Study Book

For the Training Course:

SAFETY and PESTICIDE USAGE

1971

ENVIRONMENTAL PROTECTION AGENCY
PESTICIDES PROGRAMS
Division of Pesticide Community Studies
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FOREWORD

This studybook is made available to students enrolled in the "Safety and Pesticide Usage" course to serve as a training aid and guide. We hope you will find the material presented here useful in your everyday work. Continued requests for more in-depth information about pesticides, both for general knowledge and for use in specific areas, prompted us to develop this course to touch on specific areas of interest and practical application of previously presented theory.

Although, for the most part, the studybook contains papers prepared especially for this course, it should not be considered a citable source. Any original research data contained in these papers will be published by the authors in another form in referenced scientific journals. Should you be unable to locate the appropriate citable reference for these data in the future, we ask that you contact the author directly.

We take this opportunity to express our appreciation to the authors for their participation in this training course and to wish you the students rapid progress toward our common goal of adequate protection of human health and the environment.

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PUTTING PESTICIDES AND POLLUTION IN PERSPECTIVE

Anne R. Yobs, M.D.

The uses of chemical substances become more numerous each day, leading to the formulation of new substances and the development of new commercial applications.

Man's physical environment is now exposed to a myriad of substances which are potentially toxic to man himself or to constituents of his environment. Such substances are found in nearly everything that man uses. In trace amounts in the human body, some substances may be essential to life or have no demonstrable effect, but in larger amounts, these same substances may be toxic. It has been estimated that some 2 million chemical compounds are now known and that several thousand new chemicals are discovered each year. Most new compounds remain laboratory curiosities which are never produced commercially; however, several hundred new chemicals do enter commercial markets annually. The metals, metallic compounds and synthetic organic compounds -- among these pesticides -- cause particular concern because of their rapidly increasing number and use.

United States consumption of metals with known toxic effects has increased greatly in the last 20 years. Use data tend to underestimate their increasing pervasiveness in our environment due to the many new metallic compounds being formulated and used in ever-widening varieties of new products. The use of synthetic organic chemicals is growing in a similar manner. More than 9,000 synthetic compounds are now in commercial use in amounts exceeding 1,000 pounds a year. In 1968, synthetics totaled nearly 120 billion pounds -- 60 million tons. This represented a 15 percent increase over 1967 and a 161% increase over the 10 years since 1961.[1]

Admittedly many of these substances are not toxic, but their sheer numbers, increasing diversity and use and the environmental problems already encountered from some indicate the existence of a problem of potential significance. These substances enter man's environment--and man himself--through complex and interrelated pathways. Present in air, water, soil, consumer products and food, they pervade our environment. Some become concentrated through the food chain--with minute quantities being magnified thousands of times as they are consumed by higher forms of life. Increasingly, all forms of life are being exposed to potentially toxic chemical materials.

The environmental effects of most of these substances are not well understood. Testing has largely been confined to determining their acute effects and knowledge of the chronic or long-term effects, such as genetic mutation, is inadequate. Available data, while still incomplete, indicates potential or actual hazard from a number of these substances.

Many serious effects, including such things as cancer production (carcinogenicity), genetic mutation (mutagenicity) which is the production of permanent changes in genes and is transmissible from parent to child, as well as the production of physical or biochemical defects in an offspring (teratogenecity) can occur as a result of exposure to certain of these compounds. In general, we do not know which substances cause such effects or the level(s) of a given chemical which must be reached before the effect(s) occurs. The problem is complicated by the changes which chemicals may undergo once they enter the environment becoming more or less toxic through modification or as a result of interaction with other substances.

Existing Federal controls over the introduction of toxic substances into the environment are of two types. The first is control over initial production of a substance and its distribution. For example, under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), a manufacturer must register a pesticide with the Environmental Protection Agency before it can be introduced in interstate commerce. EPA can prohibit distribution of a pesticide or require labeling of acceptable uses. This type of control, exercised at the point of manufacture, is also applied to drugs and food additives by FDA. Although this control technique can be very effective, current authorities cover only a small part of the total number of potentially toxic substances and do not deal with all of the uses of a substance which may produce toxic effects. The second type of control is media-oriented, that is directed at air and water pollution from various sources. Federal authority derives primarily from the Clean Air Act and the Federal Water Pollution Control Act. Under the latter, the Federal Government, in cooperation with the states, sets standards for the amounts of particular substances allowable in water. Under the Clean Air Act, the Federal Government sets national air quality standards, allowing the states to set more stringent standards. Enforcement of standards depends on limiting the emission of a substance from a given source.

In theory, this type of authority can be used to control all substances, but there are several limitations to the effective application of such controls. These media-based authorities are mainly concerned with pollutants which occur in large quantities. It is difficult to control minute amounts of toxic materials with this type authority partly because of the difficulty in detecting their presence in air or water and partly because many substances enter the environment through disposal of consumer products. If a product is disposed of through the municipal sewer line or by burning at an incinerator, it is almost impossible for the media-oriented controls to deal effectively with minute amounts of decomposition products. To do so requires their effective removal by the municipal waste treatment plant or incinerator stack scrubbers.

Most toxic substances are not exclusively air and water pollutants, but can be found in varying quantities in air, water, soil, food and industrial and consumer products. The multiplicity of ways by which man can be exposed to these substances makes it difficult for the media-oriented authorities to consider the total exposure of an individual to a given substance, a consideration necessary for the establishment of adequate standards.

Since the worst aspects of pesticides are usually the ones which make the most news, it sometimes seems that pesticides are credited with more than their share of the overall pollution problem. Pesticides properly used are tools, however when they move off target or are misused, they become pollutants. Pesticides might not be much of a problem if they stayed where applied, but in fact they do not remain where applied and do remain in the environment for relatively long periods of time as shown by the widespread distribution of DDT and some other chlorinated hydrocarbons.

Pesticides are deliberately introduced into the environment in order to improve the quality of the environment for man himself and for his domesticated animals and plants. These chemicals are used in agriculture to improve the farmer's cost/benefit ratio and for the ultimate benefit of the consumer. The technology of the use of modern pesticides is one important component of the agricultural revolution of the last 100 years, other components include farm mechanization and the development of chemical fertilizers. This revolution has made it possible for the United States farmer to increase his production from an amount sufficient to support 4 people in 1850 to that sufficient for an estimated 46 people today. In our present system of monoculture, farm mechanization, and complex systems of food harvesting, processing, distribution and storage, the use of pesticides often means the difference between crop production and crop failure and between economic profit and loss. In developing countries where food supplies are marginal, pesticide use may represent the margin between survival and starvation.

Food losses attributable to all forms of pests, including pathogens, weeds and arthropods, are very difficult to estimate, and to some extent the estimates are subjective in nature--it is not easy to say with certainty what the yield of a crop might have been in some hypothetical, disease-free circumstance.

The losses which can be attributed to pests are of several kinds. Sometimes, losses occur as a result of direct reduction of growth with concomitant reduction of yield; such reduction results both from competition of weeds and from damage caused by insects and pathogens. Frequently, a loss of quality is also evident; deformed, discoloured or small-sized produce often carries small market value. A third type of loss relates to costs incurred by the farmer in attempts to reduce damage caused by pests; in addition to the cost of chemicals and their application, there may be costs arising from additional cultivations or from the need to purchase more expensive, resistant varieties of crop seed. Furthermore, resistant varieties are sometimes less productive than susceptible ones, and indirect costs are incurred this way, as they may be when the farmer resorts to crop rotation for the purpose of crop hygiene.

As has been mentioned, it is difficult to quantify losses although figures of the order of 10 to 20% loss of useful crop are frequently quoted both in the United States of America and in Britain.[2]

Problems of environmental quality inevitably result from conflicts of interest, and the use of pesticides has been attacked by conservationists and ecologists as a focal point of concern for the preservation of environmental quality. Considerations in the "pesticide controversy" include a variety of technologica economic and sociological points. These include overzealous application of new products and techniques, farm labor shortages, lack of appreciation of the ecological complexities of crop production, failure to develop pest-management strategies and newer selective and biodegradable pesticides and the supermarket approach of many consumers today.[3]

There are now some 300 different chemical compounds which are used as commercial pesticides variously on crops, harvested produce, processed and stored foods, soil, water, structures and habitations. They serve to minimize and control the attacks of pests and resultant damage. Pesticides may be categorized according to the type of pest controlled - insecticides, fungicides, herbicides, nematocides, molluscacides, rodenticides and acaricides Numbers of pest species in the United States have been estimated as follows:[4]

bacteria	250 species
fungi	8000 species
viruses	250 species
weeds	500 species
nematodes	500 species
molluscs	50 species
insects	10,000 species
rodents	200 species
birds	10 species

The annual loss in the United States from pests in crops, forests, livestock and other agricultural products has been estimated at $14.3 billion with additional losses of $2.3 billion during storage and marketing.[5] Worldwide, crop production losses are estimated to be 14% due to plant diseases, 2% insects, and 9% weeds, for a total loss of $70-90 billions.[6] It has been estimated that enough food is lost to feed 1 billion people. Modern pesticides have accounted for astonishing gains in agricultural production by reducing the damage from pest attack. The average potato yield in New York State from 1936-45 with good growing practices and arsenical insecticides was 110 bushels per acre - in 1946-47 with DDT used exclusively, the yield was 172 bushels per acre - up 56%. The use of systemic insecticides to control insect vectors of plant virus diseases increased wheat yields in the California Imperial Valley by 10%. The use of phenoxy acid heribicides in small grains to control weeds has been stated to increase grain yields over a 15 year period by more than 800 million bushels.[7]

"Pesticide Technology has made it possible to increase the efficiency of farm operations and has led the way to greater productivity through mechanization of all phases of crop production from planting to harvesting and storing. ...

"Ecologically, the use of pesticides is an almost inevitable consequence of the development of modern high production agriculture. The pure monocultures of corn, wheat, cotton or rice, often extending for thousands of contiguous acres, represent the highest sort of ecosystem specialization. Compare if you will, a midwestern cornfield with its original predecessor, the tall grass prarie. The cornfield ideally contains only a single plant species without any competitors-bacterial, fungal, weed, nematode, insect, bird or rodent pests; while the prarie consisted of perhaps 100 plant species and thousands of associated animals. Through the development of the cornfield, man has aimed to maximize the harvestable energy of the ecosystem, and this has been achieved at the cost of ecosystem stability. The extent of the instability of the hybrid cornfield has been dramatically revealed in the calamitous attack of southern corn leafblight.

"Modern agri-ecosystems require large inputs of energy to maintain them in a stable state. Pesticides, fertilizers, gasoline for tractors and electric power for irrigation represent the major energy inputs required for ecosystem stability. Energy applied as pesticides is cheaper and far more efficient than the man with the hoe or fly swatter."[3]

In the drive toward increased agricultural productivity man has paid little attention to the broader aspects of the agri-ecosystem and to the sound principles of crop rotation developed during the past 100 years. These had very beneficial effects in the control of many agricultural pests, both plant and animal. Unfortunately, in many areas most of them have been all but abandoned today. Newer technologies such as the "no-till" concept depart still further from sound eco-system strategies for agricultural pest management. However much these increase crop production, a corresponding price will be paid in need for more pesticides.

The new hybrid varieties of crops which have brought about the "green revolution" have also complicated the problems of the agri-ecosystem. These have been bred largely for high production characteristics and may exhibit markedly different susceptibilities to various types of pests. Moreover, their high production characteristics are effective only under very high levels of fertilization with nitrogen and phosphorus and often with greatly increased reliance on pesticides.

The agri-ecosystem does not exist in a vacuum, and the future trends and developments in agriculture must be weighed in terms of the total quality of the environment.

The value of pesticides to the agricultural industry may also be considered from the extent to which they are employed. By this measure these materials have been outstandingly successful. Table 1 shows U. S. sales of pesticides for the 8-year period 1962-1969.

Table 1. Pesticide Use in the United States[a]
Sales in Millions of Pounds

Year	Fungicides	Herbicides	Insecticides	To
1962	97	95	442	6
1963	93	123	435	6
1964	95	152	445	6
1965	106	184	473	7
1966	118	221	502	8
1967	120	288	489	8
1968	124	318	498	9
1969	127	348	502	9

a/ U. S. Tariff Commission.

Total pesticide use has increased an average of more than 7 percent per year. For herbicides the increase is substantially higher, their use more than doubling over a 4-year period. In terms of crop applications the U. S. Department of Agriculture estimated in 1966 that herbicides were applied to 27 percent of the 350 million crop acres, insecticides to 12 percent, and fungicides to 2.6 percent.

The role of these chemicals in pest control and in crop production has been intensively studied, and their use has become virtually indispensible to modern agriculture but for the majority of the individual pesticide chemicals there is only a superficial knowledge of the effects of their long-term use on the quality of the environment. On a national level we have developed an impressive array of knowledge relating to pesticide contamination of crops, foods, soils, animals, and even humans. However, in relation to the immensity of the total pollution problem, these efforts leave many end points unresolved. Special attention needs to be given to the rates of accumulation of pesticides and their breakdown products in soils and to the extent of contamination of water resources; to the interrelatic between various combinations of pesticides and the soil microflora; to the effects of all new compounds on food chains and food-chain organisms, especially including wildlife; and to the effects of possible mutagenic and teratogenic compounds and their breakdown products upon man.[6]

The persistence of many pesticides has made possible the development of new agricultural techniques such as preemergent herbicides, soil insecticides, and seed treatments and have caused many of the environmental problems facing the nation today. The values shown in Table 2 give an indication of the relative persistence in soils of various types of pesticides.

Table 2. Persistence of Pesticides in Soils[a]

	Approximate half-life, years
Lead, arsenic, copper, mercury	10-30
Dieldrin, BHC, DDT insecticides	2-4
Triazine herbicides	1-2
Benzoic acid herbicides	.2-1
Urea herbicides	.3-.8
2,4-D; 2,4,5-T herbicides	.1-.4
Organophosphorus insecticides	.02-.2
Carbamate insecticides	.02-.1

a/ Metcalf and Pitts (13).

Difficulties have been encountered with residues of heavy-metal pesticides containing lead and arsenic, which were used extensively for 20 to 30 years in apple orchards and tobacco farms. Compounds of these elements are intrinsically deleterious to life when solubilized sufficiently to enter living systems. More than 3,500 pounds of lead arsenate was applied to a commercial orchard in Washington over a 25-year period and was found to accumulate in soil at levels which were seriously injurious to cover crops. Tobacco soils in North Carolina have accumulated arsenic up to 5 ppm. Many years are required for the levels of lead and arsenic in such soils to return to normal values. The persistent herbicides sometimes show disconcerting tendencies to render soils sterile to plant growth long after their usefulness was expended. This is particularly true where use patterns are abruptly changed.

