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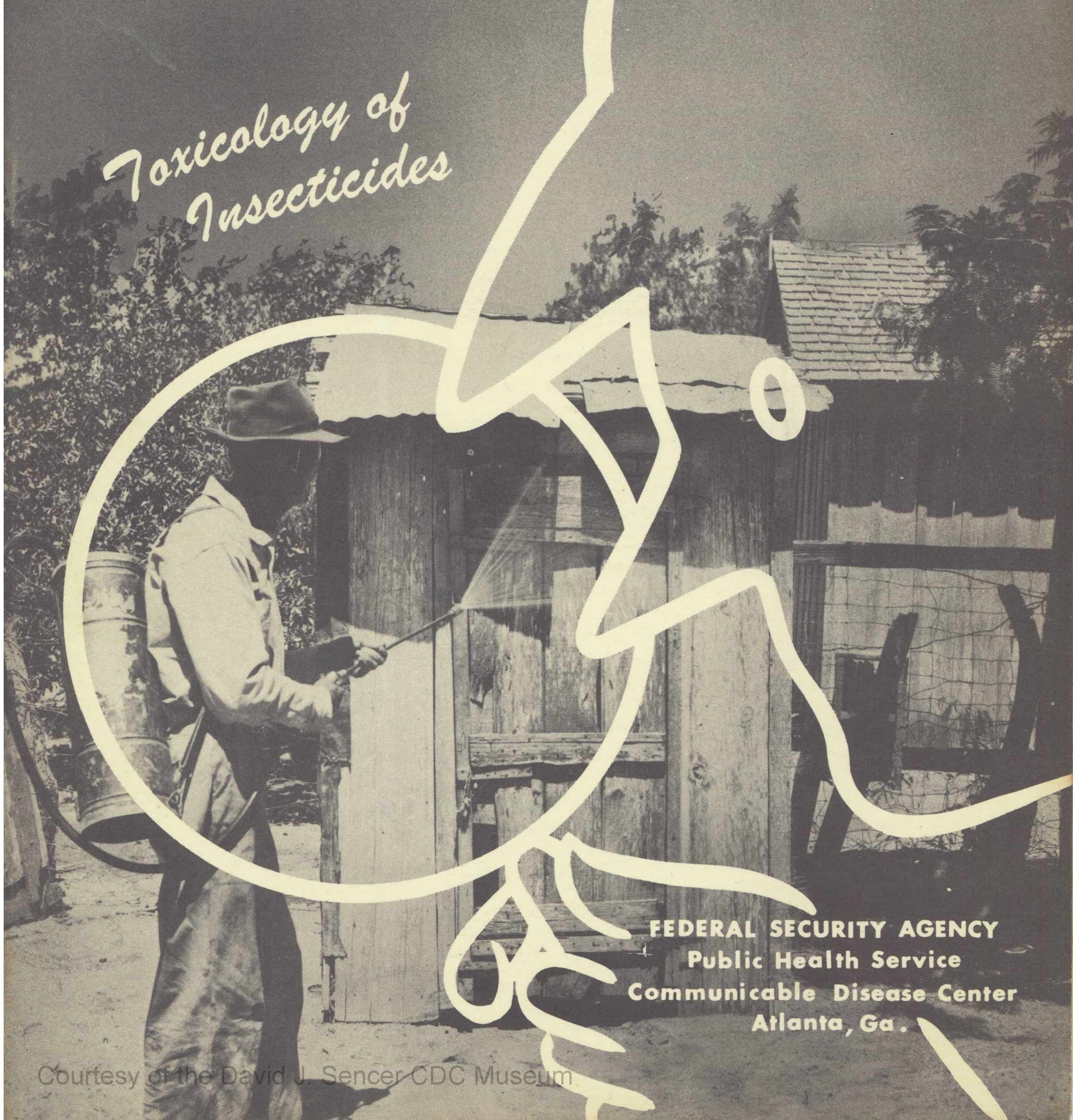
## Toxicology of Insecticides



FEDERAL SECURITY AGENCY
Public Health Service
Communicable Disease Center
Atlanta, Ga.

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# Contents



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# TOXICOLOGY OF INSECTICIDES*

**Wayland J. Hayes, Jr., Surgeon****

The Toxicology Section of the Technical Development Services was officially begun on July 1, 1949, although a few studies were started in the early spring of 1949. Its purpose is to make a general investigation of the toxicology of economic poisons. The public health aspects of the problem involve: (a) employees in manufacturing and formulating plants, (b) workers or others exposed to pesticides by agricultural uses or in disease-vector control programs, (c) persons occupying treated premises, (d) the general public who consume residues of economic poisons on or in foods, and (e) persons — often children — exposed entirely through carelessness or accident.

The health of employees of industrial plants is the special responsibility of industrial hygienists and is not, therefore, a responsibility of the Technical Development Services. On the other hand, a direct responsibility of the Communicable Disease Center is the health of spray crew operators or of pilots who disperse insecticides as a part of the Center's operational programs. The exposure problem of many agricultural workers essentially is identical to that of the Center's operational field personnel. Unlike industrial workers, they cannot be protected by elaborate or heavy equipment. Even protective clothing or a respirator may prove a burden. Again, persons occupying premises treated for disease-vector control are a responsibility of the Center insofar as their health may be affected by the pesticides used. The study, particularly from the clinical aspect, of the hazard presented by poisonous residues on or in food is a long-recognized duty of the Public Health Service. Although accidental poisoning is a difficult problem to attack, much may be accomplished by widely distributed information. Furthermore, the possibility of poisoning, either accidentally or otherwise, poses the challenge to discover specific antidotes and devise better treatments.

The entire first year of work of the Toxicology Section was devoted largely to a study of the insecticide dieldrin. When this study began, the use of dieldrin in the field was being held in abeyance because so little was known of its toxic hazard to spray workers that it could not be adequately field-tested, much less be recommended for control operations. During that year some work also was done on the possible hazard to occupants, of the residual sprays of chlordan used to treat their houses. The work in toxicology is being expanded into the broader public health field. A project is now being inaugurated to study the problem of toxic residues of insecticides on food.

## METHODS

The work of the Toxicology Section is divided into four main approaches: (a) laboratory studies, (b) investigations of operator exposure, (c) clinical studies of human cases of poisoning, and (d) information service. These four approaches are generally applicable to all of the problems undertaken. A brief discussion of these problems will be followed by a short account of work that already has been done.

Laboratory work involves animal exposures by various routes to determine the nature of clinical signs and the variation that may be expected between individuals or between species, and to obtain leads on the mode of action of the poison under study. Once animal exposure has been standardized, antidote studies are begun to see if illness and death caused by the compound may

*For information pertaining to warfarin, a rodenticide, see CDC Bulletin, August 1950, and page 17 of this Bulletin.

**Technical Development Services, Savannah, Ga.

be alleviated by proper treatment or specific medication. To aid in these antidote studies and to serve as a general basis for other work, studies on the pharmacology and biochemistry of the compound are conducted. Chemical studies are required both to determine very minute quantities of a variety of poisons in the various body tissues and to study the normal metabolic processes which may be affected directly or indirectly by the poisons. To aid in the pharmacological and chemical studies, a radioactive tracer laboratory has been established. Finally, pathological studies are made of animals which die or are sacrificed after an experimental procedure.

Field studies of the exposure of spray operators have been necessary because so little is known of the hazard to which these people are subjected. In the course of spraying for either agricultural or public health uses, the operator is exposed to an invisible but continuous rain of small droplets of the spray formulation. These droplets fall on the clothing and the exposed skin, and they may also be inhaled if the particle size is sufficiently small. Such exposure is in addition to any gross accidental contact with the spray formulation of which the operator may be aware. Methods have been developed to sample the fine spray mist contacted by experienced workers under actual field conditions.

Human cases for clinical study may be divided into three classes: (a) persons who are clearly poisoned by an insecticide formulation, (b) persons who are suspected of being poisoned but whose true diagnosis is in doubt, and (c) persons with no apparent illness and no complaints who have had long and extensive exposure to one or more of the compounds under study. Persons in the first group are of particular interest for determining the human symptomatology of poisoning and as test subjects for the most promising forms of treatment developed in the laboratory. It is considered important to study illnesses in which the possibility of poisoning exists since some of these cases eventually prove to be genuine instances of poisoning, thus broadening our knowledge of the nature of poisoning in man. Some forms of illness — for example, headache and subjective dizziness — are difficult or impossible to demonstrate in animals; yet they are quite real and may cause patients great discomfort. Other cases of suspected poisoning eventually prove to be completely unrelated diseases. However, study of such cases of suspected poisoning is not wasted even from the standpoint of toxicology, for if allowed to go misdiagnosed they may eventually cause the limitation of a useful and actually completely safe compound. It also is considered desirable to study persons with extensive exposure to insecticides in order to obtain the earliest possible indication of any adverse effect which may develop. Such examination protects not only the individual who is tested but also other workers who are similarly exposed and, eventually, the whole public who may daily consume minute amounts of the same poison that the worker encounters in relatively large amounts.

The Toxicology Section has been designated as an information center in the Public Health Service on the subject of the hazards of economic poisons where the problem is not one of industrial hygiene. Many letters are received from physicians, public health officials, and the public generally. Some of the questions have to be answered individually, but many answers are contained in a series of clinical memoranda issued by the Technical Development Services.

**RESULTS**

In the studies on dieldrin, it was found that concentrates are very hazardous and that one might be injured by spillage of even a small quantity. On the other hand, it was shown in extensive animal experiments that repeated exposures to the dilute emulsions used for actual spraying might be tolerated for long periods. The beneficial effect of immediate washing even after gross skin contamination was demonstrated but it was shown that washing is useless if delayed. A comprehensive description of the clinical signs of poisoning was obtained to aid in the diagnosis of possible human cases. Considerable success was obtained in the treatment of dogs and monkeys brought to violent convulsion by an amount of dieldrin which was uniformly fatal to control animals. On the basis of laboratory studies, it was thought safe to carry on limited field tests. The health of workers on these projects was carefully followed and no injury was observed. On the basis of all of the studies in the laboratory and in the field, it has been possible to release dieldrin for the use of governmental agencies and other trained control units for outside residual spraying aimed at the control of disease vectors.

Some of the other commonly used insecticides, including DDT, lindane, chlordan, and aldrin, have 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

KENNETH D. QUARTERMAN, Sanitarian (R)*

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

*Technical Development Services, Savannah, Ga.

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.

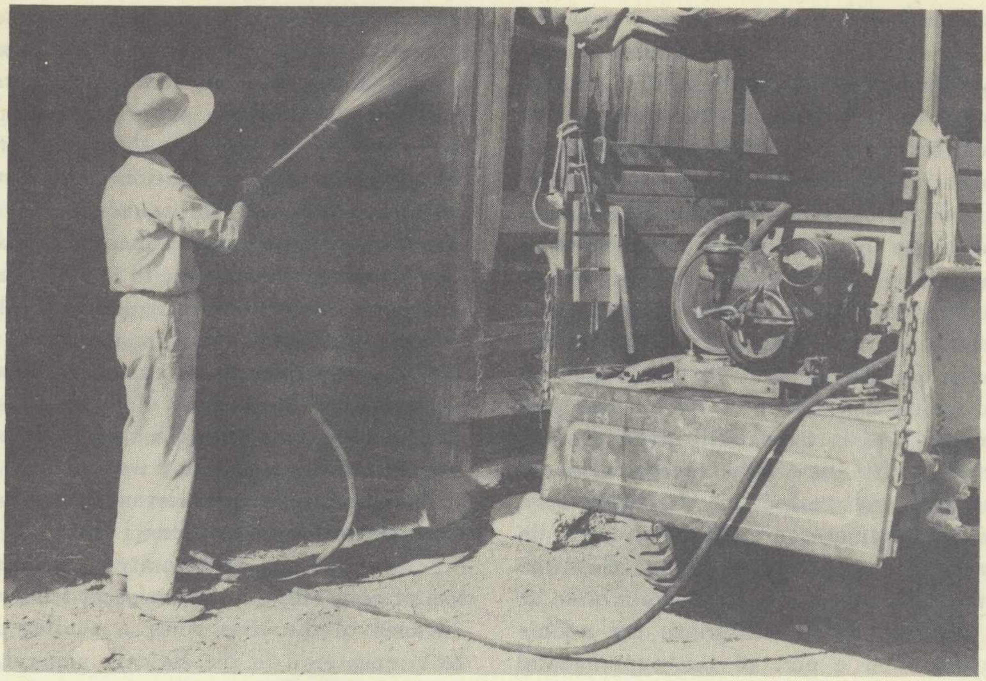
Space spray tests conducted at the city dump in 1949 indicated that the house flies in the Savannah area were resistant to DDT space sprays as well as residual sprays. Dosages of DDT space sprays which produced 80 to 95 percent kill of blow flies gave only 11 to 20 percent kill of house flies. When chlordan 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



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 participated 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 pre-treatment 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, 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.

limelight largely because of their importance in war time. The control of the typhus epidemic in Italy by the use of DDT was dramatic and captured the attention of people whose previous contact with insecticides was limited to "Quick, Henry, the Flit" advertisements. DDT was rapidly applied to other military uses and then, as soon as supplies permitted it, to world-wide efforts at malaria control. Examples of malaria control and even of eradication of anopheline mosquitoes by the use of DDT can now be found in areas covering essentially every continent of the world. The importance of this can hardly be overestimated. Areas which had become nearly uninhabitable due to the ravages of malaria have been restored to normal economic production. One of the most dramatic illustrations of this has been the experience on the antimalaria campaign in Sardinia, an island where the population had been reduced to about one-third the density of the mainland because of malaria, and which is now again being made an attractive spot for immigrants from Italy. Few would question the wisdom of awarding the Nobel Prize in Medicine to Paul Müller, the chemist who discovered the insecticidal effectiveness of DDT.

