes and rotenone were generally ineffective in all space spray tests. Pyrethrum with piperonyl butoxide gave the most encouraging results against this strain of flies, and tests are continuing to determine the dosage range which may be required to achieve satisfactory control of them.

In tests with larvicides in garbage cans, good results were obtained in initial tests early in 1950 with dieldrin and lindane. By mid-season, chlordan was ineffective as a larvicide against house flies breeding in garbage cans, and toward the end of the season considerable house fly emergence occurred from cans treated with dieldrin and lindane. All of these experimental treatments appeared to be effective against blow flies breeding in the cans. Many of the cans used in these experiments were obtained from homes located within 1 mile of the dairy at which the strongly insecticide-resistant strain of house flies had developed as discussed above. Flies from the dairy undoubtedly dispersed over much of the residential area of Savannah during the season. It is quite likely that insecticide-resistant strains of flies from other nearby dairies also found their way into the city. It seems very probable that the distribution of these insecticide-resistant flies was a primary factor in the relative ineffectiveness of garbage-can larvicides against houseflies toward the end of the 1950 season.

Similarly discouraging results were also encountered in the experimental spraying of rural premises with dieldrin. The area selected for these tests was in a nearby rural county which had par-



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ticipated in the malarial control program of residual spraying of homes with DDT for the past several years, but which had withdrawn from the program in 1950. Insofar as is known, no other widespread use of any of the newer insecticides had occurred in this county except those applied to crops for the control of agricultural insects. The initial treatment of these premises with dieldrin at a dosage of approximately 50 milligrams per square foot produced an immediate and drastic reduction in the fly population. At the end of a month following treatment, the fly population had begun to increase and within 2 months was approaching pretreatment levels. Adult house flies reared from eggs collected at this time from several of these treated premises and tested in the laboratory, appeared to be already resistant to dieldrin in varying degrees from moderate to strong. This was verified in the field when a second application of dieldrin at the rate of 50 milligrams per square foot was applied on a part of the experimental area without noticeably affecting the fly population.

The status of fly resistance to insecticides in the Savannah area appears to be as follows. Resistance has been observed only in house flies. Strains of flies which have developed resistance to more than one chlorinated hydrocarbon insecticide as a result of successive exposures to them (such as DDT followed by chlordan and then by dieldrin, or DDT followed by methoxychlor and then by chlordan) appear to be resistant to other related chlorinated hydrocarbons on initial exposure to them. A major portion of the house fly population in the Savannah area has become resistant to practically all of the presently available residual insecticides of the chlorinated hydrocarbon type. Such flies are also resistant to these insecticides applied as outdoor space sprays.

In analyzing the situation with regard to the present status of fly resistance to insecticides in the Savannah area as compared to most other areas, it seems reasonable to believe that fly resistance in the Savannah area is probably several years ahead of that in most other areas. This condition has been brought about by the intensive use of most of the chlorinated hydrocarbon insecticides which have been developed during the past several years. While these insecticides have been used on an experimental basis, the scale of operations has been large enough that the majority of the important house fly producing or attractant foci have been treated with some one, or a combination of several, of the chlorinated hydrocarbon insecticides continuously for the past 7 years. The effectiveness of these experimental treatments in previous years was such that many establishments became quite lax in their sanitation practices. Consequently, it appears that a major portion of the total house fly population in the Savannah area has been exposed to a succession of residual insecticides under conditions very favorable for fly breeding, resulting in the development of strains of house flies which are generally resistant to practically all of the available chlorinated hydrocarbons. The often expressed theory of many workers that the problem of fly resistance to DDT could be met by rotating a series of several residual insecticides has not worked out in practice.

The status of fly resistance to insecticides in the Savannah area provides Technical Development Services with the opportunity to work on the problem of controlling such resistant flies somewhat in advance of the time when a similar problem may be encountered in the field in general. (It has already been encountered in a very limited number of other areas.) While most of the work in Savannah directed toward this end has not been very encouraging, it is hoped that a practical solution to the problem may be forthcoming. It is apparent that different types of insecticides other than chlorinated hydrocarbons, or some method of preventing the detoxification of the absorbed insecticides by the flies, must be developed.

In the meantime, it would appear reasonable to assume that the situation which prevails in the Savannah area will ultimately become general, especially if the general public continues to rely on the use of insecticides as the principal approach to the fly control problem. Many municipalities are conducting highly publicized insecticidal fly control programs which are not only costly, but do not provide any permanent fly control. In fact, it is highly questionable in many instances if such programs are producing even temporary fly control at a satisfactory level. One thing about such programs appears certain, they are conditioning their local fly populations to the particular insecticides in use and are hastening the day when such insecticides will become ineffective in fly control.

A similar condition prevails throughout much of the rural areas of the United States, but is the result of a somewhat different situation. Millions of pounds of the newer chlorinated hydrocarbon insecticides are being applied to vast acreages of small grains, cotton, corn, peanuts, fruit trees,



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and other agricultural crops, as well as to millions of livestock. The vast majority of these insecticides are being applied by airplane or ground power equipment, with the result that spray and dust drifts are undoubtedly floating across a high percentage of rural premises, subjecting the fly population found there to sublethal dosages of the insecticides being used. Many of these insecticides are volatile and their fumes, drifting with the breezes, are also subjecting the flies to sublethal exposures. The frequency with which the odor of benzene hexachloride is encountered during a few hours' drive through the cotton belt on a summer afternoon is striking evidence of the extent of this condition, since for each instance where benzene hexachloride makes its presence known, there are undoubtedly several others of more subtle odor whose presence goes undetected.

The use of insecticides in agriculture is a factor in the fly resistance problem over which the health worker has little or no control and is one which will no doubt eventually bring about the development of insecticide-resistant strains of house flies in rural areas. In urban areas, however, where the principal fly breeding sources generally could be eliminated by improved sanitation, every effort should be devoted to approaching the fly control problem on a permanent basis through improving basic sanitation, with a resort to insecticides only as a supplementary or emergency tool. Such a procedure should delay indefinitely the development of fly resistance and prolong the effective use of presently available insecticides. It would also provide research agencies with more time to develop new materials or procedures with which to meet what presently appears to be the inevitable problem of insecticide-resistant flies in all areas.

# THE NEWER ECONOMIC POISONS OF USE IN DISEASE CONTROL

WILLIAM M. UPHOLT, Sr. Scientist*

Insecticides have been used for disease control for a good many years. As early as 1892, L. O. Howard** suggested the use of oil to kill mosquitoes. By 1914 oiling for mosquito control was a recognized part of the malaria vector control program in Malaya. Insecticides of one form or another, particularly pyrethrum space sprays, have supplemented sanitation and screening for control of adult mosquitoes and house flies since early in this century. Paris green was used for the control of mosquito breeding in the early 1920's. With the advent of DDT a new technique was added, in that it became possible to apply to a wall an insecticidal residue capable of killing mosquitoes and flies which rested on that wall weeks and even months after treatment. The idea of a residual insecticide was not entirely new since agriculture had used residual stomach poisons for many years. It is very likely that some of the residual stomach poisons, particularly sodium fluoride as used against cockroaches, actually may have acted, at least in part, as a residual contact insecticide as well. However, the general application of an insecticide designed to kill by contact weeks after application was a revolutionary phenomen.

Insecticides immediately spring into the public

*Technical Development Services, Savannah, Ga.
**Howard, L. O. (1892) Insect Life, 5: 12.



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