Pesticides will be used for the foreseeable future. This is the collective judgment of the Jensen Committee on Persistent Pesticides, National Academy of Sciences[8], which stated "For most purposes, nonchemical methods of control are not expected to supplant the use of chemicals in the forseeable future"; and of the Mark Commission of the Secretary of Health, Education, and Welfare[6], which said, "Our need to use pesticides and other pest control chemicals will continue to increase for the foreseeable future." This does not, however, give license to utilize pesticides on an infinitely increasing scope or to use them irresponsibly with regard to the quality of the environment. Changes must be made in pest-control practices and in some cases in the nature of pesticide chemicals themselves if the agricultural industry is to maintain public confidence in its practices and to observe an appropriate and responsible regard for public health and environmental quality.

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TOXICOLOGY OF PESTICIDES

Thomas B. Gaines

Toxicology may be defined as a science that deals with the action of poisonous materials on living cells and tissues, the response of the living structures, and the detection, identification, and evaluation of safety of these poisonous materials. Of course, many chemical compounds are quite beneficial for use in man at certain levels. On the other hand, these same materials can be quite harmful if used without regard for their potential toxicity. Drug therapy in man must be practiced with care to prevent the development of toxic manifestations. Even table salt, a common part of our diet, is as toxic in a single oral dose as some of our pesticides. Although pesticides may be quite hazardous to man, at least one of them, the organic phosphorus Dipterex, has been used experimentally for control of intestinal parasites in man.[1] This and some other organic phosphorus compounds are used for control of intestinal parasites of livestock.

Factors Influencing Toxicity

The toxicity of pesticides in mammals is influenced by compound, dosage level, schedule of dosage, duration of dosage, route of exposure, species and strain differences, sex, age, interaction of compounds, nutrition, disease, and temperature and other environmental factors. Among 100 pesticides tested for their acute oral toxicity in male rats the organophosphorus Abate was the least toxic with an LD_{50} of 8600 mg/kg and the carbamate Temik the most toxic with an LD_{50} of 0.8 mg/kg.[2] The toxicity of any one pesticide in mammals corresponds to the dosage level in accordance with the dosage-response concept. This implies that there is a dosage level great enough to kill all of the poisoned organisma and, at the other end of the scale, a dose small enough to be a "no effect" level. It should be emphasized that a "no effect" level may actually represent our inability to detect an effect. It is doubtful that there is any level of a foreign substance that fails to exert some effect when introduced into a living organism.

A schedule of dosage that involves continuous exposure to a pesticide is generally more hazardous than intermittent exposure at the same level. The degree of difference depends to a great extent on the rate at which the organism is able to excrete the poison or convert it to a non-toxic substance. The single dose oral LD_{50} for carbofuran in rats is about 8.0 mg/kg. However, if the compound is fed in the diet so that the total dose is consumed each day over a period of several hours, the rats will survive 40 mg/kg/day for 90 days. Thus intermittent exposure will prolong the time required for a toxic effect to develop even for those compounds known to be cumulative in their effect. The development of some manifestations of toxicity are dependent on duration of dosage. This is the reasoning behind the requirement for 90-day and 2-year exposure studies in animals. Effect of long-term exposure is especially important in consideration of carcinogenicity (development of malignant tumors) of pesticides.

The three most common routes of exposure to pesticides are oral, dermal, and inhalation. The oral route is the dominant route of exposure from pesticide residues in food. Formulators and applicators of pesticides are subject to considerable exposure by dermal absorption and inhalation. In laboratory tests with pesticides in rats most compounds tested were more toxic by the oral route than by the dermal route. Only five of 90 pesticides tested by both routes were more toxic by the dermal route. Three of these were organophosphorus compounds; one was a carbamate; and the other was a sulfite compound.[2]

The question of species difference in susceptibility of animals to pesticides is, of course, of only academic interest to those concerned with human health, but it may vary by a factor of 10 or more for some compounds in mammalian species.

Pesticides in a single oral dose are usually more toxic to female than male rats. Although toxicity is influenced by sex, this may vary for different animal species. Compounds also vary as to their toxicity in different age animals. In 1965, Lu and his co-workers[3] reported that in rats given a single oral dose malathion was more toxic in newborn rats than in adults. DDT and dieldrin in a single dose were more toxic to adults than to newborn rats. In acute oral toxicity studies conducted by the author the herbicides atrazine, simazine, and paraquat were more toxic to adults than to weanling rats. On the other hand, the synergist sulfoxide and the insecticide famphur were more toxic in weanling rats than in adults.

The interaction of pesticides may be of practical as well as theoretical significance. Two compounds may (1) be simply additive (2) antagonistic or (3) potentiate one another. The effect is usually additive. Antagonism between two compounds has been demonstrated between some chlorinated hydrocarbon and organophosphorus pesticides and between some chlorinated hydrocarbons and drugs.[4,5] This antagonism is associated with liver microsomal enzyme induction. When the combined effect of two compounds is greater than additive they are said to potentiate each other. EPN and malathion have been shown to produce a 50-fold potentiation in oral toxicity of these two compounds in dogs.[6] Dioxathion and trichlorfon will also do this with malathion. Potentiation between compounds has to be considered in establishing food tolerances and labeling restrictions for pesticides.

Measurement of Toxicity

In evaluating the toxicity of pesticides in man it is, of course, important to have as much data as possible from studies in humans. However, since it is practical to do only limited studies in man with pesticides, most toxicological information must be obtained from investigations in laboratory animals. In establishing dose-response relationships, types of toxicity tests include determination of the 1-dose LD_{50} (acute), 90-day exposure (subacute), and chronic exposure. The LD_{50} is a statistically calculated value which represents the best estimation of the dose required to produce death in 50 percent of the test animals. It is, therefore, always accompanied by some means of estimation of the error of the value, such as the probability range of the value.[7] If the LD_{50} for compound B is greater than that of compound A, compound B may be said to be less potent than compound A. The slope of the dose response curve is most significant when comparing two or more compounds. The LD_{50} for compound A may be greater than for B and the LD_5 for compound B be greater than that for compound A. Each LD_{50} determination usually involves about four or more dosage levels of the test material selected at a certain geometric or logarithmic interval with each dosage level being given to several animals. The most commonly used methods for calculating LD_{50} values are those of Litchfield and Wilcoxon[8], Miller and Tainter,[9] and Weil.[10] The author uses the method of Litchfield and Wilcoxon[8] which employs the use of logarithmic probit graph paper with the dosage levels in logarithms plotted against percent mortality in probits. A straight line is fitted to the plotted data so that the LD_1 or LD_{10}, etc., as well as the LD_{50} value can be read from the line. The ED_{50} (effective dose for 50 percent of test animals), EC_{50} (effective concentration in air or water for 50 percent of the test animals) and the LC_{50} (lethal concentration for 50 percent of the test animals) can be calculated in the same was as the LD_{50}. The ET_{50} or LT_{50} (the time required to produce an effect or death in 50 percent of the test animals) can be calculated according to the method of Litchfield.[11]

Ninety-day studies may involve daily dosing, or in the case of oral exposure the pesticide may be fed as a component of the diet. Hayes[12] described the application of a 90-day feeding study with an acute oral toxicity study to arrive at a chronicity factor for a compound. The factor is calculated by dividing the 1-dose oral LD_{50} in mg/kg by the 90-dose LD_{50} value in mg/kg/day. The chronicity factor is useful for comparing the cumulative toxicity of various pesticides in laboratory animals. Of the pesticides evaluated in this way some of the chlorinated hydrocarbons show the greatest degree of cumulative toxicity. The organophosphorus pesticides show little cumulative toxicity and some of the carbamate insecticides have chronicity factors of less than one. Ninety-day studies are also useful for evaluating the effect of continuous pesticide exposure upon growth, symptomatology, hematology, and pathology in laboratory animals.

Chronic exposure studies (usually up to two years in rats and longer in animals with longer life spans) are used to evaluate the effect of long-term exposure to pesticides such as the possible development of carcinogenesis. There are also special tests for evaluating the sensitization, eye irritation, neurotoxic, teratogenic (including effect on reproduction) and mutagenic effects of pesticides in animals.

Selective Toxicity

Albert[13] defines selective toxicity as the injury of one kind of living matter without harming some other kind with which the first is in intimate contact. The living matter to be injured may be referred to as the uneconomic species, and the matter which is to be unaltered as the economic species. This characteristic of certain compounds is significant in the field of chemotherapy in man in that it allows the elimination of certain organisms without injury to the host. Selective toxicity of pesticides makes it possible to use many of them effectively without injury to man. Diazinon, an effective pesticide againse roaches, has an LD_{50} of only 2 mg/kg for roaches compared with 40 mg/kg for mice.[14] The LD_{50} for malathion in mice is 815 mg/kg but only 30 mg/kg in house flies.[14]

Pesticides may be more toxic to insects than mammals because of species differences in rate of absorption, metabolism, or excretion. Mammals generally have a much better enzyme system for degrading pesticides than do insects. This may be illustrated by studying malathion, a relatively inactive compound. It is rapidly oxidized to the active malaoxon in both insects and mammals. However, the toxic malaoxon is hydrolyzed slowly in the insect and rapidly in the mammal to non-toxic products. The hydrolysis and binding of malathion itself is slow in insects but rapid in mammals.[7]

Factors Affecting Absorption

Some of the factors affecting the absorption of poisons by the oral route are the type of solvent used for the compound, the dilution of the dose, and the fasting state of the animal. Some solvents are more readily absorbed from the gastrointestinal tract than are others. Ferguson[15] reported that the death rates from 12 different drugs given orally to mice and rats were higher the greater the dilution of the dose in water. The absorption rate of a compound is generally considered to be greater in a fasted than in a non-fasted animal.

Dermal absorption is influenced by compound, type of solvent or physical state of the material, size of area of application, and condition of the treated skin. O'Brien and Dannelley[16] studied the rate of penetration through rat skin of DDT, famphur, carbaryl, malathion, and dieldrin and found that the penetration rates of the compounds increased in the order given. The vehicle in which the compounds were given also influenced the penetration rate which increased in the order corn oil, benzene, acetone. Fredriksson[17] demonstrated in guinea pigs dosed dermally with sarin that the time from dosing to respiratory arrest in the animals decreased as the area of application of the poison was increased. The dermal toxicity of parathion in rats was significantly increased when the skin was abraded by stripping with cellophane tape to remove the stratum corneum just prior to dosing.[18]

The respiratory toxicity of a compound is affected by the physical state of the material. The efficiency of respiratory absorption of compounds increases in the order of sprays, dusts, and gases. Particle size is of great importance. Particles in excess of 20 µ in diameter are seldom inhaled. The upper respiratory tract tends to capture particles between 5 and 10 µ size. The alveoli are most efficient in capturing particles of 0.1 to 3 µ in size.

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HAZARDS TO AND PROTECTION OF INDIVIDUALS WHO MIX OR APPLY PESTICIDES

Homer R. Wolfe

Man is often subjected to relatively high levels of pesticide compounds when he is actively engaged in pest control operations or working directly with the compounds in formulating plants. Experience has shown that if proper precautionary measures and directions are followed, even the more toxic compounds can be handled safely. Although illnesses and even deaths from pesticides occur each year in the United States, it should be pointed out that most of these cases are caused by carelessness or by accident.

The more extensively used modern synthetic insecticides are the organophosphorus, chlorinated hydrocarbon, and carbamate compounds. Generally, the acute toxicity of the organophosphorus group is somewhat greater than that of the chlorinated hydrocarbon or the carbamate compounds. However, the chlorinated hydrocarbon compounds, due to their greater stability, present more of a residue problem. The estimation of hazard to workers who come in contact with pesticides is based primarily on the observed acute dermal, and to a less extent oral, toxicity of these compounds to experimental animals. Where it is available, use experience is considered. The estimated relative acute toxic hazard to spraymen for a number of pesticides can be seen in the table. The classification into toxicity groups is both approximate and relative. It should be noted that these toxicity categories are not related to specific categories spelled out for label requirements.

Much of the safety in relation to pesticides rests on the user or applicator of the compounds. If he is knowledgeable concerning pesticides and understands the importance of taking proper precautions, he can do much to insure the safety of himself and others. This also applies to workers involved in the manufacture and formulation of toxic compounds. Their contact is usually with the more concentrated forms of pesticides; therefore, they should be especially aware of the need for protecting themselves from exposure. Thus, an important adjunct to safety in relation to pesticides is education, not only of supervisory personnel but also of those individuals who actually handle the materials.

There are several very important indirect ways of protecting the worker such as providing education and medical supervision, stressing the importance of personal hygiene and cleanliness, the importance of not being careless, and pointing out the need for reading and following directions on the pesticide label. However, these topics will be covered by other presentations on this program. The main purpose of this presentation is to discuss the more direct protection of the various routes of entry of pesticide into the body. Protection of these routes means prevention of exposure and prevention of exposure is undoubtedly the best insurance against poisoning.

ROUTES OF ENTRY

There are four routes of entry of pesticide compounds into the body: (1) dermal, (2) respiratory, (3) oral, and (4) through cuts or abrasions in the skin.

DERMAL ROUTE

The dermal route is considered to be the most important route of entry into the body during most exposure situations in the field and probably plays an important part in exposure of workers in formulating plants. This route is one that has undoubtedly been responsible for a great many poisonings of workers, especially from the more toxic organophosphorus compounds.

In research studies we have measured the potential exposure of several hundred pesticide applicators, and the results indicate that over 97% of the pesticide to which the body is subjected during most exposure situations, and especially to applicators of liquid sprays, is deposited on the skin. It should be understood that any given amount of pesticide is more rapidly and more completely absorbed by the oral or respiratory routes. However, absorption of pesticides by these two routes is probably too small a fraction of the total potential exposure to be considered the main factor in most poisoning cases of workers in the field.

The importance of protecting specific body areas has not been clearly defined in the past. This is because the rate of absorption of different compounds through human skin is difficult to measure with any degree of accuracy. The most useful and probably most accurate estimations or measurements on the percutaneous penetration of pesticides in man which have been accomplished thus far have been made by Maibach and Feldman.[1] Using radioactive labeled pesticides they were able to determine approximately what fraction of an applied dose would be absorbed through the skin. In this way they not only compared the degree of dermal absorption for certain pesticides but also compared absorption of a single pesticide for different parts of the human body. The results obtained indicate that sufficient importance may not have been attached to protection of certain body areas. In checking dermal penetration of parathion at different body areas these researchers found that the area of greatest absorption on man is the scrotum where approximately 100% of an applied dose was absorbed. The possibility of pesticide on this body area being completely absorbed is a very important point and emphasizes the need for increased concern about protection of the area. Of utmost importance would be the need for extreme caution in order to avoid spillage of highly toxic liquid pesticide onto the scrotum.