Early enthusiasm over the potentialities of DDT were, however, sometimes misguided. There were those who suggested that DDT would replace all other insecticides and that DDT would eradicate house flies from large areas – even entire States. Such optimism was short lived. Within 3 years of the general use of DDT, house flies in many areas began to develop a resistance to this insecticide. At first it was claimed that the newer production of DDT was of a poorer quality than that obtained originally. Others thought that perhaps the spray crews were careless in their applications. But eventually the fact had to be faced that the flies themselves had adapted to this new hazard in their environment. The recognition of the development of resistance to DDT by these flies emphasized the fact that new insecticides are ever-essential to our economy.

The insecticidal chemist had not been fooled and already there were other new insecticides on the market which were claimed to be superior to DDT. Rapidly the number of new insecticides and a variety of names for each new insecticide developed a maze of names which would confuse anyone. Each manufacturer claimed that his particular material or his particular formulation was far superior to any that preceded it. The fact that there are so many widely different uses for economic poisons meant that most manufacturers could substantiate their claims by proper selection of their test insects and of their methods of use.

When, however, all of the recently established economic poisons are analyzed and classified, it becomes apparent that we have even fewer classes of insecticides which are of major importance to communicable disease control today than was true before the advent of DDT. Previous to the second World War, the student of economic entomology had to familiarize himself with a large number of inorganic materials including such widely different elements as sulphur, copper, arsenic, thallium, mercury, lead, and fluorine. The organic insecticides included not only the relatively simple cyanides and the more complicated synthetic materials such as the thiocyanates, but also the often undetermined active ingredients of plant derivatives such as pyrethrum, derris, and nicotine. Although it is true that most, if not all, of these many different materials are still useful and still in actual use as economic poisons, nevertheless the newer economic poisons are so much more efficacious that for many purposes, including most public health applications, a large proportion of the older materials can be ignored. For practical purposes, therefore, in the control of most demonstrated or potential vectors and reservoirs of communicable diseases, attention can be centered on the chlorinated hydrocarbons (which include all of those newer insecticides which have demonstrated long residual effectiveness as contact poisons), a few synergists and synthetic insecticides which are used in connection with pyrethrum as space sprays, and a handful of rodenticides.

The amount of information which a sanitarian concerned with communicable disease control needs to know about these various materials is again not too voluminous. If he knows enough about their chemical relationship to be able to recognize and classify the information which is required by law to appear on the labels, if he has a few basic facts in regard to the operational uses and limitations of these various classes of materials, if he has an approximate idea of the hazards associated with their use, and if he knows where to look for more detailed information on any one which may be of major importance in his own experience, then he will be in a position to make proper use of the available insecticides. He must, of course, have some basic information on the different types of formulations in which the economic poisons may be used. Very often confusion is associated with the fact that there are available many different formulations of each material and that many commercial preparations involve two or more basic insecticides. Another paper in this issue is designed to provide some basic information on the types of formulations in use in public health activities. The following summary is designed to furnish some of the basic information on the active ingredients.

It must be realized that many economic poisons which are still in widespread use have been excluded from this list, not because they are no longer of any importance, but because the public health sanitarian is less likely to contact them or because, like the arsenicals, they are already well known.

## CHLORINATED HYDROCARBONS

The chlorinated hydrocarbons are a group of chemicals which, though not new, have become of major importance only since the advent of DDT. Paradichlorobenzene (PDB) and orthodichlorobenzene have long been used as insecticides and are still used for specialized purposes. Orthodichlorobenzene especially may be encountered by the sanitarian in connection with the control of fly breeding since it has been and still is successfully used as a fly larvicide. It is not, however, as effective as some of the newer chlorinated hydrocarbons. With the exception of orthodichlorobenzene and a few of the other chlorinated hydrocarbons which have high vapor pressures, this class of insecticides is noted particularly for its long-lasting residual deposits which kill insects by contact. They have been included in space sprays to some extent, and DDT particularly is of value in insuring the death of insects that are knocked down by other ingredients of space sprays.

They are the insecticides which are currently of greatest concern to the sanitarian.

### DDT AND ITS ANALOGS

It is well known that DDT was the first residual contact spray that obtained world-wide importance. Even before DDT was released, the chemists who had developed DDT had also tested many closely related compounds and, as might be expected, several of them have insecticidal activity. It is not necessary to be thoroughly familiar with all of these analogs. For instance, the fluorine analog has been shown to have considerable activity and is of considerable academic interest, but is not available commercially in this country. The analogs that are available commercially in this country are methoxychlor (which is, as the name implies, the methoxy analog) and a compound with one less chlorine atom on the ethane linkage, namely, DDD. These two and DDT are therefore the ones to be considered.

**DDT** — DDT is known commercially by a variety of names. When it was first produced in Switzerland by the Geigy Corporation, it was known under the generic name of dichlorodiphenyl trichloroethane. It was this name which provided the now general designation DDT. Since there are, however, a number of specific chemicals, all of which could be known by this general name, and since one of them is much more effective insecticidally than any of the others, the name is now limited in use to this active isomer which is chemically 2,2,bis-(*p*-chlorophenyl)-1,1,1-trichloroethane. It is sometimes referred to as the para,para isomer of DDT, or *p*,*p*'-DDT to distinguish it from the ortho, para, and other isomers. The material has been known under a variety of trade and common names. Many manufacturers have trademarked names by which they refer to DDT. The original manufacturer used the trademark names Gesarol and Neocid. Since these two names are trademark names applied primarily to finished formulations, the manufacturer referred to the basic chemical as GNB for Gesarol-Neocid Base. The first produced in the United States was referred to as GNB-A, indicating the American production of Gesarol-Neocid Base. All of these names will be found without further identification in some of the early literature on DDT.

DDT is a white crystalline solid that is soluble in most organic solvents and insoluble in water. It has been so widely used and publicized that it seems redundant to point out that it is effective against most adult household pests and other medically important arthropods, as well as many agricultural insects. It is effective against mosquito larvae, but is relatively ineffective against fly larvae. It is being used throughout the world for the control of many disease vectors.

It is available commercially in the technical grade as well as in a diversity of formulations — solutions, emulsifiable concentrates, dusts, wettable powders, aerosol preparations, and emulsion concentrates.

There have been a few cases of poisoning due to DDT reported in literature; however, it has been claimed that most, if not all, reported fatalities were caused by some other ingredient such as the solvent rather than by the DDT itself. The fact that it has been used on such a large scale throughout the world over a period of several years without apparent ill effects to users suggests that it is relatively safe, at least from the standpoint of acute toxicity. However, DDT is known to be toxic to fish, and has killed various species of mammals exposed to large doses. Reasonable precautions, therefore, should be taken to avoid breathing DDT dusts, mists, or powders, and to avoid direct skin contact. Contaminated skin should be washed with soap and water and excessively contaminated clothing should not be worn.

If DDT is to be used as a mosquito larvicide where fish and related organisms are important, the dosage should not exceed approximately 0.10 pound DDT per acre for a single application, or 0.05 pound DDT per acre where repeated applications are necessary. The Food and Drug Administration has ruled that DDT in milk is considered as a contaminant. DDT, therefore, should never be used on dairy animals, in dairy barns, nor on food products of man or animals.

With these restrictions, DDT can be used very effectively against most household pests, including mosquitoes, flies, bedbugs, and, if the application is sufficiently thorough, cockroaches. It has been used successfully for the control of rat fleas. Perhaps the most serious restriction on DDT is the fact that in many areas house flies have developed a greater or lesser resistance to DDT, and in some such areas, DDT will be found of little value in house fly control. There is some evidence that where house fly populations are kept within reasonable bounds by good sanitation, there is less danger of resistance developing. Where resistance has already developed, the only solution is to immediately promote sanitation to the point where chemical control becomes an auxiliary method rather than the primary instrument of control. Having done this, it may be possible to find a substitute material to which the flies are not resistant. Chlordan, lindane, methoxychlor, and dieldrin should be given consideration in this connection.

**DDD** — DDD is exactly what the name would imply in relationship to DDT. As the generic name for DDT is dichlorodiphenyl trichloroethane, the generic name for DDD is dichlorodiphenyl dichloroethane. Thus, it is exactly the same as DDT except that it has one less chlorine atom on the ethane linkage.

Another common name which has been suggested and is widely used for this compound is TDE. The reason TDE was suggested is because it was felt that "DDD" is so similar to "DDT" that it was hard to distinguish one name from the other. "TDE" is based upon another generic chemical name, namely, tetrachloro diphenylethane. The argument in favor of "DDD" rather than "TDE" is simply that the former name clearly shows the relationship to DDT. As was explained under DDT, neither of these generic names is sufficiently specific to satisfy the chemists, but again, the active isomer is the para,para isomer, and this is properly designated as 1,1-bis(p-chlorophenyl)-2,2-dichloroethane.

DDD has not had so many trade names as has DDT because it is not manufactured by such a great number of concerns, and is not as widely used. Probably the most common trade name is Rothane D-3.

Like DDT, DDD is a white crystalline solid that is soluble in most organic solvents and insoluble in water. It is effective against flies, mosquitoes, and other household pests, as well as a variety of agricultural insects, but in most cases it is less effective than DDT. It is somewhat less effective than DDT in its residual effect on most arthropods of public health significance. From the public health standpoint, DDD is most useful as a mosquito larvicide due to the fact that it is fully as effective as DDT, but less toxic to fish. Where fish are to be protected 0.05 pound DDD per acre should be sufficient. It has not proved of any value as a substitute for DDT against resistant flies.

It is commercially available as a technical grade material, as a dust, as a wettable powder, or as a solution. It may be formulated in essentially the same manner as DDT.

While it is somewhat less toxic than DDT, reasonable precautions should be taken to avoid unnecessary contact and breathing of DDD-laden air.

**Methoxychlor** — Methoxychlor is the common name given to the p,p'-dimethoxy analog of DDT, and is also known as the methoxy analog or dianisyl analog of DDT. Its proper chemical name is 2,2-bis(p-methoxyphenyl)-1,1,1-trichloroethane.

Methoxychlor also is a white crystalline solid, soluble in most common organic solvents and insoluble in water. Technical methoxychlor contains about 88 percent of the pure p,p'-isomer, and 12 percent of related materials.

Apparently due to some production complications, the technical material is most commonly sold as a 90 percent concentrate. This 90 percent concentrate has the appearance of a technical material even though it contains 10 percent oil. In general it can be formulated as though it were a technical material, making proper allowance for the oil present. It is also available as a 50 percent water-wettable powder which apparently does not contain the oil. For most uses the wettable powder is recommended by the manufacturer.

Methoxychlor is not as toxic as DDT or most of the other newer insecticides. However, reasonable care should be used in handling it, as in handling other insecticides, to avoid unnecessary breathing of dusts or sprays, or direct skin contact.

Though results obtained with methoxychlor as an insecticide have been somewhat erratic, it is one of the residual insecticides which is approved for use on dairy animals and in dairy barns for fly control. Because of the erratic results, it cannot be given blanket endorsement against DDT-resistant house flies, but in some areas it has given good results and therefore should be considered in any place where DDT is no longer giving satisfactory results in the control of house flies.

### BENZENE HEXACHLORIDE AND LINDANE

During the second World War, the British discovered that a well-known chemical now commonly known as benzene hexachloride had considerable insecticidal activity. The common name arises from the fact that one of the classical methods of producing the material is by chlorinating benzene. Since each of the six carbon atoms of the benzene take up one atom of chlorine, the end product became known as benzene hexachloride. Strictly speaking, it should be called 1,2,3,4,5,6-hexachlorocyclohexane, since each of the carbon atoms retains one hydrogen atom, and therefore the compound is no longer related to benzene.

There are actually 16 possible geometrical isomers of this compound. Five of these occur in technical benzene hexachloride. Of these, the gamma isomer is the most active insecticidally. Since the common technical compound contains a relatively small amount of the gamma isomer, the purified gamma isomer which is commercially available has been given the separate common name of lindane. Therefore, even though both materials contain the same active ingredient, it is desirable to discuss them separately.

**Benzene Hexachloride** – Benzene hexachloride is commonly abbreviated BHC, though it has also been referred to as HCH, as an abbreviation for the more proper chemical name, hexachlorocyclohexane. Since the molecular formula for benzene hexachloride is $C_6H_6Cl_6$, it was given the common name of "666" at the time of its introduction to this country. Since there is a proprietary chill and fever tonic known under the trade name of "666," this name has not found favor here for the insecticide. Again, in view of the fact that the gamma isomer is the active isomer, a British manufacturer coined the trade name Gammexane. The name "Gammexane" is not restricted to lindane, but is used in connection with the technical product. Apparently it refers only to the gamma isomer, regardless of whether the gamma isomer is found in association with other isomers as is true in technical BHC, or whether the isomer is in a pure state, as in lindane. In the use of this name, therefore, care should be taken that the actual amount of gamma isomer and the presence or absence of other isomers is specified. In general, with the technical material, it is considered preferable to use the common name, benzene hexachloride, and to specify the gamma isomer content. Technical grades of benzene hexachloride which are available commercially range from 12 percent to 36 percent of gamma isomer, so that it is obvious that the designation of the common name by itself is inadequate.

