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.

915375 O - 50 - 3

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.*