Although cloth coveralls or trousers provide a reasonable amount of protection where contamination does not easily penetrate clothing, the wearing of waterproof trousers provides the best protection for the lower trunk and leg areas and is especially recommended in work situations where there is a chance of liquid spillage, soaking by continued contact with more dilute liquid sprays, or penetration of clothing through excessive contact with dry pesticides. In formulating plants where the main outer protective garment is usually cotton coveralls, workers should be required to wear waterproof aprons, especially if they are on duty at bagging or mixing stations where there is often considerable contamination down the front of the clothing with relatively concentrated wettable powder formulations. Fortunately, many plants require the use of aprons. Even when the waterproof apron is used it is very important that the worker change to freshly laundered clothing each day in order to prevent contamination of the scrotum or other skin areas. Needless to say, use of clean clothing and daily bathing in an effort to avoid excess dermal absorption are essential in any type of exposure situation.

Protection of the upper trunk and arms from contamination by toxic pesticides is important, especially under conditions where heavy spray drift may thoroughly wet cloth shirts, coveralls, and underclothing or where concentrated dry pesticides come in contact with clothing and skin in formulating plants. Our studies have shown that the greatest potential contamination of spraymen in this general body area is the upper back, shoulders, and forearms of workers operating equipment which propels spray up into the air where it is more subject to drift. Under these conditions a waterproof jacket or raincoat provides the best protection for this general body area. This gear is usually worn during cooler conditions, but as the temperature rises and the clothing becomes unbearably hot to wear, workers tend to discard them and work with much less protection--perhaps only a short-sleeved T-shirt-type undershirt on the upper trunk area. Under such conditions workers should be encouraged to at least wear a long-sleeved cloth jacket that will not be easily penetrated by pesticide, and preferably one that can be properly washed.

The wearing of long-sleeved heavy grade "GI" cotton shirts or coveralls as outer clothing during hot weather, often with no underclothing, is popular with many applicators even though this is not a recommended practice. Fortunately, these items of outer clothing provide a reasonable amount of protection where spray drift is light with very fine droplets that do not wet through to the skin. Under such conditions the clothing should be changed and laundered daily. If clothing used during spraying such as shirts, jackets, or coveralls are merely hung up to dry after work and used repeatedly, as is often the practice, it doesn't take long for the pesticide material to work through where it will make contact with underclothes or skin.

In selecting protective clothing for workers it is important to take into consideration the comfort of the individual when he wears such items. The conventional black or dark green rubberized or plastic waterproof jackets in common use during past years are considered by many applicators to be uncomfortable to wear not only because of greater heat absorption but also because they may be of heavy grade material and not very flexible. During recent years, however, several jackets and jacket-trouser combinations that are lighter in color and weight have been available. Although less durable, they are less costly to replace. Nevertheless, there is still considerable discomfort in wearing any waterproof clothing during hot weather because of the trapping of body heat.

Observations of pesticide applicators have indicated that although waterproof clothing items, and especially jackets, are usually carried by the workers, or readily available to them, they usually will not don the clothing until drift of pesticide increases to the point where they feel protection is necessary. Unfortunately, by this time there is often considerable contamination of skin and clothing. The covering of contaminated skin areas by waterproof clothing may create conditions under which dermal absorption may be increased. This may be more important during hot weather where high temperatures and perspiration are involved. Whether or not there would be less absorption under these conditions than if the clothing were left off entirely depends upon the potential exposure which might occur after the worker puts on the clothing. Maibach and Feldman[1] found that covering up (occlusion) of contaminated skin with thin plastic wrap material caused approximately a four-fold increase in absorption of parathion. Although the increase of absorption of pesticide by covering contaminated skin with various items of protective clothing is not known, the above occlusion test results are cause to emphasize the need to put on protective gear <u>before</u> the skin has been contaminated to any great degree.

The use of waterproof jackets in pesticide formulating plants is not common and generally not considered a requirement if, as stated earlier, rubber aprons are worn and coveralls are kept clean. It should be noted, however, that in a plant there is more ready access to showers and other means of decontamination, should excess exposure occur, than in the field where applicators work.

Results of the dermal absorption studies noted above indicate that the head-neck area should be given more attention. In this area absorption of parathion was found to be from 32 to 47% of an applied dose;[1] much more than we would have anticipated and more than at other areas of the body studied with the exception of the armpit and scrotum. When observing either pesticide applicators or workers in formulating plants it is easy to conclude that the face-neck area is less protected than most other parts of the body. Head coverings or caps used in formulating plants are often made of material that allows easy penetration of pesticide onto the scalp. The headgear may have no bill or brim which would provide some added protection to the face-neck area, especially from pesticide material which drifts downward.

Protection from downward drift is especially important during application of liquid sprays. The headgear most commonly used by pesticide applicators is the billed cap which provides some protection for the face but very little for the remainder of the head-neck area other than the scalp. The conventional "Sou'wester" rain hat, often used when heavy downward drift occurs, does not provide exceptionally good protection for the face and sides of the neck. This is because of the narrow brim in all areas except at the back of the neck. Metal or fiber "hard hats" are also used to some extent; however, most have too narrow a brim to provide adequate protection. "Hard hats" which allow circulation of air over the head under the hat should not be used where exposure is to toxic dusts.

Our studies have shown that the greatest protection from downward drift of pesticides is afforded by some type of wide-brimmed hat, preferably made of water-repellent material. Waterproof hats, other than the "Sou'wester," were not readily available at that time. However, one is now available which is waterproof and also has a wide brim that affords good protection of the face-neck area. This type of hat should be recommended for use by all applicators who may be subjected to downward drift of pesticides.

Of particular interest in relation to exposure of the head-neck area is the finding by Maibach and Feldman[1] that absorption of parathion is relatively efficient (47% of applied dose) in the ear canal. Exposure in this area could occur through drift of fine pesticide mists or dusts or by digging in the ear with the tip of a contaminated finger. Of particular importance is the potential for drift into the ear of concentrated dry formulations of toxic compounds in the formulating plant.

It is of importance to note that wearing goggles and respirators provides considerable protection to the face.

Although a statement suggesting the use of goggles can be found on certain pesticide labels, they are rarely worn except by pilots who apply pesticides by aircraft. Questioning of pilots has revealed that they wear goggles not only to prevent poisoning and to keep wind out of the eyes but also to prevent certain organophosphorus pesticides that are direct inhibitors of cholinesterase from causing miosis. This is understandable because it has been shown that unilateral contamination of the eye with TEPP may cause pilots to inadequately judge distance.[2] The incoordination which may accompany this could be a serious threat to safety.

The hands are often the body area having the highest exposure to pesticides and they have a greater chance of coming in contact with the more concentrate formulations. They are also more subject to cuts or abrasions, which will be discussed later.

High potential exposure to the hands brings attention to the need for wearing gloves. Some people who have worked with pesticides feel it is better not to wear gloves than to wear gloves that are contaminated on the inside; something which invariably occurs to some degree. Our research concerning the use of protective gloves indicates that, unless there is gross contamination of the inside of the gloves, the potential exposure is less when wearing gloves than when not wearing them. If gloves are kept clean on the inside there is very little doubt concerning the value of their use when handling pesticides. Unlined rubber gauntlet gloves provide the best protection because the gauntlet covers the wrist area not normally covered by the jacket sleeve and they can be turned wrong side out for proper cleansing of the unlined inside surface.

Waterproof shoes or boots should be worn when handling or applying pesticides on a large scale. During liquid spray operations the ground cover of weeds, grasses, or other plants invariably becomes wet with dilute pesticide regardless of whether or not it is the target of the application. Shoes quickly become contaminated when walking through such plant growth. When leather shoes become wet with spray material they have a tendency to become cracked and dried out to the extent that pesticide easily penetrates through to the sock or foot. Both leather and canvas shoes absorb chemicals and may hold them in contact with the wearer. Boots should be washed and dried thoroughly, inside and out, as frequently as needed to remove any pesticide contaminant.

Workers in pesticide formulating plants should wear waterproof boots. Coverall pant legs should be worn outside the boot tops to prevent sifting of dry concentrated pesticide into the footwear.

RESPIRATORY ROUTE

Protection of the respiratory route is especially important where toxic dusts and vapors or very small spray droplets are prevalent, or where application is in confined spaces. Extremely fine particles and droplets found in dusts and mists are much more easily drawn into the respiratory system than the larger droplets formed by most conventional dilute spray machines. Our tests have shown that when operating an 8X (eight times the normal dilute concentration) concentrate airblast machine in fruit orchards the potential respiratory exposure is nearly 3 times greater than when operating the conventional dilute machine.[3]

Respiratory protection for most types of application can be provided by use of cartridge-type respirators or, in certain cases, gas masks with special cannisters which have greater adsorbent capacity than the cartridges. Applicator pilots who risk the possibility of flying through drift of fine droplets or dusts should use a face mask equipped with a filter cannister and attached either to their belt or to the inside of the cockpit. When fumigating or applying highly toxic pesticides in confined spaces it is advisable to use a respirator with a special compressed air supply tank so that none of the contaminated ambient air is inhaled.

Proper care of respirators is very important to the protection of the workers. The rubber face-piece becomes hardened and the head straps lose their elasticity with age and exposure to heat and sunlight. These conditions lead to poor fit and allow leakage around the face-piece. Two of the more common offenses in the care of respirators that we have observed are (1) failing to occasionally wash the face-piece with soap and water and (2) neglecting to change the filter cartridges or cannisters regularly. Washing of the face-piece of a cartridge-type respirator should not be attempted while the cartridges are in place as moisture may contact the activated charcoal filter material and reduce its effectiveness in adsorption and absorption of pesticides. Solvents should not be used as a cleaner for they may damage certain parts of the respirator. The general recommendation is that cartridges should be changed after 8 hours of continuous exposure. In most application situations this leaves much up to the individual worker to keep a record of his respirator exposure time. In a formulating plant where hours of exposure are more regular this is more easily controlled under the guidance of a foreman. Under conditions of intense exposure the useful life of the cartridge is much shorter. Thus, if the breathing seems hampered, or if the odor of pesticide is detected, the filter cartridges should be changed immediately. If the outer filter pads are separate removable units they should be changed more frequently than the cartridges.

During discussions of the respiratory route of entry into the body the question is often raised concerning the hazard of smoking pesticide-contaminated cigarettes. We have found it difficult to measure such potential exposure with any great degree of accuracy. The technique we have utilized thus far involves subjecting the cigarettes to normal handling through the process of removing them from the pack and placing them in the mouth, lighting them, and smoking one-half the cigarette. The remainder of the cigarette is then analyzed for pesticide content. The values obtained are based on the assumption that pesticide on the cigarette will be volatilized before being broken down by burning and that none of the volatile or particulate pesticide would be trapped in the butt end of the cigarette. In observing smoking by workers it was noted that the area of greatest contamination of the cigarette was far enough from the butt end to allow burning of the contaminated area in most cases.

In studies of cigarette contamination by spraymen applying endrin in orchards, the potential exposure through smoking during application operations was calculated to be not more than 0.002 mg per cigarette, even when the cigarettes were handled with hands wet with the dilute spray.[4] In later studies[5] involving spraymen applying parathion to apple orchards by airblast machines, from 0.003 to 0.005 mg of parathion per cigarette could be recovered where they were handled with hands that were contaminated but dry. When handled with hands that were wet enough with dilute spray to leave moist spots on the cigarette paper from 0.020 to 0.050 mg could be found. In a controlled study designed to determine what might be the maximum contamination of cigarettes through such handling, hands were dipped in 45% emulsifiable concentrate parathion, the hands wiped off lightly on the trousers, and the cigarettes were handled to simulate smoking. The highest value found was 0.235 mg per cigarette.

Even though values for potential respiratory exposure through smoking contaminated cigarettes may not appear to reflect any great hazard, two important points must be kept in mind: (1) Pesticide entering by the respiratory route is practically 100% absorbed, and (2) There is no assurance that a more toxic breakdown product will not be formed and inhaled as the high temperature of a burning cigarette reaches the contaminated areas rather than complete destruction of the compound by burning. For example, in the case of parathion the oxidation product, paraoxon, is estimated to be much more toxic than the parent compound, possibly 100 to 500 times more toxic. This could be an important factor as far as hazard is concerned and emphasizes the need for recommending washing of hands and face before smoking.

ORAL ROUTE

There has been little experimental work conducted to define the magnitude of oral exposure. We are studying techniques at the present time. Analysis of saliva samples of exposed individuals appears to give some indication of contamination.

The most serious oral exposure may be brought about by splashing of liquid concentrate into the mouth while pouring and measuring pesticides. Contamination may also occur through licking the lips, by rubbing the mouth with contaminated arms or hands, by careless actions such as attempting to blow out clogged spray nozzles with the mouth, or by eating or drinking with contaminated hands. Workers should wash hands and face before eating, drinking, or smoking.

ENTRY TRHOUGH CUTS OR ABRASIONS

This route of entry is one that may not have received enough attention in the past. Cuts and abrasions occur most frequently on the hands, and unfortunately the hands are the body area most often in contact with the more concentrate forms of pesticides.

Any break in the skin may allow a more direct route of entry into the blood stream. Even if the outer layer of dead cells (strateum corneum) of the skin is removed by scratching or scuffing the result may be a potential for increased absorption at that site as this layer of cells is considered the main barrier against chemicals. Maibach and Feldman[1] found that when most of these cells were removed by abrading through repeated application and removal of sticky tape, the absorption of parathion applied to the forearm could be increased more than 8-fold. There have been poisoning cases suspected as having been a result of entry through cuts or abrasions. However, there has not been enough evidence to definitely prove that this route played the major part in the illnesses.

DISCUSSION

Regardless of how specifically the measures for protection of workers from exposure to toxic pesticides may be stated for any particular situation, people who work with such compounds must realize that there is some element of risk involved. Accidents occur, even among workers who are careful. In case of accidental gross contamination of skin with a highly toxic compound every effort must be made to cleanse the contaminated area as quickly and as thoroughly as possible. The best recommendation at present is the use of plenty of soap and water. If pesticide gets in the eyes they should be thoroughly flushed with water for at least five minutes. If a person should feel ill while working with pesticides he should stop work at once and get medical attention. If his illness is diagnosed as being caused by a pesticide he should not return to work until a physician advises that it is safe to do so.