The technical material is a somewhat dirty-appearing crystalline solid which is soluble in varying degrees in a wide variety of common solvents, but practically insoluble in water. It possesses fumigant properties and has a strong, highly persistent musty odor which is disagreeable to many persons. The odor appears to be associated with some of the impurities rather than with the gamma isomer, and therefore the purer compounds such as lindane have somewhat less odor.

Benzene hexachloride is available commercially as technical material, wettable powders, dusts, solutions, and emulsifiable concentrates. Every type of preparation should be clearly labelled to indicate the percentage of gamma isomer that it contains.

The various isomers are not equally toxic to man nor are they eliminated from the body with equal ease. Therefore the danger of use varies with the composition of the technical material. In general, the use of benzene hexachloride requires somewhat greater precautions than DDT and its analogs. It should not be applied to dairy animals or to the food of man or animals.

The odor of benzene hexachloride is one of the greatest limitations to its use. It may impart an off-taste to certain foods. It has, therefore, only limited use in the control of household pests, though there are certain parts of the world where it is not found objectionable, and it has been rather widely used, particularly in Africa, as a residual spray for malaria control. It is quite effective as a mosquito larvicide. The technical grade containing 12 percent gamma isomer has been applied to small, landlocked ponds at the rate of 1 pound per acre, and as often as five times per season with no detectable injury to fish. Such an application was found to give satisfactory mosquito control for as long as 1 month per application, so that under many conditions, five applications per season should be as many as are required.

**Lindane** – The common name, lindane, is restricted to the essentially pure gamma isomer of benzene hexachloride. The name cannot be used if the material is less than 99 percent pure. The name may be used to indicate the composition of formulations prepared from lindane, but it cannot be used to refer to the gamma isomer content of formulations prepared from technical benzene hexachloride. The reason for this very strict definition is that various isomers of benzene hexachloride vary in their behavior within the mammalian body. From the standpoint of acute toxicity, the gamma isomer is the most toxic of the various isomers of benzene hexachloride, but it is excreted relatively rapidly, and therefore shows the lowest chronic toxicity. This distinction is obviously of considerable importance from the standpoint of the health hazard associsted with the use of these materials, and therefore, for the safeguarding of anyone who may be exposed to them, it is important that the distinction in names be rigidly adhered to.

Chemically, as explained above, it is known as gamma-1,2,3,4,5,6-hexachlorocyclohexane. Like BHC, it is a crystalline solid which is soluble in most organic solvents, but insoluble in water. It has a slightly musty odor but less so than benzene hexachloride, is more volatile than DDT, and possesses some fumigant properties.

Because of its acute toxicity, care should be taken to avoid breathing fumes, dusts, or sprays, and to avoid skin contact with lindane in any form. Contaminated skin areas should be washed promptly with soap and water, and contaminated clothing should not be worn. Lindane should not be applied directly to dairy animals, to animal foods and water, or to equipment used in feeding and watering animals.

On the other hand, because of its low chronic toxicity, lindane has been approved for use in dairy barns for the control of flies. The recommended dosage is 25 milligrams per square foot, or a relatively small fraction of the recommended dosage of DDT. It should be quite clear that though lindane is satisfactory for use in dairy barns, technical benzene hexachloride is not. Like methoxychlor, lindane has given somewhat erratic results in the control of flies which are resistant to DDT. However, it should be considered as a possible insecticide for fly control in places where DDT is no longer satisfactory.

### CHLORDAN AND ITS ANALOGS

As indicated heretofore, soon after DDT made its debut as a residual insecticide, the world was swamped with a number of other materials which were supposed to be even more effective than DDT. Benzene hexachloride was a contribution from Europe. In this country, one of the first and still one of the most effective substitutes for DDT was chlordan. The same chemists who developed chlordan continued investigations of related compounds and have since released a series with slightly different characteristics, but all highly effective insecticides.

**Chlordan** – Chlordan is perhaps more widely known in this country under the common name of "chlordane." The latter spelling has been accepted by the Interdepartmental Committee for Pest Control, by the American Association of Economic Entomologists and by various other organizations. The editor of Chemical Abstracts, however, maintains that the use of the "e" on the end of the name is misleading as regards the chemical structure of the compound, and that therefore the spelling without the "e" is preferable. The argument revolves around the question of whether or not a common name of this type should be in keeping with accepted chemical nomenclature. It is true that it is not designed as a chemical name. However, as a common name, it is used to refer to the chemical itself rather than to the insecticide, as is evidenced by the fact that it is frequently used in connection with the designation of a particular isomer. Thus it is not uncommon to speak of alpha-chlordan. On the other hand, there seems to be little danger of confusion, regardless of which name is chosen. Even though "chlordane" is more commonly used in this country, "chlordan" is still the preference of Chemical Abstracts and is used by such other world-wide abstracting journals as "The Review of Applied Entomology," and since there seems to be no logical objection to it, it has been chosen for use in this article.

When the material was still in the experimental stage, it was referred to as "1068," for much the same reason that benzene hexachloride got the common name "666," — namely, the molecular formula, which is $C_{10}H_6Cl_8$. This common name is still used in connection with the trade name "Velsicol 1068." It has also been referred to in the past under the trademarked name "Octa-Klor." As is true with the other insecticides, formulations containing this material may be known under a wide variety of trade names, but under present registration laws the lable must indicate the active ingredient as chlordan. The proper chemical name for the material is 1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane.

Chlodan is a dark, viscous, oily liquid which is soluble in most organic solvents and is insoluble in water. Though it does not consist entirely of the material indicated by the chemical name, the related compounds present to the extent of 25 to 40 percent in the technical material are also toxic to certain insects and therefore all of the ingredients are considered insecticidally active. In view of the variation in activity of various isomers and impurities it is not possible to insure uniform insecticidal activity by chemical requirements. Therefore, in purchasing chlordan from the manufacturer, the purchaser should be assured that the material has been tested biologically and that it measures up to a reasonable standard in bio-assay.

Chlordan is commercially available as wettable powders, emulsifiable or solubilized concentrates, oil solutions, low percentage dusts, and technical chlordan. Technical chlordan is available in two grades — refined and agricultural. Both grades appear essentially equal in their insecticidal properties. The agricultural grade may be used where-ever the staining of treated surfaces is not a problem. The refined grade is generally used around premises for the control of household insect pests.

Upon standing for long periods of time, chlordan tends to solidify to a somewhat gummy mass, which nevertheless will readily dissolve in organic solvents. Of more importance is the fact that it is rather readily decomposed with the liberation of hydrocloric acid, which, in turn, may attack metal containers and encourage further deterioration of finished formulations. It is therefore unwise to store chlordan or formulations containing it in containers other than glass, aluminum, aluminum-clad steel, or high-bake phenolic lacquer-lined metal. In general, chlordan concentrates should be used while as fresh as possible, and the sprayers in which such emulsions are used should be washed thoroughly at the end of each day's work.

Chlordan is more toxic to man and animals than DDT, and considerable care should be exercised in using it to avoid breathing chlordan fumes, dusts, powders, or mists, and to avoid skin contact in any form. Waterproof xylene-resistant gloves should be worn by operators of mixing stations. Skin areas contaminated with chlordan sprays, concentrates, or the technical material should be washed immediately with soap and water, and contaminated clothing should not be worn. Though a great deal of chlordan has been used with no apparent ill effects to users, there have been several cases reported where animals have been injured or killed when held in cages treated with chlordan, and there has been at least one human death in which chlordan apparently was a contributing factor.

Chlordan and its related compounds are even more dangerous than some of the other chlorinated hydrocarbons in that most experimental animals which have shown any symptoms of poisoning from these materials have died even though removed from further exposure. Warning symptoms of chlordan poisoning therefore are not reliable. Since it is known that young animals are more susceptible to poisoning by chlordan than adults, it has been recommended that the interior walls and ceilings of homes should not be sprayed with chlordan in such a way that the occupants, including infants, might be exposed for 24 hours a day to the fumes of this relatively volatile material. When proper precautions are taken, chlordan is very effective against a variety of insects and is particularly useful against DDT-resistant flies. It has been widely used around baseboards and other selected portions of kitchens, porches, and other parts of homes for the control of roaches and ants. Since it is somewhat more effective than DDT, a lower concentration is satisfactory.

**Heptachlor** — Heptachlor is the name given to an insecticide which is closely related to chlordan. Chemically, it is known as 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene. The origin of the common name is apparent from the chemical name, when it is compared with the chemical name of chlordan, a material which was isolated and found to be insecticidally active previous to heptachlor.

Heptachlor is a white crystalline solid which is readily soluble in a wide variety of organic solvents, but insoluble in water. It is more volatile than DDT and some of the other chlorinated hydrocarbons, and therefore not as long lasting in its residual effectiveness.

Heptachlor is not yet commercially available and appears to be somewhat more toxic than DDT, although less work has been done on its toxicity. Since it seems to have little advantage over the other chlorinated hydrocarbons as regards control of insects of public health significance, it is not anticipated that it will be commonly encountered in public health work.

**Aldrin** – Aldrin, which was known originally as Compound 118, is another chlorinated hydrocarbon rather closely related to chlordan. It has been given the trade name "Octalene," and it is chemically known as 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene.

It is a white crystalline solid which, like the other chlorinated hydrocarbons, is soluble in most organic solvents and is insoluble in water. It is even more volatile than chlordan and therefore possesses considerable fumigant properties.

It is available in essentially the same types of formulations as the other chlorinated hydrocarbons, and because of its toxicity must be handled with extreme caution. Considerably more must be learned about its toxicity if it is to be generally used. So far, its use has been restricted to a few agricultural crops. In view of its volatility, which cuts down the length of its residual effect and adds to the hazard of its use, it is not anticipated that it will find wide use in control of insects of public health importance.

**Dieldrin** – Dieldrin is a chlorinated hydrocarbon which is very closely related to aldrin, differing from it only in the presence of an additional oxygen atom. Experimentally it was known as Compound 497, and the manufacturer gave it the trade name "Octalox" at the same time that aldrin was known as "Octalene." The origin of the common names aldrin and dieldrin lies in the fact that both compounds are manufactured by a process developed by the chemists, Diels and Alder. This origin of the name provides a clue to the pronunciation of it, which should be with two syllables instead of three.

The chemical name is 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethanonaphthalene.

Dieldrin, which like many of the other chlorinated hydrocarbons is a crystalline solid soluble in some organic solvents but insoluble in water, is one of the most interesting of the newer chlorinated hydrocarbons. It is only very slightly volatile, but because of its very high toxicity to insects, it does have some fumigant properties in tightly enclosed areas. It is perhaps even more stable than DDT and therefore is effective as a residual for prolonged periods.

Up to the present, its sale has been restricted to experimental uses, but for such purposes it has been available in the usual forms. It is very much more toxic to man and animals than is DDT. Users should exercise extreme care in handling it, since it is readily absorbed through the skin, even in the dry state.

Because of its very great effectiveness it can be used in much lower concentrations than DDT, and therefore it is quite possible that it may become useful in control of various insects of public health significance. For the present, however, in view of its high toxicity, even if it is licensed for sale, its use should be closely supervised until such a time as the necessary precautions can be more firmly established.

Unfortunately, house flies which are resistant to DDT have in certain cases been able to develop a resistance to dieldrin very rapidly. Therefore it is too early to predict how satisfactory it may prove to be for the control of DDT-resistant house flies.

**TOXAPHENE**

Even before the end of World War II, several new insecticides were suggested as supplements to DDT. One of these was given the experimental name of Compound 3956. It is now known under the accepted common name of toxaphene. It is a mixture of compounds containing principally polychlorinated bicyclic terpenes of the camphene type, and therefore has also been known as chlorinated camphene.

Toxaphene is an amber, waxy solid having a mild odor suggestive of chlorine and camphor. It is readily soluble in most organic solvents but is insoluble in water.

It is available in the usual forms, including technical grade. It is somewhat more toxic to mammals than is DDT, and though it is effective against most household pests, it is inferior to DDT for the control of most of these insects. For this reason it has had little place in medical entomology. Toxaphene is quite effective against fly and mosquito larvae. It has been so toxic to fish that it has been suggested as a substitute for other fish poisons for use in studying fish populations; therefore it should never be used in water where wildlife must be conserved. Its greatest use has been in the control of agricultural insects.

### POLYPHOSPHATES

The polyphosphates are a group of insecticides which are closely related to various war gases. Most of them were developed in Germany during World War II as insecticides. Their relationship to war gases is the most critical thing for the sanitarian to know, since it indicates their extreme toxicity. None of them are currently considered useful in the control of household insects, because of their high toxicity and the fact that they rapidly decompose and therefore have no residual effectiveness. Experimentally, some of them have been tested as mosquito larvicides but have never been so recommended. In view of the extreme hazard connected with their use, it is not considered necessary to discuss each of them separately; but the most common ones are listed below, together with their synonyms and common names. Most commercial formulations which are using polyphosphates as their active ingredient will contain a mixture of two or more of those listed, or related compounds.

**Parathion** – The polyphosphate most commonly used in agriculture in this country at present has been known under the experimental designations E-605 and Compound 3422. It has been given the common name, "parathion," and has been referred to under a variety of trade names, including "Thiophos" and "Niran."

Chemically it is designated as o,o-diethyl-o-p-nitrophenyl thiophosphate.

**Tetraethyl Pyrophosphate** – Tetraethyl pyrophosphate is often abbreviated as TEPP, and the chemical name is the same as the common name.

**Hexaethyl Tetraphosphate** – Hexaethyl tetraphosphate has been abbreviated HETP, and has been known under the trade name "Bladan." Again, its chemical name is the same as its common name.

### PYRETHRUM AND ITS SYNERGISTS

This group of insecticides is of importance primarily in space sprays, including aerosols. They are in general very effective in knocking down insects, though sometimes somewhat less effective in producing final kill. In other words, it is not uncommon for insects to recover from the effects of some of the members of this group of insecticides. The compounds, particularly those found in pyrethrum, are somewhat unstable, being readily decomposed even by light and air. For this reason, they ordinarily have very little residual action.

Pyrethrum is of course a plant extract, though there have been synthesized some organic chemicals which are very similar to the active ingredients of pyrethrum. Several synthetic materials have been useful as synergists with pyrethrum, and they therefore are also considered under this general heading.

**Pyrethrum** – Pyrethrum is probably the oldest of the insecticides which are included in this discussion. The flower of *Chrysanthemum cinerariaefolium* is the source of this powerful insecticide which has been known, particularly early in this century, as insect powder, or as Kenya flowers, or Trieste flowers. The extract of the flower heads was used in fly sprays for many years before the chemists had determined the chemical nature of the active ingredients. Four of the most active ingredients have now been isolated and are known as Pyrethrins I and II and Cinerins I and II. The separate ingredients are never used in a pure state, but the strength of a pyrethrum solution is usually expressed in terms of the concentration of pyrethrins and the concentration of other active extractives. It is interesting that pyrethrum can be used to control flies which are resistant to all of the chlorinated hydrocarbons. However, pyrethrum not only is expensive, but because of its lack of residual action must be applied so frequently that under ordinary circumstances it is not considered practical for use on an operational program.

Of all of the insecticides currently in use, pyrethrum is perhaps the least toxic to mammals. It is often used in combination with other insecticides for space sprays or aerosols directed at a variety of livestock pests, as well as insects occurring in the household.

**Allethrin** – There recently has been placed on the market a synthetic material which has been widely publicized as a synthetic pyrethrum. Actually this is a misnomer, for chemically the material is more closely related to cinerin than it is to pyrethrin, and, more properly known as the allyl analog of cinerin. The development of this material is very important because of the fact that pyrethrum continues to be an insecticide of major importance in the control of a variety of insects and yet it is an insecticide which is very susceptible to war shortages, since it has never been produced economically in this country. It was actually the wartime shortage of pyrethrum in this country that stimulated a search which uncovered the merits of DDT. The possibility of synthetically manufacturing an insecticide with characteristics similar to pyrethrum therefore is of considerable importance to national security.

The currently available allyl analog of cinerin has not proven as generally useful as natural pyrethrum, but its development is certainly a very important step in the right direction.

**Synthetic Synergists** – In view of the above described critical shortages or anticipated shortages of pyrethrum, a great deal of effort has been devoted to searching for methods of extending the usefulness of short supplies of pyrethrum. Sesame oil was first found to serve as a synergist for pyrethrum. That is to say that by the addition of a small amount of sesame oil, which in itself is essentially valueless as an insecticide, a small dosage of pyrethrum may be made as effective as a large dose of pyrethrum would be by itself. In trying to improve aerosol formulations, it was found that the addition of simple lubricating oil served in much the same manner. The search was continued, and there are now several synthetic chemicals which have been proven to be quite effective as synergists for pyrethrum. It should not be necessary to describe these synergists in detail, but the current list includes the piperonal derivatives, piperonyl butoxide and piperonyl cyclonene. Piperonyl cyclonene has also been known under the name piperonyl cyclohexenone. Both of these piperonal derivatives have been claimed as stabilizing agents for pyrethrum and thus permit some residual action. However, this has not been particularly successful and they must still be considered primarily as extenders for pyrethrum when used as a space spray. N-isome and Synergist 264, formerly known as VanDyk 264, are other synergists which also have been shown to have considerable value when used with pyrethrum in space sprays. The use of these and other synergists with so-called synthetic pyrethrum is under investigation at present.

## THIOCYANATES

A number of years before the beginning of World War II, the group of insecticides known as thiocyanates was developed for use in combination with pyrethrum in space sprays in order to insure that insects knocked down by the pyrethrum would be killed and not recover. The thiocyanates, of which there are a number, have been sold under the trade names of "Lethane" and "Thanite." They have been useful in a variety of other applications and are not dependent upon the presence of pyrethrum, and therefore they cannot be considered as synergists. However, their usefulness as regards the control of insects of public health importance is largely restricted to space sprays. Since they are appreciably more toxic than pyrethrum, and presumably more toxic than the above-named synergists, they must be used with caution and their concentration in a space spray should not exceed recommended dosages.

## RODENTICIDES

There has been a large number of new rodenticides introduced in this country since the beginning of World War II. Most of these have been found to be of little value. Several of the older rodenticides such as sodium arsenite and red squill are still in use but are not included because they are well known to anyone who has been working with rodenticides.

Of the newer ones, ANTU, 1080, and warfarin are the only ones which need be considered.

**ANTU** – Alpha naphthyl thiourea is commonly abbreviated to form the common name, ANTU, for this rodenticide which found considerable use during World War II. Because of the physical nature of ANTU, it was possible to use it as a dust and rats could be killed simply by tracking through the dust and subsequantly cleaning their paws with their mouths. ANTU has proven reasonably effective against adult Norway rats, but much less effective against immature Norway and roof rats. Since the roof rat predominates in many areas, this selective action has greatly limited its usefulness. Even against Norway rats it was not 100 percent effective, though it was somewhat of an improvement over the old rodenticides. It has now been largely supplanted by better materials.

**Sodium Fluoroacetate** – Sodium fluoroacetate is commonly known as "1080," a name which has no significance except that it was an arbitrary number assigned to an experimental chemical. It is one of the most toxic rodenticides that has been used, being comparable in toxicity to sodium cyanide. It is a white crystalline material slightly resembling flour or sugar. It is odorless and very soluble in water. When exposed to the air it absorbs water, becoming quite gummy. It is extremely fast acting, producing symptoms in rats within 30 minutes and resulting in death in 1 to 8 hours. Because of its high toxicity to man and domestic animals, its use has been restricted to trained personnel, and even under these restrictions, some accidents have occurred. It should never be allowed to fall into the hands of untrained individuals and should always be handled with utmost respect.

**Warfarin** – Warfarin is the common name which was given to the experimental rodenticide known as Compound 42 to honor the Wisconsin Alumni Research Foundation which owns the patent on this material. It has recently been licensed for general sale as a rodenticide. It is one of the most interesting of the newer economic poisons since it successfully employs a new principle as a rodenticide. It is primarily an anticoagulant, and in single doses, even massive doses, produces no noticeable harm to the animal. However, repeated doses, even though they be extremely small, eventually produce spontaneous hemorrhage which results in death.

It is sold under the trade names of "Dethmor" and "Rax Powder," and the accepted chemical name is 3-(α-acetonylbenzyl)-4-hydroxycoumarin, though it has also been known chemically as 3-(α-phenyl-β-acetylethyl)-4-hydroxycoumarin.

Warfarin is a stable, colorless, crystalline solid at ordinary temperatures and pressures. It is odorless and tasteless not only to man, but also to rats which accept baits containing the compound as readily as they do the same bait containing no poison. It is available in the form of a 0.5 percent powder. The diluent is corn starch, making it suitable for mixing with such additional baits as corn meal, bread crumbs, and meat.

It has been tested in solution, but ordinarily is not recommended for use in this form since one of its attractive features is the fact that it can be left in permanent bait stations with only infrequent checking. Dry baits are obviously desirable from this standpoint.

Warfarin is toxic to other mammals and to birds the same as it is to rats. The key to its safety is the fact that single large quantities are not likely to be fatal. If the bait is properly selected so that it will be attractive to as few animals other than rats as possible, and if it is placed in protected situations where it is not readily available to other animals to which it may be attractive, it can be rendered very safe. The greatest danger when the material is properly used is that cats – and presumably dogs – might be killed if, over a period of several days, they ate a number of rats sick or dead from ingesting the poisoned bait. It is suggested that under some circumstances the use of a suitable warning coloring agent may be advantageous.

# INSECTICIDAL FORMULATIONS

DR. GEORGE W. PEARCE, Chemist,

MARY B. GOETTE, Sr. Asst. San. (R), JANET T. SPILLANE, Jr. Asst. San. (R)*

During the last decade a singularly large increase in the number of chemicals useful in controlling insect and other pests of plants, animals, and man has occurred. Practically all of these new pesticidal chemicals are organic in nature and generally have proved superior to the older inorganic poisons such as lead arsenate, calcium arsenate, and paris green. The initial inspiration for this large increase in the number of new insecticides was the discovery of the insecticidal properties of DDT, one of the most useful of the new materials. This compound was prepared originally about 75 years ago, but it was only during the second World War that the remarkable insecticidal

*Technical Development Services, Savannah, Ga.

properties of DDT became known. Since DDT can be considered chemically as a chlorinated hydrocarbon it was only natural that other compounds falling in this general class were made and tested for their insecticidal properties. As a result we now have eight or nine chlorinated organic compounds having rather excellent pesticidal properties.

In addition to the chlorinated organic compounds, several organic phosphorus compounds have been developed, parathion being one of the outstanding materials in this group. These materials have been found very useful in the agricultural field, but have little application to public health problems because of their extreme toxicity to man and animals, and because they have practically no residual insecticidal effects. The residual insecticidal effectiveness of DDT and its relatively low toxicity to man are two of the qualities which have made it most useful in fly and mosquito control.

There are a number of other materials in the process of being tested as pesticides. Altogether, there are roughly 20 essentially new materials available for controlling insect, disease, rodent, weed, and other pests of agricultural crops, domestic animals, and man. This number of materials seems small, but from the standpoint of formulations it represents a very large number. For example, DDT is now available on the open market in the form of 79 different formulations. Chlordan can also be obtained in 79 formulations. It has been estimated that there are about 5,000 different formulations of pesticides marketed at present in this country. A large portion of these preparations include the newer materials mentioned above. One can understand then why each new material discovered can easily lead to preparation of 25 to 100 different formulations. It not only complicates the formulator's job, it also makes the intelligent use of the various formulas which are developed very difficult, and it behooves the user to be familiar with the function and proper use of the preparation he is employing.

Fortunately for public health workers we can limit ourselves largely to formulations suitable for application in and around living quarters. The many and varied agricultural preparations are not suitable for this purpose. Moreover, the number of insecticides meeting the requirements with respect to health hazard is very limited. Formulations containing DDT, chlordan, or BHC are of greatest importance in this field currently. In general, these or other insecticides are seldom applied to infested areas in the form of the pure or technically pure state because there is no equipment which can apply uniformly such materials in the small amounts required. As in the case of medicinals, vitamins, and other biologically active materials we must resort to dilution of the active principles as a practical means of controlling dosage levels. In effect, formulation consists of diluting the insecticide in such a way that it can be handled conveniently and economically and that it can be applied in accurate dosages and with maximum safety to the operator or user.

Various inert or nontoxic materials can be used as diluents. In the case of DDT preparations designed as residual treatments of living quarters, the DDT may be diluted by dissolving in nonstaining solvents such as highly refined kerosenes. Normally these solutions contain 5 percent DDT and are applied "as is", without any further dilution. The solvent evaporates from the treated surface, leaving a well distributed deposit of DDT. Such formulations have the advantage that they leave less noticeable residues on surfaces than other types of preparations. Thus, where less visible residues are preferred the use of oil solutions of DDT are useful. However, these are usually the most expensive formulations and involve greater hazards in their use than other types.

The "emulsifiable concentrate" formulation is probably the most widely used in CDC operations. In this case a solution of the insecticide is prepared using a solvent having a high affinity for it. For chlorinated organics such as DDT, xylene and methylated naphthalenes are frequently used. Highly refined kerosenes cannot be used because they will not dissolve sufficient DDT. Certain aromatic petroleum fractions can be used, but, in general, they are likely to have color and odor which are objectionable when treating living quarters. The emulsifiable concentrate is usually prepared in 25 percent strength, although some preparations contain as much as 35 percent DDT. The required amount of DDT is dissolved in a portion of the solvent (special grade xylene for CDC operations; the Navy prefers the methylated naphthalenes because of the lower fire hazard) along with a suitable oil-soluble emulsifier. This solution is then diluted with solvent to the desired strength, e.g. 25 percent DDT. With moderate agitation this concentrate can be diluted with water to any given strength forming a fairly stable milk-white emulsion, and is then ready for application. Thus, a 5 percent DDT emulsion would be formed by agitation of 1 part of the concentrate with 4 parts of water. In this case one has diluted the active insecticide by two devices. First, it is diluted partially by dissolving it in a solvent. The solution formed is then further diluted by addition of water. This second dilution results in the formation of minute evenly distributed particles or droplets of the xylene solution of DDT in the water. As long as these droplets do not coalesce or cream out (i.e., as long as the emulsion does not break) an effective and inexpensive dilution of the DDT is produced. Care must be exercised at all times to be sure the emulsion prepared has not broken. Otherwise, either plain water or a 25 percent solution of DDT in xylene would be applied. Vigorous reagitation is necessary if the emulsion has been allowed to stand for one-half hour or more. Extremely hard waters and those containing appreciable amounts of salt, such as sea water, affect the stability of these emulsions greatly. If difficulty is experienced a check on the water is indicated. In short, the effectiveness of the "emulsifiable concentrate" as a method of formulating DDT into a diluted DDT spray for application is dependent on how well dispersal of the water-diluted mixture can be maintained. The "emulsifiable concentrate" type of formulation may be used for preparing concentrates of all the chlorinated organics, such as chlordan and BHC. The most desirable percentage of active constituent is variable, however, as is the amount and type of emulsifier needed.