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ESTIMATED RELATIVE ACUTE TOXIC HAZARDS OF PESTICIDES TO SPRAYMEN

The estimates of hazards in this table are based primarily on the observed acute dermal and to a less extent oral toxicity of these compounds to experimental animals. Where it is available, use experience has also been considered. It should be noted that the classification into toxicity groups is both approximate and relative. These toxicity categories are not related to specific categories spelled out for label requirements.

MOST DANGEROUS	DANGEROUS	LESS DANGEROUS*	LEAST DANGEROUS
Bidrin	Aldrin	Akton	Abate
Carbanolate (Temik)	Azodrin	Azinophos-Methyl (Guthion)	Alar
Carbofuran (Furadan)	Baygon	Binapacryl (Morocide)	Aramite
Dasanit	Bidrin	BHC	Bromophos
Demeton (Systox)	Bux	Chlordane	Captan
Disulfoton (Di-Syston)	Carbophenothion (Trithion)	Ciodrin	Carbaryl (Sevin)
Dyfonate	Dichlorvos (DDVP)	Coumaphos (Co-Ral)	Chlorobenzilate
Lannate	Dieldrin	Diazinon	2,4-D
Mevinphos (Phosdrin)	Dioxathion (Delnav)	Dicapthon	DDT
Monitor	DNOC	Dichloroethyl ether	Dicofol (Kelthane)
Parathion	DNOSBP	Dichlorvos (DDVP)	Dilan
Phorate (Thimet)	Endrin	Dimethoate	Dinocap (Karathane)
Schradan (OMPA)	EPN	Dinobuton (Dessin)	Diquat
TEPP	Methyl parathion	Endosulfan (Thiodan)	Gardona
Zinophos (Cynem)	Nicotine	Ethion	Malathion
	Paraquat	Fenthion (Baytex)	Maneb
	Pentachlorophenol	Fundal	Methoxychlor
	Phosphamidon	Galecron	Mirex
	Zectram	Heptachlor	Morestan
	Zolone	Imidan	NAA
		Lead Arsenate	Omite
		Lindane	Perthane
		Naled (Dibrom)	Phostex
		Oxydemetonmethyl (Meta-Systox-R)	Piperonyl butoxide
		Ruelene	Ronnel (Korlan)
		Toxaphene	Rotenone
		Trichlorfon (Dipterex)	Sulphenone
		VC-13	TDE (DDD)
		Vapam	Tedradifon (Tedion)

*The fumigant compounds acrylonitrile, D-D, or Vidden D, and Telone have toxicities which would indicate their placement in the "Less Dangerous" category. However, special note should be taken of the fact that the volatility of these compounds and their capacity to produce irritation of skin, eyes, and other tissues indicate that appropriate caution should be exercised in their use.

SELECTION OF THE PROPER PESTICIDE

Donald A. Eliason, M.P.H., Dr.P.H.

1. Define the problem

Before attempting to choose the proper insecticide for a particular job, that job must be defined. Although this statement should not have to be made to anyone engaged in pest control, all too often the failure of a chemical control measure or unexpected side effects may be due to failure to clearly define the problem. Chemicals now used for pest control are more specific in their action than similar compounds only a few years ago. It is therefore essential that the specific problem be defined. Doing so can greatly simplify the process of choosing the proper pesticide.

2. Consider non-chemical control measures

With our ever-increasing problem of pollution, it becomes imperative that non-chemical control measures be used wherever possible. Culture methods, water management, biological control agents, and other non-chemical control methods should be considered before resorting to chemical control.

3. Chemical control - the label

When considering the chemical for the job, use only those compounds that are labeled for control of the specific pest in the specific situation you have defined. In addition to the label, you should also check your local State restrictions on pesticides. Many states have now passed laws restricting certain compounds.

Years of research have provided background for the label and its warnings and restrictions should be heeded.

The label contains much information including: the concentration and chemical name of the active ingredient and the amount of inert ingredients; a listing of pests, crops, and methods of application for these situations; restrictions on the number of days a compound may be sprayed on a crop before harvest; and warnings of hazard to humans, animals, plants, and property.

4. Chemical control - choice of the proper pesticide

Once the pest problem has been defined, non-chemical methods have been considered, and information has been gathered on compounds that are labeled for the use intended, a decision must be made on which compound to purchase and use. Elimination of compounds not labeled for that use has reduced the number considerably. Factors that now become important are:

a. The compound must be effective against the target insects.

b. The compound should present the least possible hazard to beneficial insects and other non-target organisms including birds, mammals.

c. The compound should present minimal hazard to humans including the applicator.

d. The compounds must be available in the required formulation and economically feasible to use.

In considering the requirements listed above, it is obvious that some compromises may need to be reached. It should be remembered that every application of a pesticide is a calculated risk.

THE MATHEMATICS OF MIXING AND APPLYING AGRICULTURAL CHEMICALS

John M. Wise

The one problem individuals working with agricultural chemicals always seem to have in common is the mathematics involved in mixing and application of chemicals to obtain a desired effect. This does not have to be such a troublesome task if it is approached in a systematic manner, with a basic understanding of the materials you are working with.

In order to achieve such an understanding, one must first have a knowledge of the terms most often encountered. Hence a definition of these terms follows:

1. Oil Concentrate
   Oil concentrates are liquid formulations containing, preferably, a high concentration of active ingredient. They are generally used after dilution to a practical or convenient low concentration with an inexpensive hydrocarbon solvent such as fuel oil or diesel oil. The concentration may be expressed either in terms of pounds of active ingredient per gallon of concentrate or in terms of percent by weight of active ingredient.

2. Emulsifiable Concentrate
   Emulsifiable concentrates are similar to the oil concentrates with the exception that they contain an amount of surfactant or emulsifier suitably selected to permit dilution of the concentrate with water for practical application. The majority of emulsifiable concentrates, especially those which are used for agricultural pest control, contain the active ingredient expressed in terms of pounds per gallon. Because of convenience to the user, emulsifiable concentrates may be considered the most popular form in which pesticide formulations are used.

3. Dust base or concentrates
   Dust bases or dust concentrates are dry, free-flowing powders containing a high concentration of active ingredient which will vary generally from 25 to 75%. Such products are seldom applied in this concentrated form. They are usually diluted or cut back to a practical concentration with a suitable inert for final application

4. Wettable Powders
   Wettable powders are similar to dust bases with the important difference that they are formulated for dilution into a final spray with water. The speed of wetting of wettable powders when placed in water is made possible by the proper choice of wetting agents which will reduce the surface tension between the particles and the water. Good suspensibility is attained by reducing the particle size, preferably, to below 325 mesh (44 microns). Surfactant types called dispersants are generally added to wettable powders as a part of the regular formulation to prevent the agglomeration of particles and in turn to slow down the rate of sedimentation which occurs as a function of particle size.

5. Dusts
   As the name implies, dusts are very finely powdered dry pesticides. They are formulated to field strength which may vary from as low as 1% to as high as 10% active ingredients, depending upon the potency of pesticide and the rate of application. They must be free-flowing so that they can be accurately metered in application equipment. Particle size may vary although it is usually under 200 mesh (74 microns).

6. Granules
   Granular pesticides are distinguished from powdered pesticides according to mesh size range. It is generally accepted that a granular pesticide is a product which is limited to a mesh size range from 4 mesh (U.S. Standard Sieve Series) to 80 mesh. For any given material (for example, a product labeled 30/60), at least 90% of the finished product must be within this specified mesh range, and the remaining 10% may be distributed on either side of the specified mesh sizes.

   The concentration of active ingredient in granular pesticides may vary from as little as 1% to as high as 40% depending upon the properties of the active ingredient and the characteristics of the carrier or upon other factors such as the potency of the insecticide and the desired rate of application of the finished product.

7. Pounds per Gallon
   Pounds per gallon is a term commonly used to express the amount of active ingredient in a formulation of either oil concentrate or emulsifiable concentrate. For example, an 8 pound per gallon Chlordane solution contains 8 pounds of actual Chlordane in each gallon of solution.

8. Percent by Weight
   Percent by weight is also a term used to express the amount of active ingredient in a formulation. For example, a 20% Chlordane solution contains 20 pounds actual Chlordane for each 100 pounds of solution, or 20% of the total weight.

The actual calculations involved in preparing a finished spray or dust concentration are simple and accomplished by following a set of basic formulas. The following formulas will solve most solution prepara-

(1) Emulsifiable Concentrates - expressed in pounds per gallon

Gallons emulsifiable concentrate to use = $\frac{8.33 \times G \times D}{100 \times C}$

G = Gallons of dilute spray desired
D = Percentage dilute spray desired
C = Pounds toxicant per gallon in emulsifiable concentrate

Example: Make 96 gallons Chlordane .5% solution, using Chlordane 8 pound per gallon Emulsifiable Concentrate

Gallons Chlordane 8 lb./gal. E. C. to use = $\frac{8.33 \times 96 \times .5}{100 \times 8}$ = .5 gal.

Use .5 gallons Chlordane 8 lb./gal. E. C. with 95.5 gallons of water.

Note: To convert from gallons to ounces, multiply by 128.

(2) Emulsifiable Concentrates - expressed in percent by weight

Gallons emulsifiable concentrate to use = $\frac{8.33 \times G \times D}{C \times W}$

G = Gallons dilute spray desired
D = Percentage dilute spray desired
C = Percentage active ingredient in emulsifiable concentrate
W = Weight in pounds of one gallon of the emulsifiable concentrate

Example: Make 5 gallons Diazinon .5% solution, using Diazinon 25% E. C.

Gallons Diazinon 25% E. C. to use = $\frac{8.33 \times 5 \times .5}{25 \times 8.3}$ = .1 gallon

Convert to ounces by multiplying by 128 = 12.8 oz.

The above two formulas will work also on oil concentrates, with one slight change. The 8.33 is the weight of one gallon of water. When oil is used, substitute the weight of one gallon of the oil used for dilution (approximately 7 pounds per gallon).

(3) Wettable Powders

Pounds of wettable powder to use = $\frac{8.33 \times G \times D}{C - D}$

G = Gallons water or gallons finished spray desired
D = Percentage diluted spray desired
C = Percentage concentration of wettable powder

Example: Make 100 gallons of 1% DDT solution using DDT 50% W. P.

Pounds DDT 50% W. P. = $\frac{8.33 \times 100 \times 1}{50 - 1}$ = 17 pounds - add H_2O to ...

(4) Dust Concentrates

Pounds of dust concentrate to use = $\frac{D \times G}{C}$

G = Pounds of finished dust desired
D = Percentage of dust required
C = Percentage concentration of dust concentrate

Example: Make 1200 pounds of 5% Malathion Dust using Malathion 25% Dust Concentrate

Pounds Malathion 25% = $\frac{5 \times 1200}{25}$ = 240 pounds

Use 240 pounds of Malathion 25% and 960 pounds of Inert Dust Base.

In order to apply agricultural chemicals, the first step is to have equipment you are familiar with and know how to operate. Once you have surpassed this obstacle, you can begin the mathematics of figuring the application rate.

Determine first the proper recommended rate of application in either gallons/acre or pounds/acre. If the rate is in gallons/acre, it will usually be expressed in a given percentage of active ingredient. Example, 200 gallons/acre of a 2% Chlordane solution. This is simply a matter of calculating the number of gallons required to do the job and using the formulas already given to mix the proper percentage solution.

The area of application which gives most individuals problems is in rates expressed in pounds/acre. Here again, it need not be made as complicated as we sometimes make it, if we approach it systematically.

First, determine the material you are working with. Is it dust, granular, or liquid? If it is liquid, is the concentration expressed in percent by weight or pounds per gallon?

Next, determine the amount of material to apply per acre. This is easily accomplished by following the following formulas:

(1) Dust or Granular

Pounds to apply per acre = $\frac{A \times 100}{B}$

A = pounds/acre active ingredient recommended for treatment
B = percentage active ingredient in base material

Example: Treat a field with 2 pounds/acre Malathion using 25% Malathion Dust

Pounds to apply per acre = $\frac{2 \times 100}{25}$ = 8 pounds

(2) Liquids expressed in percent by weight

$$\text{Pounds to apply per acre} = \frac{A \times 100}{B}$$

A = pounds/acre active ingredient recommended for treatment
B = percentage active ingredient in liquid concentrate

Example: Treat a field with 1-1/2 pounds/acre Chlordane using 75% Chlordane Emulsifiable Concentrate

$$\text{Pounds of 75\% Chlordane to apply/acre} = \frac{1.5 \times 100}{75} = 2 \text{ pounds}$$

(3) Liquids expressed in pounds/gallon

$$\text{Fluid ounces of concentrate} = \frac{A \times 128}{B}$$

A = pounds/acre active ingredient recommended for treatment
B = pounds/gallon active ingredient in liquid concentration

Example: Treat a field with 2 pound/acre Malathion using Malathion 5 pounds/gallon E. C.

$$\text{Fluid ounces of concentrate required} = \frac{2 \times 128}{5} = 51.2 \text{ oz.}$$

Use 51.2 fluid ounces of concentrate to treat each acre.

In both examples (2) and (3) you should mix this amount of concentrate with enough water to treat the acre of land. The amount of water to use will vary with the output of your spray equipment.

At this point a brief word of warning is needed. All agricultural chemicals are not chemically compatible when mixed together. Before mixing two or more chemicals, check a reliable compatibility chart, such as the one that follows, your state or county agricultural extension service, or the manufacturer of the material. This may save you a respraying job or, even worse, a complete destruction of the crop being treated.