Another type of formulation which has found some use is the so-called "solubilized concentrate." This type is used primarily for formulations of chlordan. Solubilized concentrates are concentrates which can be mixed with water to give a more or less clear mixture. No milky appearance develops as in the case of the "emulsifiable concentrate" although a slight opalescence or murkiness may be seen. Actually, the water-diluted mixture produced is an emulsion the same as is that produced with the emulsifiable concentrates. However, the "solubilized concentrates" form, as a rule, much more stable emulsions which do not break readily even after extended periods of time. The dilution principle is the same as in the case of the emulsifiable concentrates; that is, a partially diluted insecticide solution is further diluted to the desired application strength by using what may be our cheapest carrier or diluent—water. Although there are other reasons for using the emulsifiable concentrates and solubilized concentrates, the most important factor is that with them water may be used as the major diluent. All of our chlorinated organic insecticides are highly insoluble in water, and it is extremely difficult to make a finely dispersed concentrated suspension of them in water which could then be diluted with more water at the place of use. (It should be clear that shipment of preparations diluted and ready for application are generally too costly because of the large proportion of diluent present.) A practical alternative is a preparation using a relatively concentrated solution in a solvent which can be dispersed in water with the aid of an emulsifier.

Two other types of spray formulations which may be encountered occasionally by the field operator may be described as the stock or paste emulsion and the so-called "colloidal suspension" concentrates. The stock emulsion consists of a fairly concentrated solution of insecticide which has been emulsified with a small portion of water. This concentrated emulsion is diluted with water to the required strength at the time of application. The stock emulsions usually are thick mayonnaise-type products which do not flow or pour easily and thus are somewhat difficult to measure out accurately by the user. The paste emulsion is similar except that it is even less flowable and must be dipped out of the original container. The thick paste characteristic is obtained by addition of small quantities of certain thickening materials. Both the stock and paste emulsions are commonly prepared at a strength of 50 percent toxicant. The "colloidal suspension" concentrates contain about 40 percent toxicant, 20 percent mixed solvents, 6 percent emulsifier, and 34 percent water. Since only a small quantity of oil is used in the concentrate, the active ingredient is present as very finely divided dispersed particles. The material is like a heavy cream which pours easily, and may be diluted with water to the desired concentration. The settling rate of the diluted material is slow compared to that of water-wettable powders. Surfaces sprayed with this type suspension have little noticeable residue. "Colloidal DDT" is not readily available at the present time but several manufacturers are experimenting with it.

Another method of formulating insecticides into the diluted products needed for practical application is to mix them intimately with inert solids. Such mixtures may be designed for dusting infested areas or for suspension in water to be applied as sprays. The dusting formulations are generally not suitable for wall and ceiling treatments. However, they find wide application in the treatment of agricultural crops and in dusting rat runs and harborages for flea control. They may be used in other ways also for ectoparasite control. Such dusts are marketed commonly in concentrations of 1 to 10 percent toxicant, 5 and 10 percent dusts being the most prevalent concentrations employed. The diluent must have satisfactory characteristics as regards bulking, particle size, and flowableness, and must not be alkaline if the toxicant is subject to decomposition by alkalies, as is DDT.

The so-called water-wettable powders are compounded so that they may be readily suspended in water and then sprayed in the same manner as an emulsion prepared from the types of concentrates discussed above. They are particularly useful for treatment of living quarters constructed of mud or adobe. It has been observed that the DDT concentrates utilizing the emulsification principle or those preparations using solvents as diluents are less effective than the wettable powders when applied to structures of mud or adobe. Evidently, the DDT tends to be carried into the pores of such materials and thus is not readily contacted by insects alighting on them. On the other hand, treatment of outdoor surfaces with the wettable powders is not as effective as the emulsion type of preparation. The wettable powders do not resist weathering very well, being easily removed by winds and rain.

DDT water-wettable powders are most commonly prepared at 50 percent strength. That is, they contain 50 percent DDT by weight. Seventy-five percent and even 90 percent powders are sometimes encountered particularly for export purposes. The recommendations for use are somewhat different than in the case of emulsions, being based, in this country, on pounds per gallon of water.

For indoor treatments the usual rate of application of 50 percent wettable DDT powders is about one-half pound per gallon of water if a deposit of 200 milligrams of toxicant per square foot of surface is desired. This is 25 times more concentrated than the strength commonly used in agricultural spraying. Power equipment which ordinarily is used in treating crops can handle a coarser powder, especially at the lower concentration required. However, the hand type of equipment generally used for indoor work will not handle these coarser agricultural powders at the concentrations needed. Consequently, especially finely ground wettable powders have been developed for this purpose.

On the whole, wettable powders represent the cheapest type of formulation but are objectionable for indoor work because of the clearly visible deposit. The oil solutions and emulsion types of preparations are much to be preferred from this standpoint.

The formulations discussed above are those used primarily to treat surfaces with insecticides which will remain over extended periods of time and thus have a residual action by destroying pests which contact the treated surface. These are broadly referred to as residual sprays or treatments. Another method of insect control which is particularly useful in indoor operations is the use of what is commonly referred to as space sprays.

The prime objective in the case of space treatments is to disperse the active toxicant into very fine particles or droplets in the air. The particles are so fine that they stay suspended in the air for marked periods of time and any insects in the air space are thereby contacted with the insecticide. Essentially air is being used as the final diluent of the active insecticidal substances. Two principal methods are used to accomplish this, both requiring special formulations.

Typical of one type of space spray is the well-known household preparation in which DDT and/or pyrethrum is dissolved in an oil base, usually water-white, odorless, and volatile petroleum fractions. In this case the solution is atomized with hand sprayers of various types. The fine droplets of solution are dispersed into the air and, in a very short period of time, the solvent evaporates, leaving much smaller particles of the insecticide suspended in the air. These fine particles remain suspended in the air for substantial lengths of time and are very effective in clearing the atmosphere of various insects.

A second type of space spray is the aerosol. An aerosol is an extremely finely divided material suspended in air. The essential difference between the aerosol and the suspension produced by atomization of solvents containing insecticides is in particle size, the aerosol producing much finer particles largely within the realm of colloidal dimensions. Special equipment and formulations are required for producing aerosols. The term "aerosol" is often loosely used in referring to such formulations, but strictly speaking this term should be applied only to the air suspension of the toxicant. Thus, the aerosol bomb commonly marketed does not contain an aerosol but only the formulation which will produce an aerosol spontaneously when the bomb valve is opened.

A brief description of the physical principles involved in producing aerosols may be in order. The toxicant is dissolved in a small amount of nonvolatile oil. The solution thus formed is dissolved in a liquified gas in a container which will stand the high pressure of the liquified gas. Freon gas, which is used in many of our household electric refrigerators, is the principal gas used in aerosol bombs. This gas is nontoxic, noncorrosive, and noninflammable, so it is ideally suited for aerosol bomb formulations. When the bomb valve is opened the liquified Freon is forced out the valve orifice at high velocity because of the internal pressure in the bomb. In passing out of the orifice the mixture is divided into very minute droplets or particles and the Freon volatilizes as a gas leaving the fine droplets of the concentrated oil solution of the toxicant suspended in the air. The best proportion of Freon to oil concentrate for aerosol bomb formulations is 85 parts Freon to 15 parts oil concentrate. Pyrethrum and DDT are the toxicants most commonly employed although most of our new organics can be used in aerosols. Various synergists and other accessory materials are often added to improve the physical characteristics or to increase the effectiveness of the toxicants. There are other methods of preparing aerososl, but in most cases the principle of forcing a rapidly volatilizing carrier under pressure through an orifice is utilized.

**DESCRIPTION OF**
**FORMULATIONS OF INTEREST TO SANITARIANS**

| Formulation Name | Concentration of Toxicant in Original Product (DDT, chlordan, or BHC) | Appearance of Original Product | Dilution* for Spraying (Volume parts) | Appearance of Diluted Spray Mixture |
|---|---|---|---|---|
| Oil solutions | 5% | Clear, colorless | None | Original product |
| Emulsifiable Concentrates | 25% | Clear, straw to amber color | 1 part conc. 4 parts water for 5% spray | Milky white emulsion |
| Solubilized Concentrates | 50% (chlordan only) | Dark-brown, molasses-like | 1 part conc. 12 parts water for 5% spray | Clear, slightly colored |
| Stock or Paste Emulsions | 50% | White to cream colored mayonnaise-like | 1 part conc. 9 parts water for 5% | Milky white emulsions |
| Colloidal Suspensions | 40% (DDT only) | White cream | 1 part susp. 7 parts water for 5% | Milky white suspension |
| Wettable Powders | 50% | White powder | ½ lb./gal. water | Milky white suspension |

**Dilutions used for spraying of living quarters at 200 milligrams per square foot.*

# THE EQUIPMENT DEVELOPMENT SECTION OF THE TECHNICAL DEVELOPMENT SERVICES

LAWRENCE B. HALL, Senior Sanitary Engineer*

The Equipment Development Section is concerned with the engineering functions of the Technical Development Services. To carry out these functions the Section is staffed with engineers, an aircraft pilot, machinists, sheet metal workers, mechanics, an electrician, a plumber, and laborers. It is well equipped with offices, drafting rooms, and laboratories; and machine, sheet metal, automotive, electrical, and plumbing shops. The efforts of the Section fall into three general groups as described below.

**EQUIPMENT FOR FIELD USE**

One of the primary functions of the Section is to design, fabricate, and test equipment needed for field operations in the control of communicable diseases. This function, in fact, is the historical basis for the existence of the Section since the first major job was that of developing the specialized equipment needed for the residual spraying of DDT when that insecticide first came upon the scene in the last years of World War II. The details of the application of DDT to the walls of homes are now so familiar that it is difficult to recall the time when no one was quite sure which equipment and methods were best. Less attention has been given to these problems in recent years, but a number of projects are still under study.

For instance, the search for a completely leakproof shut-off valve has not yet been successful. A number of commercially developed valves have been advertised as leakproof, but tests have shown that they do not completely meet the requirements created by the introduction of the many new, highly toxic poisons into the insect control field.

Cut-off valves designed and fabricated in our own shops have been leakproof; but they have been unable to meet the requirement of simplicity imposed by potential manufacturers or the rugged characteristics required for equipment subjected to continuous hard usage in the field. Nevertheless, the search for a satisfactory valve continues.

The definite advantage of the constant-pressure sprayer, as introduced to the field by the Georgia Communicable Disease Center Activities, has led to efforts to have a satisfactory sprayer of this type manufactured commercially. Although several designs have been submitted to various manufacturers, no manufacturer has been able to place a satisfactory constant-pressure sprayer on the market for a price which most malaria control programs can afford to pay for them in the quantities required.

A recently completed project, also falling in the category of field equipment, is the development of a package-sprayer apparatus designed to be installed in various models of several small airplanes. The need for such equipment is evident in the event of an epidemic or disaster requiring larviciding or insecticiding by airplanes and in an area in which properly equipped airplanes are not available. Unfortunately, the usual spray airplane can not be flown rapidly across country due to its low speed and lack of equipment for night and bad weather flying. The equipment as now designed and approved by CAA for installation in the Piper Cub J-3 and Piper Cruiser (PA-12) airplanes can be flown in transport airplanes or otherwise shipped into the problem area, and once there, can be installed in a few hours in local aircraft without so much as cutting the fabric or drilling a hole. Spray booms are rapidly bolted to wing struts, tanks are placed on the rear seat and the components are

*Technical Development Services, Savannah, Ga.

Package-sprayer designed for use in various models of small airplanes is compact, can be shipped by regular transport, and at point of destination is easily and quickly installed.

connected by rubber hose. Instead of using a wind-driven pump to provide pressure at the nozzle, the entire system is placed under pressure by means of carbon dioxide carried in a cylinder attached to the sprayer tank. One $CO_2$ cylinder provides the necessary pressure for discharging four to six 18-gallon tanks of solution. Accurate control of the spray is obtained by means of a cut-off valve actuated by a flexible wire control brought to a point in the plane convenient to the pilot's hand.

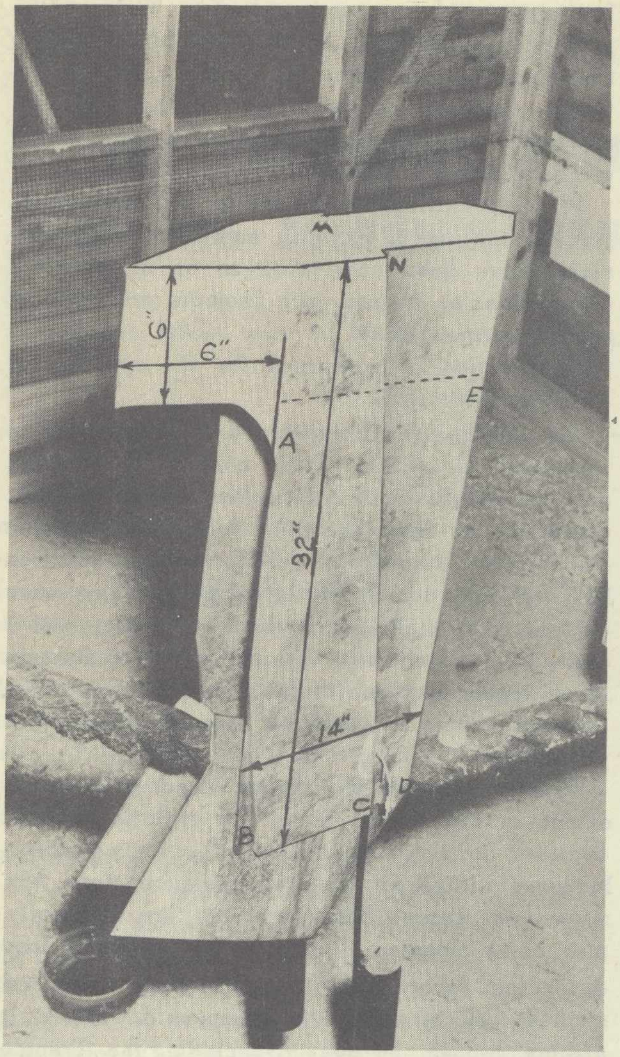
Another solution to this problem which has been investigated in recent months is based on the flow of the solution by gravity from the tanks to double throat Venturi units mounted on the wings. The Venturi tubes create a negative pressure on the lines and break up the solution into small droplets as it is discharged through the Venturi throat into the slip stream. Such a system would have the advantage of simplicity, few parts, and ease of installation. Work on this project has been carried to the point of testing the spray pattern with the Venturi tubes at different positions on the wing, but the work currently is being held in abeyance in favor of projects having a higher priority.