One final formula that will help you as much, if not more than any of the others is:

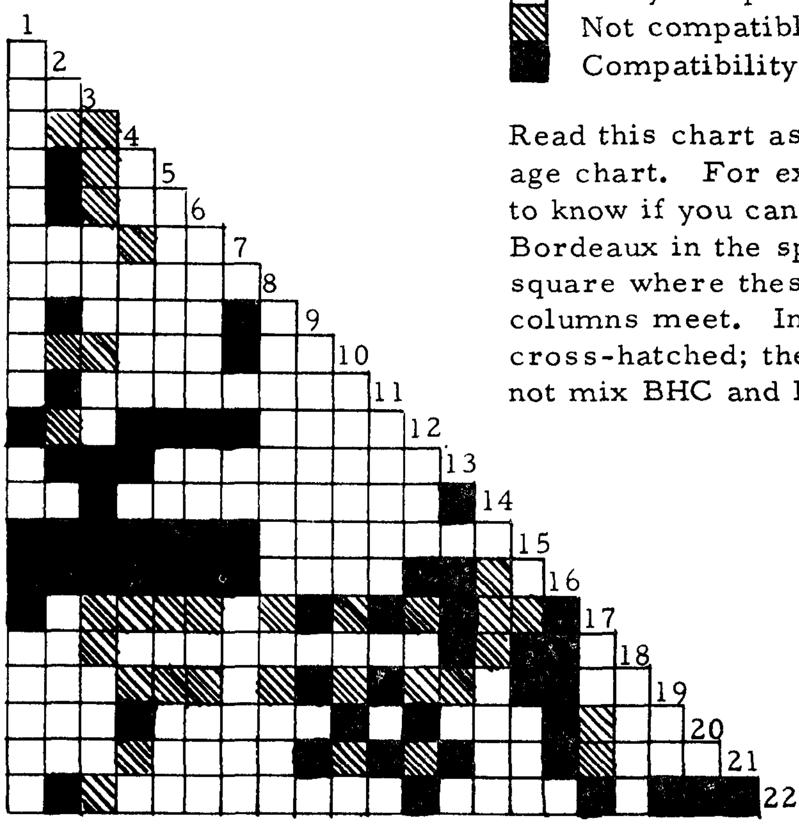
A + B = X

A = 1 pound of chemical
B = 5 pounds of judgment
X = Fewer problems

Compatibility of Common Spray Materials

Alphabetical List of Pesticides

Aldrin-9
BHC-10
Bordeaux-21
Calcium Arsenate-2
Carbamate fungicides-22
Chlordane-9
Copper Zinc Chromate-20
Cryolite-4
DDD(TDE)-8
DDT-8
Dieldrin-9
Dinitro compounds-16
Dormant oils-15
Endrin-9
Ferbam-22
Fixed Coppers-20
Heptachlor-9
Lead Arsenate-1
Lime-19
Lime Sulfur-17
Lindane-10
Maneb-22
Meta-Systox-R-13
Methoxychlor-8
Methyl Parathion-13
Nicotine-7
Parathion-13
Paris Green-3
Perthane-8
Pyrethrum-6
Rotenone-5
Strobane-11
Summer oils-14
Systox-13
TDE-8
Tetraethyl Pyrophosphate-12
Thiram-22
Toxaphene-11
Wettable Limes-18
Zinc Sulfate plus Lime-19
Zineb-22



Fully compatible
Not compatible
Compatibility questionable

Read this chart as you would a mileage chart. For example, if you want to know if you can mix BHC and Bordeaux in the spray tank, check the square where these two lines or columns meet. In this case, it is cross-hatched; therefore, you should not mix BHC and Bordeaux.

SAFE USE OF PESTICIDES ON THE FARM

John I. Freeman, D.V.M., M.P.H.

Pesticides are designed, manufactured, and sold as a product to destroy or alter a biological process, namely those things we classify as pests. However, the selectivity of many pesticides is dependent largely on the applicator and his ability to limit contact to the target organism. Parathion, for instance, is just as effective in killing little children as it is in killing flea beetles on tobacco. This has been demonstrated quite well in North Carolina as well as numerous other states.

Perhaps highly toxic pesticides can be used safely, and it would then be advantageous to keep such in our arsenal of tools against pests. However, I think the amount of illness and death directly attributable to pesticides is somewhat out of proportion. We have no balance in which to weigh the benefits of pesticides, such as food production, recreation, disease control, etc., against the human illness and morbidity. Perhaps it would even be unwise to make such a comparison. The results may be to "cut off our nose to spite our face;" that is, eliminate pesticides only to suffer greater ills at some point in the future.

Assuming that pesticides are essential to our modern society, then we have but one choice; i.e., the use of pesticides in such a way as to give maximum benefit and minimize hazards to human health and the environment. We may be approaching the maximum benefit from the use of pesticides, but we are a long way from minimizing the hazards. Let's look at some statistics we have accumulated in North Carolina. On July 1, 1970, we initiated a voluntary pesticide morbidity reporting system. A specific card was designed and mailed to every practicing physician in the state. By the end of December 1970, 132 of these cards had been returned to our office indicating an exposure either with or without symptoms. Of these 132 cases, 55 were marked as due to organic phosphorous pesticides. As of the end of June 1971, a total of 38 cases have been reported; 9 of these were due to organic phosphorous compounds. Comparing these figures to our list of reportable diseases, pesticides are a major cause of illness in North Carolina. Pesticides ranked seventh numerically in a list of forty reportable diseases. Pesticides as a cause of illness was exceeded by tuberculosis, hepatitis, measles, salmonellosis, malaria (military), and shigellosis. I will be the first to admit that reportable disease data is a rather poor indicator of the true incidence of any disease; however, the above figures have indicated to us that we have a major problem with pesticides-induced illness in North Carolina.

We have concentrated most of our efforts toward determining the "how and why" of pesticides-induced illness at the farm level. North Carolina has the second largest number of individual farmers and thus we have a large population at risk; that is, a high percentage of these farmers use one or more pesticides in their farming operation. In our investigations we have found essentially every way conceivable to misuse pesticides. While this paper is titled "Safe Use of Pesticides," perhaps it is worth our time to explore some aspects of misuse.

It is perhaps unfortunate that the chlorinated hydrocarbon insecticide preceded the organic phosphorous compounds. Farmers, at least in North Carolina, developed rather reckless procedures for handling pesticides during the chlorinated hydrocarbon era. One could dust cotton or tobacco all day with DDT and by sunset look like a snow man, but you con't follow the same procedure with parathion. The attitude, "well, I've done it this way for twenty years," has gotten users of insecticides into trouble during the transition from predominantly chlorinated hydrocarbon to organic phosphorous compounds. These reckless habits are evident not only during the mixing and application but also in attitudes toward transportation, storage, use of protective clothing, and disposal. I think it goes without saying that before we can expect to see pesticides used safely at the farm level, these kinds of attitudes must be changed. Now, how can this be accomplished?

Education is obvious for those that can be educated. Use and application laws are perhaps necessary to protect those that cannot be educated to a reasonable degree for self-protection and safe use. Not only the farmers or users must be educated, but the dealer or seller must also be schooled in the broad area of self-protection and safe use of pesticides. The majority of farmers, at least in North Carolina, acquire their information about pesticides from the dealer and this is generally at the time the product is purchased. Thus it would appear that the dealer, with whom the farmer is frequently acquainted, has the opportune time at which to stress the importance of and, if necessary, give explicit details about safety precautions in mixing, application, protective clothing, storage, and/or disposal.

Use and application laws can have considerable impact on the safe use of pesticides on the farm. The 1971 General Assembly of North Carolina enacted a broad Use and Application Law which will be administered by our State Department of Agriculture and governed by a seven-member policy board. This legislation gives the board authority to promulgate rules and regulations in the area of use and application of pesticides as well as formulation, storage, container design, marketing, transportation, and disposal. Through such legislation some of the inherent dangers can be removed or eliminated, such as parathion in glass jugs or paper labels that can easily be washed off by a rain.

Restricting the use of certain pesticides, generally the more toxic compounds, will affect the safety at the farm level. The legislation previously mentioned restricts the use of certain pesticides in time and place as well as the user or applicator. Under the North Carolina Use and Application Law, the purchaser of restricted pesticides will sign a statement to the effect that he is aware of the dangers of the product and assumes the responsibility of the product. It is quite evident that with a tenant-landowner arrangement, the tenant is frequently subjected to undue hazards due to his illiteracy and the unfortunate results are often justified by, "well, he didn't follow the instructions on the label." The point is that even the most explicit and detailed label is meaningless to a man who cannot read or comprehend the message. Under this law, the landowner will have the responsibility to see that the tenant exercises reasonable safety precautions for self-protection or be liable for consequences. Perhaps this is a hard-line approach to changing the attitudes of some landowners, but it will probably be effective and the results will be a reduction in morbidity and mortality due to exposure to highly toxic pesticides on the farm.

I would now like to relate some of the specific problems we have encountered on North Carolina farms. While most of what we have seen could more correctly be classified as misuse or improper use, we have developed some ideas that we feel are practical at the farm level for safe use of pesticides.

Concentrates

From the standpoint of human exposure, concentrate pesticides are particularly hazardous. Spills that occur while pouring concentrates from the original container to the spray tank are extremely common and perhaps the use of a wide-mouth funnel would prevent a large number of the accidental spills. Yet, farmers object to using a funnel for a simple and justifiable reason; i.e., it collects dust and dirt participles which you then wash into the spray tank and eventually clog up the spray nozzles. This then would require disassembly of the spray rig with probably skin exposure to the diluted material. Thus, the simple suggestion of using a funnel may be totally impractical in a dusty field. Likewise, the use of rubber gloves and a rubberized suit is somewhat impractical in July or August. There is not much value in protecting an individual from exposure to organic phosphorous compounds to the point of heat prostration or sun stroke. So, while the use of rubberized clothing will probably do the job, it is often quite impractical.

If one minimizes the time that concentrate pesticides are on the farm, the likelihood that an accident will occur is also reduced. I have observed teenage tobacco primers and parathion on the same pick-up truck many times; also, livestock feed and pesticides on the same pick-up truck. During the spray season a farmer's pick-up truck frequently serves as a temporary storage facility for pesticides. From the standpoint of safety, we strongly urge that the farmer purchase only that required for the immediate application. It is certainly safer to let the dealer store pesticides until the next application than to haul it around on a pick-up or set it out in the yard.

Another observation we have made appears to be somewhat reversed. Frequently a farmer and one or more teenage children will be applying pesticides and most often the teenager will be recharging the spray tank while the adult is operating the equipment. We had five such cases to occur this year which involved Dysyston and Dasanit. In each case the farmer had reached the conclusion that it was more hazardous to operate the spray equipment than it was to handle the concentrates and recharge the spray tank; thus, the teenager was assigned the less hazardous task. If teenagers are to be employed or, in the case of one's own child, and working during application, they should in fact operate the equipment. While the risk of minimum exposure is perhaps increased, the likelihood of sudden acute illness is probably decreased. Children and teenagers are more susceptible to the effects of organic phosphate compounds than are adults. Therefore, accidental spills are probably less likely to occur when adults handle concentrates, adults are more likely to be cognizant of the danger of a spill, and the risk of acute illness would probably be less for any given accidental spill.

While handling concentrates on the farm, one should always recommend the use of protective clothing, pouring funnels, etc. It should also be stressed that concentrates should be purchased and used immediately, thus minimizing the time they are actually on the farm. Concentrates should only be handled by an adult.

Application

During the past two years we have investigated numerous pesticide cases that were the result of improper application practices. Most of these cases were the result of prolonged exposure from several days to several weeks. Both farmer-applicators and commercial applicators have been involved; however, the epidemiology of these two groups have been almost identical. Careless practices, the path of least resistance, and urge to get the job completed sums up our experience with application cases. More often than not, the operator of a spray rig in eastern North Carolina will be seen with no shirt or mask. It is more comfortable to ride a tractor without a shirt or mask - the path of least resistance. Farmers are notorious for "getting in a hurry" once they finally get started. Many hours may be spent at the local county store in heated debate of topics ranging from A to Z. However, when they finally get on a tractor to apply pesticides, they are suddenly behind schedule and little regard is given to protective measures, wind direction, and resultant drafts. Repair of clogged nozzles or leaking lines are frequently done in the field without gloves or source of water to wash after completing repairs. Commercial applications frequently schedule their work loads to the maximum acreage load of their equipment, which gives little time to consider weather conditions and repairs.

These practices result in excessive exposure during application which have an accumulative effect to gradually lower one's cholinesterase level to the point that symptoms of organic phosphorous poisoning occurs. While it is reasonable to suggest that a farmer select the optimum weather conditions to apply pesticides, this cannot always be accomplished. However, exposure can be minimized by wearing tight weave cotton clothing and a respirator, such as a Wilson, both of which are reasonably comfortable even in extreme hot weather. It is our recommendation that a farmer or commercial applicator completely change clothes at noon and that a change of clothes be carried on the equipment. In the event of an accidental spill in the field, the clothes should be changed immediately and then proceed to the nearest place where water is available.

Clothing

I have heard many discussions and viewed numerous films that recommended a complete rubberized suit including hat, gloves, and boots as the panacea in protective clothing. I am not trying to belittle the value of this type of clothing, but I have learned through experience the limitations of such during hot weather. During the latter part of June of this year, we assisted in the cleanup following a fire which completely destroyed a large pesticide warehouse in eastern North Carolina. Since considerable liquid waste was impounded at the fire site and many tons of granular material was mixed in the rubble from the warehouse, we began by requiring all persons working in the area to wear light weight rain gear plus rubber gloves, rubber boots, and respirators. The temperature was approximately 90 degrees and the rain gear lasted about four hours. While this may have been the best way of protecting the workers against dermal exposure, it was totally impractical. The rain suits were discarded in lieu of long sleeved shirts plus the rubber gloves, boots, and a Wilson-Agratox respirator. The clean-up was completed in six days without anyone developing illness and apparently with minimal exposures. Twenty-four bloods were collected for cholinesterase levels and they ranged from 10 to 17 m/min/ml.

Consideration must be given to protective clothing and each recommendation must be applicable and practical to the given situation. The purpose is either to eliminate or minimize dermal exposure; therefore, the more comfortable the operator can be and still accomplish this objective, the more likely he will be to follow a recommendation.

Availability of Water

It is reasonable to assume that accidents will continue to occur on the farm that will result in dermal exposures. The results of such exposures can range from death to only an irritation or rash of the exposed skin area. While it is more important to give prompt attention to those accidents that involve highly toxic compounds, the procedure that one should follow regardless of the type of compound is the same. The clothing should be immediately removed and one should proceed without delay to the nearest source of water and thoroughly wash the area. Now, it is extremely difficult to get farmers to understand that "immediately" does not mean when they finish a particular field, or waiting till noon time. There are several factors that affect dermal absorption, one of which is time, and this is the only factor over which one has some control once an accidental spill has occurred and the skin has been contaminated.

While water is generally not available in the field, at least in quantities beyond that for drinking purposes, it is usually near by, at least in North Carolina. In an emergency situation a farm pond, stock tank, creek, river, or neighbor's house may be reached in several minutes, thus reducing the time variable and dermal absorption.

Storage

The simple answer to the storage problem is a lock and key. Yet, probably no more than 10% of the farmers in eastern North Carolina store their pesticides under lock and key. A survey of 245 farmers in one county revealed that 10.9% of the farmers actually had pesticides stored in a locked building. This is incredible when this is compared to the number of locked gasoline storage tanks on the same farms. On every farm that had a gasoline storage tank, it was locked.