Projects calling not for design and fabrication, but for testing of existing equipment and materials, have been undertaken as an aid to field operations. Among such projects are tests of rubber sprayer hose, of new model commercial sprayers, and of equipment for the spraying of water-wettable DDT.

The ability of different types of rubber hose to withstand the action of the commercial solvents and insecticides with which they are in constant contact is an important cost factor. To determine the potential stability of samples of hose used on DDT spraying equipment, 14 samples of hose were subjected to soaking in xylene for a period of 7 days, after which they were examined for damage. As a result of these tests it has been possible to write more appropriate specifications than previously.

Water-wettable DDT, though used to a minor extent in the United States for malaria control, is used in large quantities in other countries. In some situations the water-wettable form has many advantages, but operations are frequently plagued by clogging of nozzles, with resultant loss of time and labor. Tests have been made on several methods of straining the suspension before it passes through the nozzle, including the Trapido dip-tube strainer, nozzle strainers, and strainers used in filling the spray cans. As a result of these tests, specifications for strainers have been prepared which are being submitted as CDC's recommendation to the World Health Organization Expert Committee on Insecticides.

Not all of the Section's efforts are devoted to facets of the malaria problem; a number of field rodent-control problems have received attention. Tests of the "Tiger Rat Guard," a commercial device designed to be placed on a ship's hawser, were made to determine its efficiency as a rat stopping device. The unit was claimed to have a number of advantages, including ease of placing in position. Tests indicated that rats passed the guard, if not with ease at least in relatively large number. The guard was redesigned and again tested. The new design, although less convenient to place on the hawser, stopped




The manufacturer's model of "Tiger Rat Guard" (shown in place on a 3-inch-diameter ship's hawser) was tested by Technical Development Services and, after modification, was found to be very effective in preventing passage of *Rattus rattus*.

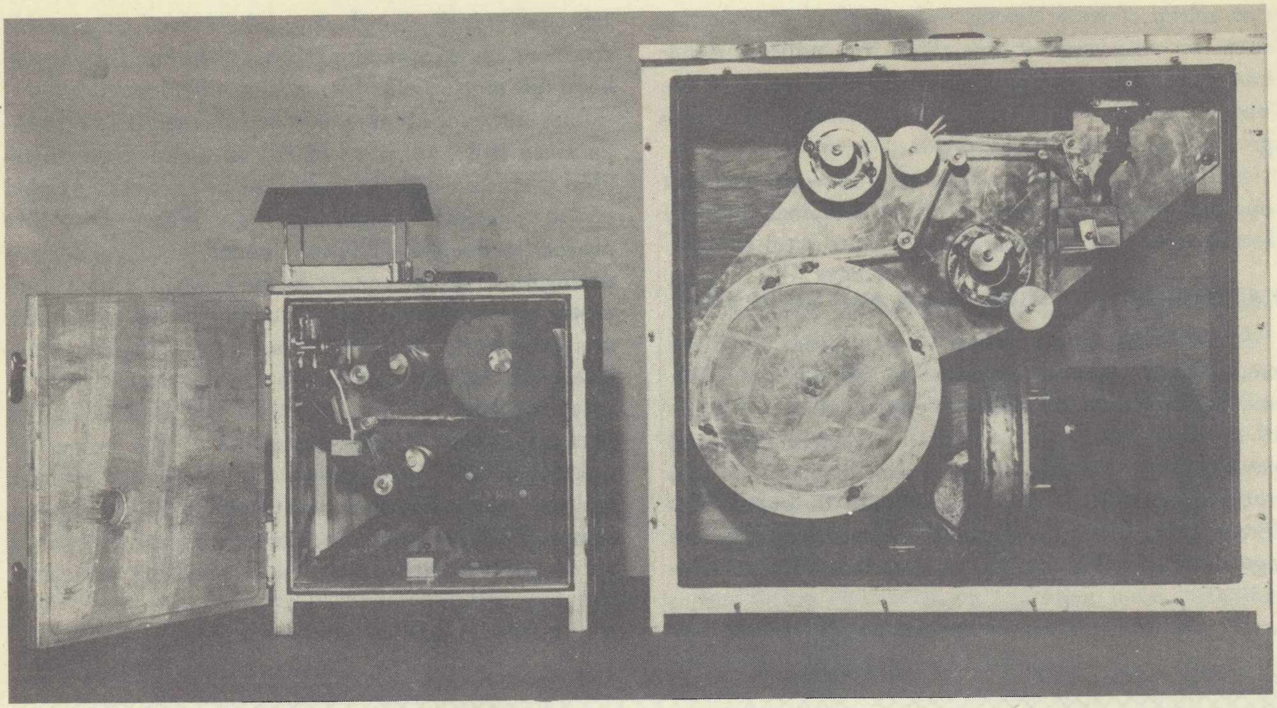
the passage of all but one rat, and this avenue of passage was closed by a simple change. Such devices, apparently effective on casual examination, show flaws only under careful test. Failure thus to test this type of equipment can lead to serious consequences.

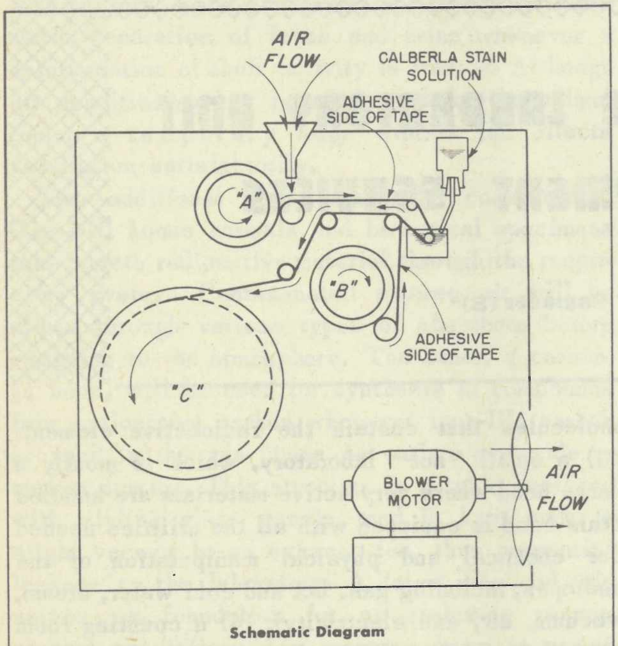
Another commercial product submitted to test was a rubber grain-storage bin. The units, small models for the test purposes, were made of rubber-covered fabric which enclosed numerous air cells. The entire unit could be inflated for use. It was believed by the manufacturer that the rats would be unable to attack successfully the rubber walls due to their resiliency. This was found to be true for a period of 2 or 3 months, but the rats finally found a loose edge of rubber and gained access to the grain.

An entry has also been made into the field of air-borne pathogens. For some time it has been desirable to have an air sampling device which would permit the identification and quantification of small particles in the air such as dust, pollen, and spores. A device, based on the use of transparent cellulose tape upon which the particles are impinged, has been developed. The particles are drawn inside the sample box by a fan which creates a negative pressure. After the particles have been impinged on the adhesive side, the tape passes through a staining bath, then joins another piece of tape with the adhesive sides together so that the stained particles are held in a plastic "sandwich." An automatic timer punches three tiny holes in the tape once each hour, thus relating points on the tape to the time of day. The resulting tape is stretched in a special holder which in turn is mounted on the mechanical stage of a microscope. Particles are counted by making sweeps across the tape at various points of interest. At the present time the device is being tested as a ragweed-pollen collection device while plans are being made to use it in connection with surveys of dust and the spores of histoplasmosis. For a special application, a survey of ragweed pollen over a large land area, one of the continuous recording pollen samplers has been mounted in an airplane. The forward speed of the airplane itself is utilized to force large volumes of air through the sampler thus providing a sample of adequate size in relation to the speed of the airplane. There appear to be good prospects for the valuable utilization of this device and further application of the principle of imbedding samples between two pieces of transparent adhesive tape.

**EQUIPMENT FOR LABORATORY USE**

A second major function of the Section is the development and fabrication of highly specialized equipment for laboratory use by the other sections of the Technical Development Services. One of the most involved problems undertaken to date was the design and construction of equipment for exposing animals to toxic vapors in a test chamber. Specifications for the required apparatus included requirements for the accurate control of the air flow, the amount of the toxic substance, the droplet size, and other factors. An apparatus meeting these requirements was constructed and is in frequent






The pollen sampler as originally designed (above, right) and as modified after testing (above, left). Note that modified collector is approximately half the size of the original model.

use for the exposure of animals, from mice to monkeys.

Apparatus strictly for laboratory use is often required, ranging from tongs for the handling of radioactive material to automatic shakers for agitation. In the latter group a mechanical agitator, capable of holding up to 16 500-milligram pear-shaped separatory funnels, was built for use in speeding up milk sample analysis for DDT content determinations. Variations in the speed and length of stroke permit a wide range in controlling the conditions of agitation, while interchangeable racks permit the use of a wide variety of glassware.

Another reciprocating device using the principle of the hydraulic balance was constructed to provide regular oscillations for the activation of a basal metabolism device for small animals.

A considerable amount of miscellaneous equipment for the handling of animals has been built to meet particular needs. The handling of large numbers of animals is, at best, a rather smelly and unsightly process. Every effort has been made to design and construct animal cages, watering and feeding devices, and dropping pans in such a manner that a maximum of sanitation can be accomplished with a minimum of labor. Replenishing the drinking water for rats in the normal style of cages is ordinarily a time-consuming job. This has been obviated in the Technical Development Services animal houses by the installation of water piped to a special valve in each rat cage. Water does not normally flow from these valves, but when the surface of the valve is licked by a rat a drop of water forms, to be replaced by another drop as required by the rats. Not only is labor saved by this piping of the water directly to the cage, but the elimination of spilled water has greatly improved the sanitation.

All animal holding equipment, as well as other special equipment, is constructed almost entirely in the station's own shops.

### MAINTENANCE OF BUILDINGS AND EQUIPMENT

In addition to its duties of equipment development the Section is responsible for the provision and maintenance of utilities essential to all parts of the laboratory. These include electric light and power, process and heating steam, compressed air, vacuum, conditioned air, and waste disposal. Unfortunately, these problems are complicated by the age of the facilities and the fact that the installation was not designed as a laboratory. As a result constant maintenance activities are under way to keep the station at top operating efficiency.

The air conditioning of the laboratories for temperature and humidity control is alone a considerable problem, with an installed capacity in excess of 30 tons of refrigeration. To insure that this equipment does not fail as a result of power failure during the not infrequent hurricanes, a diesel generator plant is kept on a standby basis. This unit has a capacity of 42 KVA, sufficient for the absolutely essential requirements of the station.

In addition to maintenance of the physical plant is the job of maintaining much of the scientific apparatus of the station. Innumerable electric motors, scales, balances, ventilators, elevators, lights, bells, signals, cameras, cages, and traps, all require a watchful eye and unending attention.

# THE RADIOACTIVE ISOTOPE LABORATORY UNIT AT TECHNICAL DEVELOPMENT SERVICES

JENS A. JENSEN, Sanitary Engineer (R)*

During the past year activities at Technical Development Services have been extended to the field of radioactive isotope tracer technique. This new activity will be particularly useful to the Toxicology Section with its accelerated program on the study of the toxicities of various economic poisons. Although the radioisotope laboratory is a part of the Toxicology Section it may be called on to solve problems for any section of Technical Development Services or other Services of the Communicable Disease Center.

The laboratory consists of six units: (1) housing for biological specimens such as insects, and experimental animals up to the size of dogs and monkeys; (2) a chemistry laboratory where complex compounds can be synthesized from the simpler molecules that contain the radioactive element; (3) a small "hot" laboratory, which is mostly a large hood where very active materials are handled (this hood is equipped with all the utilities needed for chemical and physical manipulation of the isotopes, including gas, hot and cold water, steam, vacuum, air, and electricity); (4) a counting room with Geiger tubes, ionization chambers, and associated electronic equipment (only low levels of activity, contained in samples to be analyzed, are carried to this room); (5) a sample and specimen preparation room where a material whose activity is to be determined can be divided into aliquots, or where insect specimens and small animal tissues may be prepared; and (6) an office.