Most of our experience with improper storage has involved children and contamination of rural wells. We have investigated numerous cases of illness and several deaths that were the results of leaving toxic pesticides, generally parathion, in areas accessible to children. Children drink a liquid and play in the dust and granules. It is quite amusing to a 5-year-old to get a white powder all over him and then play "monster."

We have observed contamination of rural wells due to pesticides being left in close proximity to the well. In most cases, the tractor and spray tank was pulled alongside the well to be filled. The pesticide was added to the tank and the container set down beside the well. Subsequently, the containers were either broken or a child poured it out and contamination of the well resulted.

If pesticides are to be stored on the farm, then the use of a locked building is an effective and practical way of eliminating their accessibility to children. This is a method of protection that farmers are accustomed to and have accepted as effective. The real question is how do you motivate farmers to exercise the same degree of protection for their children and their neighbor's children as they do for a gallon of gasoline? Storage under lock and key is the first step, but consideration must also be given to other commodities within the building, which should not include animal feed or edible products.

Disposal

Disposal of pesticides and/or containers at the farm level is indeed a difficult question. Yet, disposal must be considered as part of the farm safety pesticides program and it must be considered in light of the immediate hazard as well as the long range effect. Much has been said about incineration and compositing of pesticides, neither of which is practical or available to the average farmer. So this leaves the farmer with three methods of disposing of pesticides and their containers, i.e. landfill, burial on premises, and the traditional method of open dump. The open dump method, perhaps more descriptive would be "at site of last use", is by far the most common method of disposal in North Carolina. The survey mentioned earlier indicated that greater than 80% of the farmers who had previously disposed of pesticides or their containers did so by either leaving them in or near the field or discarded with the domestic and farm refuse onto an open dump, generally on the immediate farm.

The landfill method is perhaps the most feasible method available at the present time. Yet without county-wide collection systems, even this is somewhat impractical. Pesticide waste should not be mixed with general refuse nor would it be desirable to have farmers deposit this material at the landfill site on a routine basis. The trend in solid waste management in general is toward area-wide collection systems and landfilling. Once area-wide solid waste management practices are established, it would seem reasonable to integrate the disposal of pesticides and perhaps other hazardous material into the system.

At the present time, the only reasonable avenue of disposal of pesticides and their containers that is available to the farmer is to bury them on the farm. While this may not be the most desirable method, it is the most practical at this point in time. As long as little children continue to experience illness and death, I cannot accept the approach of hold the pesticides and containers until a method better than burying is developed. We have arrived at the following recommendations from our experience in the field.

1. Farmers should purchase only the amount of pesticides required for each application.

2. Excess pesticides should be applied as per recommendations or returned to the dealer.

3. Pesticide containers should be rendered unusable and buried at least eighteen inches deep in a remote area away from sources of water.

These procedures are applicable only when incorporated into an over-all safety program and adhered to throughout the usage season. Should one decide on a general cleanup for the purpose of discarding all unused pesticides and containers, we have suggested that a strong lye compound be added to the liquids to raise the pH to the point that alkaline hydrolysis occurs and the toxicity of the organic phosphate compounds are reduced. The containers and liquids are then buried in a remote area away from a source of water and preferably in an area underlayed with clay.

We recently landfilled both the solid and liquid waste from the fire that I mentioned earlier. This material is in two separate half acre cells. This area will be monitored for several years to determine the movement of pesticides from the landfill site.

There are twenty-seven pesticide formulation plants in North Carolina all of which have no means of disposing their solid waste. Our current plans are to work with these plants in getting this waste material into approved landfills. This perhaps is not the ultimate answer to pesticide disposal but appears to be the only practical approach for the present and the immediate future.

Pesticides and Institutional Environments

Frank S. Lisella,* Ph.D./Eldon P. Savage,† Ph.D./and Harold G. Scott,‡ Ph.D.

Nursing and convalescent homes, hospitals, child-care facilities, mental hospitals, and other institutions have unique challenges as far as environmental control is concerned. The problems involved in maintaining a wholesome institutional environment are magnified by the increased number of persons served and the services provided by these institutions as well as by the increased number of such institutions.

Pesticides are used to alleviate some health problems in institutions, and the use of these chemicals has helped to control many vector borne diseases. They are a necessary part of institutional sanitation programs. It is, therefore, extremely important that sanitarians and other environmental health workers have the latest information on both health hazards and efficiency of various compounds available for pest control.

In addition to the use of pesticides, measures should be taken to prevent the introduction of vermin into institutions. For example, many of the occupants of mental institutions are not capable of keeping their living areas sanitary. These areas can be the foci of insect and rodent problems. Storing foodstuffs (particularly home-cooked foods brought in) in bedside stands may contribute to cockroach problems. Nursing home patients may bring clothing, furniture, and books into the institution from their homes and bring roaches and silverfish in with them. Routine inspections could help prevent these incidents.

Pesticides are applied either by commercial pest control firms or by housekeeping or maintenance personnel in the institution. Whoever is responsible, the instituional environment may pose special problems with respect to pesticide use, and adequate precautionary measures must be taken.

Human Exposure

Before chemical treatment of an infestation, the problem of human exposure to the pesticide becomes a major concern. Pesticides enter the human body through oral ingestion and respiratory and dermal exposure.[1] The size of the dose and the duration of exposure are important in determining what adverse effects any pesticide may have on human health.[2] The institutionalized patient, regardless of the reason for his confinement, cannot afford the extra burden of an illness caused by the improper or careless use of any pesticide. The association between pesticides and human illness has been reported by several individuals in other publications.[3, 4, 5, 6] Thus, the decision to use any pesticide must be based on the potential hazard of the chemical to patients and applicators, health status of the exposed patients, persistence of the pesticide, alternative methods of control, knowledge of the life cycle of the insect or rodent species, and a series of interrelated ecological factors.

These safety precautions should be observed. All persons who use pesticides should know the precautions shown on the label for each compound, and the information should be followed carefully.

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Ideally, pest control operators or maintenance personnel should carry, on their person, records indicating blood type, history of transfusion reaction, significant history of disease such as diabetes, epilepsy or asthma and other allergies including history of drug sensitivities, and the name of any drug taken regularly.[7] If this is not practical, the desired information should be contained in the individual's employee health record. Cholinesterase values should be checked periodically on those individuals who apply organic phosphorous chemicals. Within the administrative framework of the institution, certain individuals should be responsible for advising all members of the professional staff on what types of pesticide compounds are being used, and the appropriate antidotes should be stocked in case of emergency.

Mixing the Chemical

When directed by the container label, persons mixing wettable powders (or applying toxic dusts) should wear protective clothing, gloves, goggles, and an approved respirator. Gauntlet-type gloves made of natural rubber or other approved materials are preferred. The pesticide material should be mixed according to the directions contained on the label. In no case should beverage bottles, fruit jars, or other empty food containers be used to measure or store pesticides. Each year, tragic preventable poisonings occur when children obtain food containers filled with insecticides or other "empty" insecticide containers.[8]

Personal Hygiene

After using pesticides, and before eating or smoking, people must wash their hands. The clothing worn during application of pesticides should be removed and washed after the job is completed and the person should bathe thoroughly. In the event that a pesticide is spilled on the skin, the affected area should be washed with fresh water and medical attention sought immediately. Contaminated clothing should be washed separately before reuse.

Insecticides

There are specific safety precautions for using insecticides and rodenticides in institutions. Insecticides can be classified on the basis of their chemical structure. For example, there are the chlorinated hydrocarbon compounds such as DDT, chlordane, endrin, aldrin, dieldrin, heptachlor, and many others. The organic phosphorous group includes parathion, malathion, diazinon®, fenthion, ronnel, DDVP, dipterex®, and others. Rotenone and pyrethrum are classified as botanical since these chemicals are of plant origin. The carbamate insecticides include carbaryl and baygon®. Specific recommendations for the use of these compounds are outlined elsewhere.[9] The symptoms and treatment for poisoning by these compounds also differ for each class.[10]

Efforts for the elimination of insects must be accompanied by environmental improvement programs in food preparation, storage, and other sections of the institution. Adequate housekeeping procedures should be implemented in the main food service facilities, ward kitchens, special diet kitchens, infant formula preparation rooms, cafeterias, boiler rooms, dumbwaiter shafts, laundry chutes, vending machine areas, laboratories, and other likely places of infestation. Extreme caution must be observed when applying insecticides so that food and food products do not become contaminated with the spray material.

Careful attention should be paid to label instructions on the insecticide container to determine whether or not the chemical is safe for use in rooms, wards, or cells where persons may be confined for extended periods of time The applicator should avoid spraying bedpans, emesis basins, carafes, and other items which may be brought in direct contact with the patients or attendants. When applying pesticides for bedbug control, the mattress must not be soaked with spray. Treatment of infant bedding, including the crib, should be avoided.[9]

Rooms in which oxygen is being administered, or where isolation procedures are in effect, should not be sprayed. Intensive-care units should not be treated while occupied. In the event that it is necessary to treat the grounds of the institution with a chemical agent, humans and animals should be kept off the treated area until it has been well watered and completely dried.

During recent years, metered intermittent aerosol insecticide devices have become available. Of widespread use are those devices which utilize the chemical pyrethrum in combination with piperonyl butoxide as a synergistic agent. In addition to the precautions listed on the label, these devices should not be used in nurseries or rooms where infants, ill or aged persons are confined.

Insecticide-impregnated polyethylene strips containing DDVP (dichlorovos) are being marketed for insect control. These strips should be used in accordance with the instructions on the label, and as an added precaution, they should not be used in rooms where infants, ill or aged patients are housed. Vaporizing devices employing the chemical lindane should never be used in the institutional environment because of the highly toxic nature of this material.

Rodenticides

Rats and mice are a major concern in the institutional environment. The presence of vermin of this type can lead to health and psychological problems among the patients. Rats and mice are usually associated with poor garbage and refuse storage facilities and other insanitary conditions in the institution.

The use of rodenticides may frequently be necessary as an adjunct to environmental improvement programs. Rodenticides may be classified on the basis of their mode of action in the target animal. The degree of safety associated with the various compounds differs. All rodenticides that are to be used within occupied buildings or on the grounds of an institution must be placed where they will be inaccessible to patients. Paraffin-coated baits might be attractive to children; therefore, their use must be carefully supervised.

Because of their high toxicity to man and animals, chemicals such as sodium monofluoracetate (1080) or fluoracetamide should not be used in any structure housing persons.[9] These chemicals should be applied only by licensed pest control operators to outbuildings or other structures which can be made secure against entry by unauthorized persons. Norbormide is a recently developed rodenticide which has a low order of toxicity to man and other mammals except the Norway and brown rat. It can be used safely in the presence of pets, livestock, and poultry.[9]

The low order of toxicity of the anticoagulant rodenticides to man make these chemicals suitable for use in the institutional environment. It appears unlikely that poisoning with these pesticides will occur except with suicidal intent or as the result of gross carelessness and ignorance.[9]

The rodenticide, red squill, is also reasonably safe. This material is a natural emetic for man and animals and is suitable for use against the Norway rats where there is risk of human exposure.

Precautions must be taken when using hydrogen cyanide for rodent burrow gassing. This gas is active in a moist environment; thus, if applied when the burrows are dry, fumes may be liberated for an extended period of time. Frequently, rodent burrows end at buildings on the institutional complex; therefore, caution must be taken so that the gas is not used in an area where there is any possibility that it might escape into a housing unit.

Fumigants

When fumigants such as methyl bromide are to be used, special precautionary measures must be taken. This chemical should be applied only by licensed pest control operators with special training in fumigation techniques. Guards should be posted at all entryways to the building being fumigated before, during, and after the fumigation process. Approved gas masks and other safety equipment should be required.

Storage of Pesticides

As a means of preventing accidents, all pesticides should be properly stored. Areas in which food is prepared or stored — main kitchen, ward kitchen, special diet kitchens, utility closets, and similar locations—are not suitable for storing pesticides.

All pesticides should be stored in a locked cabinet or locked storage area reserved for that purpose in the plant maintenance department or similar location away from the main institutional complex. The area should be inaccessible to animals and unauthorized personnel, and keys should be available only to authorized persons. The storage area or cabinet should be dry and well ventilated, and maintained at room temperature. All pesticide containers should be adequately labeled and tightly closed.[11] Under no circumstances should pesticides be placed in empty food or drink containers of any kind. An important facet of proper storage is the examination of pesticide containers for leaks or damage.[12] If this occurs, the material should be transferred to a leakproof container which is clearly labeled and dated with the same date as the original container. The old container should be decontaminated, made unusable, and disposed of in an approved manner.

Professional pest control operators servicing the institution should be required to keep everything locked in the service truck so that supplies cannot be removed by anyone other than authorized servicemen.[13]

Disposal of Pesticide Containers

The disposal of large numbers of pesticide containers from institutions may pose a problem since used containers might have to be stored prior to collection and transfer to the disposal site. If this is necessary, the empty containers should be stored in a locked, protected area, especially if the labels have been lost and the empty pesticide containers are used for another purpose.[14]

The recommended disposal methods for most types of solid wastes originating from institutions include burial (sanitary landfill) and incineration. The recommended procedure for sanitary landfill operation includes strict engineering practices in site selection, planning, design, and operation. Precautions must be taken so that underground and surface waters are not contaminated. The sanitary landfill operation should include provision for daily covering of the compacted refuse with six inches of compacted earth. The finished landfill should be covered with two feet of compacted earth.[12]

Many pesticide containers can be disposed of by incineration. This involves burning the material in a properly designed incinerator with a stack temperature of 1200 - 1800 degrees F. Many institutional incinerators are not capable of attaining these temperatures: thus, the local health authorities or manufacturers' representatives of the incinerators should be consulted. The incinerator design should also provide for the disposal of gases emitted from combustible materials and the disposal of residual ash. In all situations involving disposal of pesticide containers, state or local health department authorities should be consulted.

Training

The cohesive nature of most institutions creates an ideal situation for conducting pesticide safety training programs. These programs should be directed to all staff levels and should revolve around the safe use, storage, disposal of pesticide containers, and potential hazards to patients and inmates.

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SAFE USE OF PESTICIDES IN VECTOR CONTROL

Harry D. Pratt, Ph.D.

Effective, safe vector control is best accomplished by trained personnel who

1. Know the biology of the vector,
2. Understand the control equipment, its capacity and limitations,
3. Use only approved pesticides, and
4. Read the label and follow directions.

The four major groups of vectors are the rodents, mosquitoes, flies, and fleas. Each group has such different habits, biology, and control techniques that they will be considered separately.

RODENTS

Rodents cause an estimated $100 million to $1 billion economic loss each year in the United States. They are of great public health importance because of rat bites, rat bite fever, salmonellosis, leptospirosis, murine typhus, plague, and other diseases (1).

Rodent control procedures involve

1. Good sanitation (primarily good practices in the storage, collection, and disposal of garbage and refuse, good storage of foodstuffs, and harborage removal),
2. Rodent stoppage, and
3. Rat killing, including trapping and proper use of rodenticides.

The four rodenticides most commonly used to control commensal rats and mice are the anticoagulants, red squill, zinc phosphide, and calcium cyanide.

The anticoagulants, such as warfarin, fumarin, pindone (Pival), diphacinone, and chlorophacinone (Rozol) kill by decreasing the ability of the blood to clot or coagulate (hence their common name "anti-coagulants") so that the rodents literally bleed to death. With warfarin, fumarin, and pindone (Pival), the rodents must eat the anticoagulant baits for four or five days or longer before maximum kill begins. Therefore, the anticoagulants are called "multiple dose poisons". Usually it is recommended that the baits be exposed for two weeks or longer. On the other hand some people feel that rodents may be killed three to five days after one feeding on diphacinone or chlorophacinone anticoagulant baits. More research is being conducted at the present time on this important aspect of commensal rodent control.

The anticoagulants are used either as liquid or solid baits. The liquid baits are usually prepared by adding a package of the powdered anticoagulant to a quart of water for dispensing with chicken water fountains or similar devices. The solid baits are used at the following strengths (2) as shown on the table below.

Table 1. Multiple-dose rodenticides employed against mice, roof rats and Norway rats.

Rodenticide	Percent Concentration		
	Mice	Roof Rat	Norway Rat
diphacinone	0.012-0.025	0.005-0.01	0.005-0.01
warfarin	0.025-0.05	0.025	0.005-0.025
Fumarin	0.025-0.05	0.025	0.025
pindone(Pival)	0.025-0.05	0.025	0.025

Dilution factors:

0.05% (500 ppm) = 1 part of 0.5% concentrate to 9 parts of bait.
0.025% (250 ppm) = 1 part of 0.5% concentrate to 19 parts of bait.
0.01% (100 ppm) = 1 part of 0.5% concentrate to 49 parts of bait.
0.005% (50 ppm) = 1 part of 0.5% concentrate to 99 parts of bait.

Many of the anticoagulants are available as 0.5% concentrates which can be prepared as final baits by mixing 1 part of the 0.5% concentrate with 19 parts of yellow cornmeal or a mixture of yellow cornmeal and oatmeal, scratch feed, or grain to give the final percentage of 0.025% used to control Norway rats. The addition of one part of sugar and/or vegetable oil may make these baits more attractive to roof rats and house mice which are nibblers and have more finicky appetites. Some authorities prefer to use 1 part of the concentrate to 9 parts of bait for controlling mice.

The anticoagulants should be placed in protected places in cardboard, foil, metal, plastic, or crockery containers; in bait boxes, some of which can be padlocked; or in paper or plastic bags, often stuffed down rodent burrows or hiding places. Sometimes these plastic bags are manufactured with an attractive synthetic odor smelling somewhat like vanilla, maple syrup, roast beef, apple, or citrus. Studies are currently being conducted to determine if these synthetic odors increase attraction and bait acceptance. Sewer rats may be controlled by the use of paraffin bait blocks containing these same mixtures of the anticoagulant baits in paraffin. This type of preparation prevents mould formation in the warm, damp sewer environment, and also the washing away of bait in loose grain form when sewers are periodically flooded following rainstorms. The paraffin bait blocks are usually fastened with wire to a masonry nail driven into the sewer wall.

Great care should be taken to keep these anticoagulant rodenticides away from people, particularly children, and pets. No harm is done by a single massive feeding. Even if a child should eat the unappetizing dry bait mixture for four or five days, he can be saved by the prompt administration of whole blood or vitamin K.

Red squill is a single-dose vegetable poison made from the powdered bulb of an onion-like plant, *Urginea maritima*. It has a bitter taste and natural emetic action, factors that contribute to its safe use as a rodenticide. Rodents, unlike humans and most domestic animals, are unable to vomit and are therefore not protected by the emetic quality of the red squill, which kills them by paralyzing the heart. This poison is not well accepted by roof rats and house mice, but it can be used effectively against Norway rats if exposed in a very attractive fresh bait at the beginning of a killing

The usual methods of application are (1) pieces of bread smeared with the liquid red squill, or (2) "torpedoes" or "kisses" made with one part of fortified red squill (with an LD_{50} of 500 mg/kg.) and nine parts of fresh, attractive bait materials such as ground meat, fish, or grains, or a combination of these materials.

The red squill baits are usually placed in rat burrows, in protected places away from children and pets, or scattered over an open dump prior to its conversion to a sanitary landfill.

Zinc phosphide is a single-dose rodenticide which is used at 1% strength, such as 4 oz. of zinc phosphide and 25 lbs. of fresh cubed sweet potato or apple. The baits are placed in rodent burrows, or protected places away from people and pets. In general, people and pets are repelled by the garlic-like odor of the zinc phosphide but Norway rats accept these baits very well.

Calcium cyanide fumigation is used to supplement other methods of rat killing, particularly to kill rats in burrows in banks, under slabs, along railroad tracks, and similar situations well away from buildings. The calcium cyanide dust is blown into the burrows with a foot pump, where the chemical reacts with the moisture in the air or ground to liberate hydrogen cyanide gas which kills both rodents and rodent fleas. This work should be done only by trained personnel wearing masks, always working upwind to prevent the possibility of accidental poisoning with the cyanide dust.

Many other rodenticides such as strychnine, thallium sulphate, arsenic trioxide, 1080, 1081, and Gophacide have been used in the past, but their use is restricted or prohibited today (1, 2, 3.). One promising new rodenticide, norbormide, holds promise as the ideal type of rodenticide since it is lethal to Norway rats, but not to most other mammals including man. Field trials have indicated good kill but erratic acceptance. With new bait materials, or attractants, norbormide may have an important role as a single-dose, safe rodenticide for Norway rats.

MOSQUITOES

Mosquitoes cost the American public $75-$100 million in organized mosquito control programs and much more for repellents, aerosol bombs, and screening by the individual householder to prevent the discomfort, reactions, secondary infections and diseases resulting from mosquito bites. Some of the diseases transmitted by mosquitoes are malaria, yellow fever, dengue, filariasis and the arbovirus encephalitides (4, 5).

Mosquito repellents for personal protection are widely used, including such materials as deet (diethyl toluamide), dimethyl phthalate, Rutgers 612, Indalone, and similar materials. Follow the directions in using these chemicals, either as liquid or aerosol preparations, paying particular attention to keeping them away from the eyes, nose, mouth and other mucous membranes, and synthetics such as watch crystals.

Mosquito larval control includes draining and filling, proper water management, and the use of approved larvicides. Some of the larvicides most widely used include -

1. Fuel oil, preferably with a spreading agent such as T-Det, Triton X-100 or Hercules B-1956 to reduce the application rate to 2 to 5 instead of the usual 15 to 20 gallons per acre.
2. Flit MLO at 1 to 5 gallons per acre, depending on vegetation and the type and temperature of the water.
3. Paris green granules at 15 lbs. of 5% granules per acre.
   Note: in some states the use of this copper-aceto-arsenite is prohibited because it is considered an inorganic arsenical, while in others its use is permitted as an organic arsenical, depending on whether one interprets

4. Organic phosphorus compounds such as -
   Abate at 0.05-0.1 lb. per acre; Dursban at 0.0125-0.05 lb. per acre
   fenthion (Baytex) at 0.02-0.1 lb. per acre
   malathion at 0.2-0.6 lb. per acre
   methyl parathion at 0.1 lb. per acre
   parathion at 0.1 lb. per acre.
5. Methoxychlor at 0.05-0.2 lb. per acre.
6. Pyrethrum at 0.006-0.007 lb. per acre.

Care should be taken in the application of these materials to prevent damage to vegetation or other non-target organisms. To obtain the dosage listed above, *follow label direction carefully. For example, to obtain 0.2-0.5 lb.* of malathion per acre, apply 4 to 10 quarts of 2.5% malathion spray per acre; to obtain 0.1 lb. fenthion per acre, apply 2 lbs. of 5% granules per acre, or 4 quarts of 1.25%, 2 quarts of 2.5% or 1 quart of 5% spray per acre; to obtain parathion at 0.1 lb. per acre, apply one gallon of spray containing 0.1 lb. parathion per gallon per acre.

Adult mosquito control inside homes is usually achieved through proper screening and the use of aerosol sprays containing pyrethrum or allethrin because these insecticides give quick knock-down of the insects, a synergist such as piperonyl butoxide, and a low-toxicity insecticide such as methoxychlor to produce the final kill.

Space spraying is the chief method of achieving adult mosquito control in many communities, through fogging, misting, or most recently, the ultra-low-volume application with airplane or ground equipment. Only two insecticides are currently approved for the ULV aerial method of application:

malathion at 1 to 3 fluid ounces per acre, and
naled (Dibrom) at 0.5 to 1 fluid ounce per acre

Specifications for airplane equipment for the ULV method have been published by Kilpatrick (6) involving special tanks, electrically-driven pumps, spray booms, and 8001 to 8008 Tee-Jet nozzles.

In general ULV applications should be made -

1. When temperatures are below 80°, or before any temperature inversions occur (usually early morning);
2. With droplets averaging 25 to 60 microns MMD (Median Mass Diameter) and at least 10 droplets per inch; and
3. By multi-engine aircraft flying at a height of 100-150 feet, at speeds of about 150 miles per hour, with swath widths of 300-500 feet, or with single-engine aircraft flying at 100-110 mph with pump pressures and nozzle sizes adjusted to provide the 25-60 MMD micron particle size.

Great care should be taken not to fly airplanes over areas with new General Motors type cars with acrylic finishes. Helicopters should not be used over cities because of damage which may result from large particle size, above 100 microns, insecticide droplets, particularly to new automobile finishes.

Other insecticides used in controlling adult mosquitoes are listed in the 1971 Public Health Pesticides as follows (2):

Table 2. Insecticides Employed as Outdoor Ground-Applied Space Sprays

	Lb./acre	
carbaryl	0.2-1.0	Dosage based on estimated swath width of 300 ft. Apply as mist or fog during the dusk to dawn period. Mists are usually dispersed at rates of 7 to 25 gal. per mile at a vehicle speed of 6 mph. Fogs are applied at a rate of 40 gal./hr. dispersed from a vehicle moving at this speed; occasionally at much higher rates and greater speeds. Finished formulations contain from 0.5 to 8 oz./gal. actual insecticide in oil, or, in the case of the non-thermal fog generator, in a water emulsion. Dusts also can be used. For ground ULV application, technical grade malathion is dispersed at a rate of 1 to 1.5 fl. oz./min. and a vehicle speed of 5 mph or at a rate of 2 to 3 fl. oz./min. and 10 mph.
fenthion	0.01-0.1	
malathion	0.075-0.2	
naled	0.02-0.1	

FLIES

Effective fly control can be achieved only by maintaining a high level of environmental sanitation to reduce or eliminate fly breeding sources. These measures can be supplemented by insecticidal treatments, including residual sprays, impregnated fly cords, resin strips, fly baits, and space spraying. Larviciding, which is of such great importance in mosquito control, has been much less successful in fly-control programs (7).

Residual treatments. The chlorinated hydrocarbon insecticides, which were used with great success in the late 1940's, have been replaced by the organophosphorus compounds. Flies developed resistance to the chlorinated hydrocarbon insecticides such as DDT, BHC, chlordane, and dieldrin. In addition, when the chlorinated hydrocarbons were used, residues of these long-lasting insecticides often appeared in milk or meat.

At present seven organic phosphorus compounds are labeled for residual application as discussed in the 1971 Public Health Pesticides (2), and shown in Table 3 reproduced from this publication.

Impregnated fly cords. Commercially manufactured fly cords impregnated with parathion, diazinon, or ronnel have been labeled for use in dairy barns, chicken ranches, and food-handling and -processing establishments. The cords are installed at a rate of 30 linear ft. of cord per 100 ft. of floor space. This method has given effective fly control in dairies, chicken houses, and "pig parlors" for periods ranging from 6 weeks to an entire season. The use of fly cords has not been approved in all 50 states. Resistance to the chemicals in fly cords has developed in some areas.

Fly baits. Quick control of flies for a few days can be achieved by using dry fly baits containing Bomyl, diazinon, dichlorvos, malathion, naled, ronnel, or trichlorfon, and an attractant such as sugar. Dry fly baits can be used in dairy barns or outdoors near food-preparation areas. The baits are placed in trays, jar covers, or permanent bait stations at a rate of 2 or 3 oz. per 1000 ft. of floor surface and are renewed about twice a week. Liquid bait dispensers made from a chicken-watering device and a cellulose sponge have been used successfully in chicken houses. The liquid bait contains 0.1% dichlorvos or trichlorfon in 12.5% sugar solution.

Outdoor space sprays. Spray treatments are employed against flies chiefly in problem areas where residual treatments or larviciding fail to give satisfactory control. This method is frequently used at open dumps and also in disaster areas, such as stockyards where animals have been killed by flooding, or warehouses where large quantities of food have been damaged following flooding or power failure. According to the CDC 1971 Public Health Pesticides (2), six organophosphorus compounds have been labeled for outdoor space sprays: diazinon, dichlorvos, dimethoate, fenthion, malathion, and naled.

Table 3. Organophosphorus Insecticides for Use in Fly Control (2).

Type Application	Toxicant	Formulation	Remarks
		For 50 gallons of finished spray, add water to:	
	Diazinon	2 gal. 25% EC or 16# 25% WP	— Maximum strength permitted 1%. Labeled for use in dairy barns, milk rooms, and food-handling establishments, but not poultry houses.
RESIDUAL	dimethoate	1 gal. 50% EC	— Maximum strength permitted 1%. Can be used in dairy barns (except milk rooms), meat processing plants, and poultry houses.
	Gardona	8# 50% WP or 6# 75% WP or 2 gal. 2#/gal. EC	— Maximum strength permitted 2%. Labeled for use in dairy barns but not poultry houses.
	malathion	2-4.5 gal. 55% EC or 32-64# 25% WP	— Maximum strength permitted 5%. Labeled for use in dairy barns, poultry houses, meat packing plants, premium grade material accepted for use in milk rooms and food-handling plants.
	naled	1 gal. 50% EC	— Maximum strength permitted 1%. For use in dairy abrns (except milk rooms), in food-handling establishments[b], and in poultry houses.
	ronnel	2 gal. 25% EC or 16# 25% WP	— Maximum strength permitted 1%. For use in dairy barns, milk rooms, food processing plants, and poultry houses.
	fenthion	0.7-1.3 gal. 93% EC	— Maximum strength permitted 1.5%. **Not to be used in dairy barns, poultry houses, or food processing plants.**

AVOID CONTAMINATION OF HUMAN AND ANIMAL FOOD AND WATER CONTAINERS. DO NOT TREAT MILK ROOMS OR FOOD PROCESSING AREAS WHILE IN OPERATION. REMOVE ANIMALS FROM STRUCTURE DURING SPRAY OPERATION WHEN LABEL SO ADVISES.