The walls of the animal and specimen room, the

*Technical Development Services, Savannah, Ga.

chemistry laboratory, and the hot laboratory are lined with aluminum sheathing bonded on one-half-inch plywood panels over which a removable film of plastic has been applied by spraying. This feature is included only for ease of decontamination in case of accident, such as spills of "hot" material, small explosions, breakage of equipment, and soiling by animals that have become radioactive. Table tops are covered with aluminum pans on which "diaper" paper, an absorbent paper with a grease-proof and waterproof backing, is placed. This paper is discarded when accidentally contaminated. The floors are covered with asbestos tile, and it is thus possible to decontaminate limited areas merely by replacing the tiles. Incoming shipments of radioactive materials are kept in the hot laboratory when activities are in the order of a few millicuries or less. Provisions are being made, however, for storage of more active material in steel pipes sunk into the ground to a depth of 10 to 15 feet.

Animals are kept in metabolism cages equipped with feeders, water fountains, and means for automatic separation of feces and urine whenever a determination of their activity is wanted. Although air conditioning has been planned for the animal room, a temporary large window fan effects ventilation satisfactorily.

Two additional hoods are under construction. One will house animals and biological specimens that excrete radioactive material through the respiratory system. Contaminated expired air will be drawn through various types of absorbers before escaping to the atmosphere. The other, a carbon-14 hood, will be used for synthesis of compounds from radioactive carbon whenever long-life carbon is used in the gas phase as carbon monoxide or carbon dioxide. This structure is a table enclosed with sliding glass panels, and is kept under a slight vacuum by an exhaust fan, thus preventing leakage to the laboratory. A large steel-rod grid serves as foundation for an elaborate vacuum system consisting of a megarac pump in series with an oil diffusion pump. Associated gauges, thermocouple and Pirani type, are mounted on the exterior. All chemical reactions will take place in an enclosed system of reaction flasks, traps, lines, and vessels; and chemical contents will be moved in gaseous form by either vacuum or pressure.

The instrument room is equipped with a large-scale, constant-voltage transformer, tables, and cabinets, and two scalers, one a decade type with pulse discriminator, regulated auxiliary power supply, and timer, the other a scaler of 64 with pre-set timer. A lead shield with built-in shelf arrangement serves to eliminate extraneous and stray radiation from being recorded. This feature is particularly important whenever samples with low activity are counted. On hand is a well-rounded selection of Geiger-Müller tubes, end window type, dipping type, open window type, and annular liquid or gas flow type.

Two types of instruments are used for radiation health protection, namely, the Geiger counter type and the ionization chamber type. The former type includes both a Tracerlab monitor and a Victoreen portable monitor. These instruments indicate only the rate at which the isotope emits particles or electromagnetic rays per unit of time; they are, however, very sensitive even to an extremely minute amount of radioactivity.

Ionization chambers, on the other hand, measure the actual rate of ionization produced by particles and rays. They are made from materials similar in nuclear aspects to the tissue of the human body. Ionization damage produced in the body of personnel may therefore be determined by observing the reading of the chambers. Each person is given two small pocket ionization chambers and an X-ray film badge before entering the laboratory. These devices are read once a day and radiation exposure recorded. A large ionization chamber is on hand for determining large radiation doses such as those encountered when isotope shipments are unpacked or when large amounts are transferred or otherwise handled. A supply of 2-inch-thick lead bricks can be interposed between the investigator and the "hot" material in isotope manipulations. Although the bricks give excellent protection from penetrating gamma rays they also cause "Bremsstrhalun-gen" effect. These are electromagnetic rays produced when beta particles collide with the heavy lead nuclei, and they are rather damaging. Very good protection can be had merely by keeping as far away as possible. A plentiful supply of remotely controlled pipetting devices and tongs affords this type of protection.

An assortment of electronic repair parts and test instruments is available for servicing of equipment.

A project on marking various species of flies with radioactive phosphorus has been completed. $P^{32}$ is readily administered in food (milk) and the uptake and retention are excellent. Marked flies can be detected readily with a Geiger counter for a period of 3 weeks. This type of marking provides an excellent, efficient, and highly sensitive method for the study of fly migration, fly resting habits, and fly population determinations. Much information was also gathered on the phosphorus metabolism of diptera. In a current project the iodine analog of DDT has been synthesized from aniline and radioactive iodine. This compound, very similar to DDT, is administered to rats for the purpose of determining in greater detail the metabolic rate of DDT in animals.

The laboratory is supervised by a chemical and sanitary engineer who has been trained at Oak Ridge Institute of Nuclear Studies, and he is aided by a graduate physicist who has had considerable experience in maintenance and calibration of electronic equipment.

# EPIDEMIC AND DISASTER AID

FRANK R. SHAW, Sanitary Engineer Director*

## Part I.

### INTRODUCTION: DISASTER AID OF LONG AGO.

The public health activities of the Public Health Service were the outgrowth of epidemic and disaster aid. The Service originated in 1798 as the Marine Hospital Service for the care of sick and disabled seamen. With the establishment of hospitals, first at Norfolk in 1807 and later at New Orleans, New York, San Francisco and other ports of entry, it developed that the Medical Officers in Charge of these hospitals were called upon more and more by local and State authorities for aid in combating epidemics of smallpox, yellow fever, cholera, and plague.

The early acts of Congress and the establishment of local and State boards of health resulted from concern over epidemics of the aforementioned scourges. Fear of epidemics prompted the authorities of Baltimore to appoint a health officer in 1793, and the disastrous yellow fever epidemic in Philadelphia in the same year resulted in the establishment of a Board of Health for that city in 1794. Other epidemics of yellow fever and outbreaks of cholera were responsible for the formation of other city health boards and State boards of health.

The first related act of Congress, in 1794, was for its own protection in the event of the occurrence of an epidemic at the seat of government. However, in 1799 the Congress took its first step in matters of disaster aid by providing for the establishment of warehouses for the storage of goods taken from ships held in quarantine. This quarantine function became the responsibility of the Secretary of the Treasury. A widespread epidemic of cholera in the United States in 1833 caused Congress to permit the use of revenue cutters in enforcing the quarantine laws of States and cities. The widespread epidemic of yellow fever in the Mississippi Valley in 1878 was the incentive for the passage of the first national quarantine law. This law related to the prevention of the introduction into this country from abroad ot smallpox, cholera, yellow fever, and plague, and resulted in the creation of the Foreign Quarantine Division of the Marine Hospital Service. This

*Engineering Services

law was extended in 1893 to include all communicable diseases.

**FINANCIAL AID BEGINS**

The first financial aid by the Federal Government to State and local boards of health was granted in 1833 for the control of yellow fever. In 1888 an appropriation of $200,000 was made by Congress for the suppression of infection in interstate commerce. This appropriation was directed primarily towards the control of yellow fever. The continued occurrence of yellow fever in the Southern States during the summer and the desire for prevention of internal spread of disastrous epidemics led to the passage of the first Interstate Quarantine Law in 1890. The responsibility for its enforcement was placed upon the Marine Hospital Service which became the Public Health and Marine Hospital Service in 1902 and the U. S. Public Health Service in 1912.

The world-wide pandemic of influenza in 1918 caused Congress to appropriate $1,000,000 for the Public Health Service to aid State and local health departments in the suppression of the disease in the United States.

Prior to 1935, Federal aid to States was in the nature of promotional and consulting services by officers of the Service; but the enactment during that year of the Social Security Act with its money grants to States constituted what might properly be considered the greatest aid to prevention and control of disasters, both from epidemics and natural causes, by expanding and improving local health service.

Prior to 1937, the only direct aid rendered by the Public Health Service during disasters was the loan to the affected State health departments of such officers of the Service as could be spared from normal activities. Officers so assigned served to supplement the forces of the State and local health departments and functioned under the direction of the State health officer. Occasionally, biological products (vaccines and sera) also were furnished. In this manner aid has been rendered in the following disasters: to the city of New Orleans during the country's last yellow fever epidemic in 1905; to that same city, and to San Francisco and a few other ports in rat extermination and ratproofing activities following the occurrence of cases of human plague about 1914; to Chicago during the typhoid epidemic of 1926; to the Mississippi River Flood area in 1927; to the Florida Hurricane area in 1927; to the Puerto Rico Hurricane area of 1928; during amoebic dysentery outbreak in Chicago in 1934; and in other less severe epidemics, windstorms, and floods.

The year 1937 marked the next expansion of disaster aid by the Service. To aid the States affected by the Ohio River flood of that year, the Service assigned to the stricken area all the engineer officers that possibly could be spared, and arranged to secure from the State health departments of unaffected States many sanitary engineers and sanitarians. Those who held reserve commissions were called to active duty and others were employed on civil service basis for the duration of their assignment to the stricken area. The salary and travel of all of these men were paid from Federal money allotted for the purpose. The aid rendered in this case was more extensive and more far reaching in its effect than any aid given before that time.

**DISASTER AID BY A NEW PATTERN**

With the development of the Communicable Disease Center and the general expansion of Service personnel and activities following World War II, it became possible for the Service to render greater aid, not only in number of persons supplied but also in equipment and material furnished. Notable examples of this expanded service were the Texas City disaster, April 16, 1947, and the Northwest (Columbia River) flood in the spring of 1948. These will be described in some detail hereinafter.

At the December 1947 annual conference with the Surgeon General of the Public Health Service, the State and Territorial health officers recommended that epidemic and disaster aid to States be expanded to include equipment and materials which could not logically be stockpiled by local and State health departments. The resolution included the recommendation that special funds be appropriated by Congress for this purpose. Subsequently, the Surgeon General designated the Communicable Disease Center to plan, administer, and furnish material aid to the State health departments in meeting emergency demands resulting from non-military disaster or disease epidemics when State and local health organizations are unable to fully cope with the public health problems involved.

Aid to States in connection with outbreaks of communicable diseases during the past 2 years has been intensified. Equipment that would be helpful to States in connection with environmental sanitation after certain types of disasters has been purchased. This includes five 2½-ton-truck-mounted water purification plants capable of handling 100 gallons per minute, five ¼-ton trailers for these units, five 3,000-gallon rubberized-fabric water tanks, and ten 1,000-gallon rubberized-fabric water tanks. All of these were purchased from the War Surplus Administration. These units have been equally divided and stored at Boston, Atlanta, Kansas City, Dallas, and San Francisco. Four ¾-ton Dodge power wagons, purchased in June 1949, are stored at Boston, Atlanta, Dallas, and San Francisco. At the Regional Offices at New York, Washington, Chicago, Kansas City, and San Francisco and at CDC headquarters in Atlanta there are stored trailer dry-feed chlorinators. CDC has in storage in Atlanta and at a few field stations, a small number of portable chlorinators and hypochlorite feeders. Certain insecticide spraying and larvicide dusting equipment has been earmarked for disaster aid, and, like equipment in the field, is available when needed in connection with disasters.

Shortly after being designated on October 2, 1947, as the Office to handle all matters relating to epidemic and disaster aid, CDC issued a pamphlet "Epidemic and Disaster Aid to States — Health and Sanitation — General Information and Policies." This pamphlet set forth the types of disasters and circumstances which would warrant aid, recognized the sovereign power of the State, and indicated the responsibility of the Public Health Service in regard to the interstate spread of disease. It also stipulated that aid would be supplementary to State activities and under the direction of the State health officer and would be rendered in local disasters only at the request of the State health officer. The pamphlet also outlined the type of aid which could be given, and indicated whom to contact day or night when seeking aid.

In 1949 a pamphlet was issued entitled, "Supplement to Epidemic and Disaster Aid to States — Administrative Procedure." This was designed to guide administrative officers in the field relative to personnel, property, emergency purchases and contracts, and sources from which office supplies, equipment, biological products, and such necessary items could be secured. It contained instructions for the guidance of regular officers and employees and for reserve officers relative to reporting for duty, travel, payrolls, and reports. It contained a brief outline of travel regulations and tabulated the contents of each of two cases which had been packed with essential stationery and forms and made ready for immediate shipment.

The first-mentioned pamphlet was distributed to Regional and CDC field offices and to all State health departments. The latter was distributed only to the Regional and CDC offices since it related only to CDC procedure.

# Part II.

## A NATURAL DISEASTER AT TEXAS CITY

As will be recalled, the Texas City disaster resulted from a series of devastating explosions beginning at 9:12 a.m. on Wednesday, April 16, 1947. The Grand Camp, a French vessel loaded with ammonium nitrate being shipped abroad for use as fertilizer, exploded with terrific force, and, in addition to the damage immediately caused, started fires which sparked other explosions, including the S. S. High Flyer, an American vessel likewise loaded with ammonium nitrate. The disaster resulted in deaths variously reported from 400 to 600 and property damage variously estimated from $50,000,000 to $150,000,000. Ironically, this catastrophe apparently resulted from violation of a safety regulation and had its origin in a carelessly discarded lighted cigarette. Some idea of the effect of such a disaster can be gleaned from figures 1 and 2.

In catastrophic natural disasters, aid is needed immediately. In keeping with this principle, the two CDC field representatives in Galveston and Houston, Tex., proceeced to Texas City immediately after learning of the disaster and arrived there the day of the disaster. At 3:30 p.m. Thursday, April 17, the States Relation Division of the Surgeon General's Office officially directed CDC to represent the Service and make available to the Texas health authorities all necessary facilities for medical care, emergency relief, and rehabilitation. In principle, this was in accordance with Public Health Service practice of the past, but the fact that it was supported by a directive from

Figure 1

Remains of bulk storage tank one quarter of mile from scene of Texas City explosion.

Figure 2.

Grain elevator standing amidst ruins 600 yards from blast area.

the President to all Federal agencies made possible more extensive material aid and assistance with the rehabilitation problem.

The Executive Officer of CDC, an engineer, arrived at Texas City the afternoon of Saturday, April 19, and under the administrative direction of the county health officer, began the organization of plans based on the allotment of $48,000 for activities during the current fiscal year ending June 30, 1947. The county health officer indicated that there had been made available from other sources sufficient medical and nursing personnel and an adequate supply of biologicals, but that assistance with the sanitation problem was pressingly needed.

Service activities actually began the day of the first explosion when 2 Service officers and 15 Service men on duty in the Houston and Galveston areas moved in. Fifteen Service vehicles, mostly trucks, were promptly brought to the area. The first use of these facilities was the transportation of injured persons to first aid and emergency hospitals; later they were used for the hauling of the dead to emergency morgues. These forces, together with 15 field men employed by the county but assigned to the Service officers, began sanitation activities on Friday, April 18, to supplement the work of State and local sanitation personnel.

The area supervisors of CDC Activities who moved in with men and equipment the day of the disaster, were supplemented the following week by four engineers and sanitarians from other areas, and one administrative officer. One medical officer was furnished by CDC when a request was made for such an officer to serve as Medical Officer at Camp Wallace, which was used as a camp for evacuees.

It was immediately apparent that the most imminent danger was the distribution of contamination from broken sewers and other sources by flies which would breed in the exposed food and debris scattered by the explosions. Therefore, the first efforts were directed to the DDT dusting of the blasted dock and industrial areas and then the business section. The dusting of these areas was completed by Sunday, and the activity then was extended into alleys and the residential areas. These activities involved hand, power, and airplane dusting.

Subsequently, there followed DDT dusting of rat runs and harborages; and rat poisoning, restaurant sanitation, mosquito control by the application of larvicide and residual sprays, garbage and waste disposal, and premises inspections to determine water supply and sewage disposal needs and general sanitary conditions. All conditions found were carefully reported and tabulated to serve as a reference for the county health department in carrying out rehabilitation and routine sanitation improvements. It is also to be noted that practically all evacuees at Camp Wallace were dusted with DDT to insure against the presence of body lice and the danger of louse-borne typhus.

The work done by CDC forces, supplementing that done by the county health department, during the first month following the initial explosion included:

**Fly Control:**

Two hundred and thirty-eight blocks of the city were sprayed with a 5 percent DDT water emulsion. In addition, food and other potential fly breeding media in the devastated area were sprayed biweekly.

**Mosquito Control:**

All standing water within the area was sprayed with 5 percent DDT in diesel oil. Six thousand premises were treated by residual spray using 20,000 gallons of solution.

**Typhus Control:**

In addition to the dusting of rat runs and burrows in the devastated area, 155 blocks of Texas City proper were dusted with 10 percent DDT. Four hundred and eighty-five premises were dusted with 540 pounds of DDT.

**Food Sanitation:**

Milk was not a problem, since it was secured from Galveston and all of it was pasteurized. All restaurants were inspected periodically and sanitation established on the basis of the Public Health Service recommended code insofar as equipment would permit. Surveillance over food sanitation at the Camp Wallace Evacuee Center was maintained throughout the period.

The emergency activities were continued through July at a total cost of $52,631. CDC continued its activities for an additional 3 months, as rehabilitation and promotional health activities. So impressive were the results, particularly with regard to fly and mosquito control, that a popular demand arose for the continuance of the work as a regular function of the county health department. To accomplish this a fund of $50,000 was secured by subscriptions from industrial and business firms.

This experience is another incident in the history of the Public Health Service of "aid to the disabled" which is dramatically symbolized by the anchor with the fouled chain in the Corps device of the Service. In relation to more recent years it demonstrated how epidemic and disaster aid can serve to awaken the public conscience to the need for more financial support for local health activities which the local health authorities would like to carry out.

# Part III.

## THE NORTHWEST FLOOD

**(Columbia River Basin Flood — Spring 1948)**

The Northwest or Columbia River Basin flood was the most disastrous in the history of the Northwest and probably the most costly in the history of the United States. The Columbia River and all of its tributaries, which drain 259,000 square miles of land, were involved. The greater part of the States of Washington and Oregon and nearly the entire State of Idaho were affected, and drainage was contributed by parts of the States of Nevada, Utah, Wyoming, Montana and British Columbia.

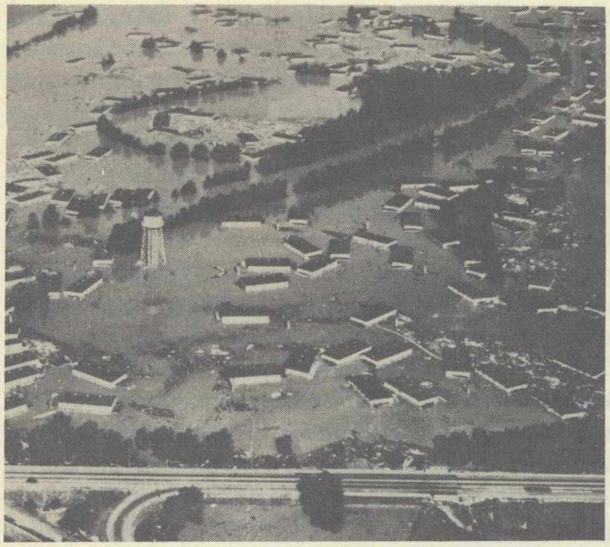


**Figure 4.** Flooded communities in the Okanogan Valley of Washington, spring 1948.

from the following citation of some of the factors and accomplishments. The activities extended from June 4 to August 1 and the personnel concerned during all or part of this time included 9 engineers, 2 entomologists, 1 sanitarian, 1 administrative officer, 2 clerk-stenographers, 2 malaria control aids, and 3 foremen of laborers. The work of the CDC entomologist was supplemented by three entomologist assigned to the area by the Division of Animal and Plant Quarantine of the U. S. Department of Agriculture.

Approximately 125,000 cubic centimeters of typhoid vaccines were purchased and furnished to the State departments of health.

In the Portland-Vancouver zone during the period June 11 (when insecticide operation began) through July 28, the two city airplanes and two airplanes rented by CDC flew a total of 171 hours and 11 minutes, and dispensed 20,850 gallons of insecticide over approximately 50,000 acres of actual or potential mosquito and fly breeding areas. The treatment involved from one to six applications. Ground forces equipped with exhaust aerosol units, power spray units, and pressure spray cans treated approximately 3,000 acres of small breeding area using 3,000 gallons of insecticide and 4,000 pounds of 10 percent DDT dust. In addition, one application by two airplanes, one of which was furnished by CDC, was made over approximately 1,000 acres in the Kelso-Longview, Wash., area and two applications by ground forces were made over the entire area of Deer Island. Insecticide was furnished other areas for application by local forces.

Some materials were furnished for rodent control, which activity was under the direction of State and local personnel and representatives of the U. S. Fish and Wildlife Service.

In some areas technical personnel of CDC rendered aid in connection with water supplies, food sanitation, sewage and waste disposal, home rehabilitation, and general sanitation.

The over-all magnitude of disaster aid can be visualized from the expenditures, which included \$9,929 for personnel and \$58,612 for materials, supplies, equipment, and airplane services. This does not take into account general administrative expenses at Atlanta and the depreciation of equipment brought into the area from CDC field activities.

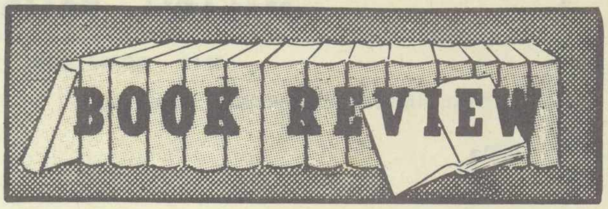
So impressed were the State health officers of Oregon and Washington with the aid rendered that they sponsored a second resolution by the State and Territorial health officers at the 1948 conference with the Surgeon General of the Public Health Service advocating expansion of material aid and a special appropriation for epidemic and disaster aid.

# Part IV.

## RECENT EPIDEMICS

*(An article on this subject will appear in a later issue of the CDC Bulletin.)*

# Subtropical Entomology




**Walter Ebeling**

*Citrus Experiment Station, University of California, Riverside, California.*

*Lithotype Process Company, San Francisco, California.*

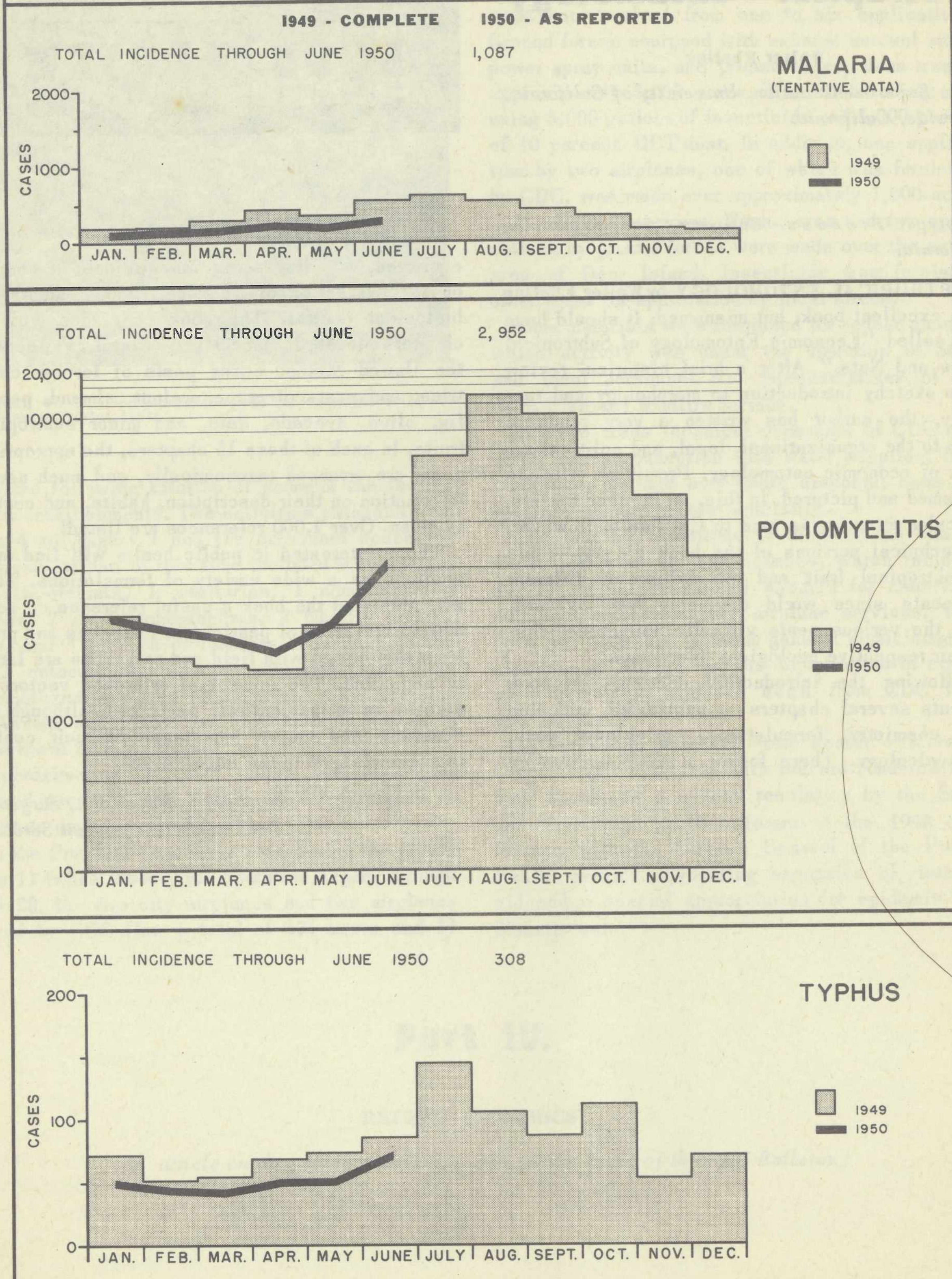
SUBTROPICAL ENTOMOLOGY by Walter Ebeling is an excellent book, but misnamed. It should have been called "Economic Entomology of Subtropical Fruits and Nuts." After a brief historical review and a sketchy introduction to morphology and taxonomy, the author has written a very practical guide to the organizational, legal, and political aspects of economic entomology. Prominent officials are named and pictured. In this, as in other matters, particular attention is paid to California. However, the technical portions of the book are applicable to subtropical fruit and nut culture of different continents since world commerce has, by now, made the various pests virtually ubiquitous within their respective ecological tolerances.

Following the introductory section, the book presents several chapters on pesticides, outlining their chemistry, formulations, agricultural uses, and toxicology. There follow a short section on equipment for dispensing insecticides, a chapter on the evaluation of treatment, and a chapter on biological control. The book concludes with 11 chapters devoted respectively to citrus pests of the United States; citrus pests of foreign countries; and pests of grape, walnut, almond, pecan, fig, olive, avacado, date, and minor subtropical fruits. In each of these 11 chapters, the appropriate pests are arranged taxonomically, and much useful information on their description, habits, and control is given. Over 1,000 references are listed.

Those interested in public health will find suggestions on a wide variety of formulations. They will also find the book a useful reference on some agricultural uses of pesticides. Practices and problems associated with field and row crops are largely neglected. The control of arthropod vectors of disease is almost entirely neglected, although the economic and human importance of their control is acknowledged in the introduction.

*Wayland J. Hayes, Jr., Surgeon*
*Technical Development Services*

# MORBIDITY TOTALS FOR THE UNITED STATES *
# MALARIA, POLIOMYELITIS, TYPHUS




FSA-PHS-CDC ATLANTA, GA.

* SOURCE OF DATA: NATIONAL OFFICE OF VITAL STATISTICS



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