FLEAS

Fleas are annoying, blood-sucking pests whose bites may itch intensely and cause serious discomfort to people, pets, and domestic animals. Some species, particularly the oriental rat flea (*Xenopsylla cheopis*), are of great importance as vectors of plague, murine typhus and other diseases.

The chlorinated hydrocarbons, particularly 10% DDT dust, have been used with great success from 1944 to 1968 to control the oriental rat flea in areas where murine typhus or plague occurred, both in the United States and overseas. However, with the development of resistance to DDT in some strains of the oriental rat, cat, and dog fleas, and the restrictions on the use of this chemical in recent years, alternate insecticides have been used.

The vegetable insecticides, rotenone and pyrethrum, continue to be the insecticides of choice in controlling fleas on kittens, cats, and puppies. Other insecticides which can be used on pets, particularly dogs, are listed in Table 4 from the 1971 CDC Public Health Pesticides (2).

Carbaryl (Sevin) dust, a carbamate insecticide, is widely used to control the oriental rat flea and wild rodent fleas, usually as 2 to 5% dusts. For control of wild rodent fleas in western United States, various formulations such as 3 ounces of 2% carbaryl dust, or 2 ounces of 5% carbaryl dust, per prairie dog burrow have given good control (2).

Table 4. Insecticides Used On Pets For Flea Control (2).

Toxicant	Formulation	Percent Concentration
carbaryl	Dip or wash	0.5
	Dust	2.0-5.0
coumaphos	Dip	0.2-0.5
	Spray	1.0
	Dust	0.5
lindane	Dust	1.0
malathion	Dip	0.25
	Spray	0.5
	Dust	4.0-5.0
pyrethrum	Spray	0.2 + 2.0 synergist
	Dust	1.0
rotenone	Dust	1.0

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THE DIAGNOSIS AND TREATMENT OF ACUTE PESTICIDE INTOXICATION IN MAN

G. A. Reich, M.D., M.P.H.

Pesticide poisoning is reported by the National Clearinghouse for Poison Control Centers at about 5,000-6,000, cases per year. This represents, for t most part, accidental poisoning among children. Many more cases than this occur, especially among pesticide exposed workers, but there are few reports of these. The fatality rate in pesticide poisoning is considerably higher than that seen with the more common agents in poisoning such as aspirin, tranquilizers, and birth control pills.

The incidence of pesticide poisoning varies a great deal from region to region in the U.S.A., being highest in agricultural areas and in urban centers surrounded by agricultural areas.

Poisoning at times occurs on a mass scale when flour, sugar, or the like, become contaminated with pesticides in transit or in storage, since pesticides survive the cooking and baking processes quite well. Examples of these are the food poisoning episodes of recent years in the Middle East, Columbia, and Mexico. Episodes on a much smaller scale have occurred in the U.S.A.

The Community Studies have been conducting prospective epidemiological studies of workers exposed to pesticides to determine if their health is being adversely affected. In addition to this, our Studies provide diagnosti and therapeutic assistance in their local areas to Doctors handling cases of acute poisoning. Most of our reports to date have come from south Texas and south Florida which represent primarily cases of individual poisoning but at times are of group poisoning.

In south Texas, the incidence of poisoning increased for several years, then declined only to rise again. Most cases occurred in June and July during the period of greatest pesticide use. Most cases were among teen-agers and young adults who were employed by farmers and spray pilots to assist in mixing and applying pesticides. Parathion and methyl parathion were the usual agents, and the route of exposure was almost always dermal. Very few deaths occurred, even though pesticides are by far and away the leading cause of poisoning in this area.

The signs and symptoms observed in these cases indicate that a variety of biochemical and physiological functions are altered by pesticides. The central nervous system, cardiovascular system, gastrointestinal system, and musculoskeletal system are the most obviously affected in pesticide poisonin; The diagnosis may be difficult, because of this variety of signs and symptom: which are suggestive of other conditions as well as pesticide poisoning.

In south Florida, poisoning reflects three sorts of circumstances: (1) accidental ingestion by 1 to 2 year old children in and around the house; (2) accidental dermal exposure in occupational exposed workers; and (3) suicidal ingestion in middle-aged to older adults. Numerous pesticides have caused deaths in this area, ranging from old types like Paris Green up to newer pesticides like Zectran. In Florida, pesticide poisoning is a year round phenomenon rather than coinciding with the season of greatest agricultural use of pesticides. This is due to the importance of the accidental cases among children and the suicidal cases among adults. The highest death rates are among adults, but this represents the fact that such a large proportion of these are suicidal. The agents of most importance are the organophosphates, especially parathion, but numerous compounds singly or in combination have been involved. There have been several homicidal attempts with pesticides too, most of which have been successful. In this area, the leading cause of death from poisoning among children is pesticides.

How important pesticide poisoning is in your area will depend upon several factors already noted. Determining what the true incidence is in any particular area may be difficult, because of errors in diagnosis and the lack of an effective system of reporting. Such poisoning is, however, preventable -- though suicidal cases present particular problems.

When one considers that only about 10% of the true incidence of poisoning in the U.S.A. is reported, and that the Poison Control Centers report over 100,000 cases per year, it is apparent that poisoning (not just with pesticides) represents an important public health problem.

HOUSEHOLD USE OF PESTICIDES

Frank S. Lisella, Ph.D.

Introduction

Some common household uses of pesticides include ridding homes of insects or rodents, defleaing or delousing pets, and destroying garden pests. Thousands of pesticide formulations are sold through retail outlets for use in the home environment and in garden areas. These chemicals, when properly used, are desirable additions to our armamentarium of technical agents which are used to maintain and improve our standard of living. On the other hand, pesticides can present a hazard to people, pets, wildlife, and desirable plant species if they are not used in accordance with the appropriate recommendations.

Pesticide Products

In choosing a pesticide to apply to eliminate a pest species, there are a number of factors which must be considered--among these are the nature of the pest, location of infestation, toxicity of the product to be applied, and the ease of application of the product.

Some information with respect to the use of the common pesticides for the control of household pests is summarized in the following tables:

RODENTICIDES

RODENTICIDES	PEST SPECIES	COMMENT
Warfarin Pindone Diphacinone Fumarin	Norway Rats Roof Rats	Anticoagulants - must be available to rats at least 2 weeks
Norbormide	Norway Rats	Ineffective against mice
Red Squill	Norway Rats Mice	Emetic Mice - Tracking Dust

INSECTICIDES (Household Use)

INSECTICIDE	PEST SPECIES	COMMENT
Pyrethrins	FLIES	Quick knockdown
Malathion	FLIES	5% maximum concentration Exterior use - vegetation and wall surfaces - resting areas
Ronnel	FLIES	1% maximum concentration Exterior use only
Malathion	SPIDERS	2-3% water-based spray - harborage areas 5% dust
Chlordane	SPIDERS	2% water-based spray 5% dust
Chlordane	Ants	10% dust - runways, cracks in concrete, garbage pails, etc.
Propoxur	COCKROACHES	1% spray - odor and staining reported 2% bait
Dichlorvos (DDVP)	COCKROACHES	0.5% spray 1.9% bait
Kepone	COCKROACHES	0.125% bait - aging a problem
Malathion	COCKROACHES	5.0% spray or dust - odors
Dursban	COCKROACHES	0.5% spray - PCO use only - 1971
Fenthion	COCKROACHES	2.0% spray - PCO use only - 1971
Diazinon	COCKROACHES	0.5% spray (coarse) 1.0% dust — Spray treatment - baseboards, cabinets under refrigerators, stoves 1% spray, 2-5% dust - PCO use only - 1971

Safety Practices

A pesticide should be used only when it has been established that a need exists. When a product is selected for use, it should be the least toxic chemical which will achieve the desired results. The following precautions should be noted:

General

1. Read the label each time the pesticide is used and follow the stated instructions label exactly.

2. Keep the pesticide in a plainly labelled container, preferably the one in which it was bought. Never transfer pesticides to unlabelled or mislabelled containers.

Before Application

3. When handling, mixing, or applying pesticides, avoid inhaling dust and fumes and avoid getting materials on the skin.

4. When directed by the label, wear protective clothing, such as goggles, gloves, aprons, respirators, and masks.

5. Check sprayers before each use, to make certain that hose connections are tight and that valves do not leak.

6. Check the label of the product before using, so that you know what to do quickly if there is an accident. If clothing or skin becomes contaminated, wash the skin and change to clean clothing. If the slightest illness appears, call a doctor or get the patient to a hospital immediately.

7. The very few people who suspect they may have a special sensitivity to pesticides should consult an allergist, and, if necessary, take steps to avoid any exposure to the offending agent.

During Application

8. If indoors, work in a well-ventilated area, to avoid inhalation of fumes.

9. If outdoors, do not spray into the wind.

10. Cover food and water containers when using pesticides around areas for livestock or pets.

11. When mixing or using inflammable chemicals, be especially careful to avoid the fire hazards caused by smoking, defective wiring, and open flames.

12. In applying pesticides to food plants (a) use the proper dose recommended for the purpose, and (b) allow the full recommended time between applying the pesticide and harvesting the plant to avoid having a harmful amount of pesticides remaining on food to be eaten. Do not plant food crops near ornamental plants which are to be sprayed.

After Application

13. Get rid of used pesticide containers in a way that will not leave the package of leftover contents as a hazard to people--particularly children--or to animals.

14. Wash hands thoroughly after using pesticides and before eating or smoking.

15. Change clothing after each day's operations and bathe thoroughly.

Pesticides should be stored in a locked cabinet or storage area and out of the reach of children, pets, and people who might not be able to understand their danger. The storage area or cabinet should be dry and well ventilated. The chemicals should never be placed in empty food or drink containers of any kind.

Environmental Sanitation

Proper environmental improvement measures must be associated with the application of all pesticides. For example, in order to achieve adequate control of rodent populations, it is necessary that all harborage and sources of food be removed. Structural harborage, such as small protected enclosures under cabinets, shelves, and stairs should be eliminated. The proper storage of usable materials reduces the food and harborage available to rodents to a minimum.

The improper storage of refuse (garbage and rubbish) and of food products invites insect and rodent infestations. Refuse storage facilities should include enough containers to hold all garbage and rubbish that normally accumulates between collection days. A satisfactory refuse container should be rust-resistant, water-tight and not exceed 32 gallons in capacity. All garbage should be drained and wrapped in newspaper prior to being placed in the refuse containers. The containers should be washed periodically to further prevent fly, rodent, and odor problems.

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DISPOSAL OF WASTE PESTICIDES: PROBLEMS AND SUGGESTED SOLUTIONS

H. C. Johnson and L. P. Wallace, Ph.D.

One of the many problems encountered in the disposal of our nation's solid wastes is the handling of toxic and/or hazardous materials including pesticides. Within EPA's Office of Research and Monitoring, the Solid Waste Research Office (SWR) has been and is presently studying effective means of handling and disposing of these hazardous wastes, particularly pesticides. Because of their toxicity, some pesticides must be detoxified before any disposal or reclamation processes can be safely applied, while other pesticides can be disposed of directly. Emphasis in this presentation will be centered on those solid waste management systems which are applicable to, or hold promise for, the disposal of pesticides and pesticide containers.

Land Disposal Methods

The sanitary landfill is currently regarded as the most important land disposal method and consequently, considerable research is directed towards improving this technique and assuring that the environment will be properly protected when this method is used. If correctly located and engineered, one of the most favorable qualities of the sanitary landfill is its ability to receive heterogeneous solid waste loads. These loads vary from being relatively innocuous and chemically inert to being putrescible and even toxic. It is, however, most important that the requirements given in the following definition be met in order for a facility to be considered a "sanitary landfill":

> Sanitary landfilling is a method of disposing of solid waste on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary.

For every sanitary landfill, and particularly those receiving such toxic materials as pesticide residues, it is important to assure that there is no contamination of nearby ground and surface waters. A Solid Waste Research sponsored study is being performed by researchers at the University of Illinois on the hydrology of several solid waste disposal sites. Data from the study are useful in evaluating the factors that control ground water and landfill leachate movement. Five different hydrogeologic environments were selected for the study and piezometers were installed in drill holes, strategically located to define fluid potential distribution, and water samples were taken for chemical analysis. In addition to total dissolved solids and chlorides, which are good indicators of leaching, a host of chemical determinations were done on those samples. The results were used to predict the best physical placement of landfills to avoid leaching. No pesticides were detected in the leachate during the time of the study.

At one in-house project, Solid Waste Research is operating a field-scale landfill in Walton, Kentucky, to further study leachate movement and gas formation. The cell being used has been lined with clay and plastic to assure total collection of rainfall or applied water. Information from this study will give further guidance in the safe operation of sanitary landfills for hazardous materials such as pesticides.

Another land disposal system has been under investigation in Alkali Lake, Oregon. Under the sponsorship of Solid Waste Research, scientists at the Environmental Health Sciences Center at Oregon State University have been studying the feasibility of transporting the waste liquor and by-products from 2, 4-D and 2, 4, 5-T manufacturing process to an arid area in Oregon where they are being diluted and applied to the land for natural degradation. The 55-gallon drums used for transporting are chemically cleaned, compressed, and buried or baled and reused as scrap metal. The theory behind the project is that herbicides and pesticides do not have an infinite life in the environment. In every instance where persistence of pesticides in soil has been studied, it has been found that the chemical disappears within acceptable time limits (2-3 years) to a level of little biological significance. The factors causing the disappearance are photochemical decomposition, chemical decomposition, microbiological degradation, and physical factors such as adsorption, volatilization, or leaching. The physical factors, however, only take the pesticides from one place to another, they do not really make them disappear.

Data from trial applications at the site have supported the degradation theory. Application to small plots have shown that very little vertical or lateral movement occurs during the degradation period which has been twenty months for 60 percent degradation. It is planned to start using subsoil injection routinely for the waste liquor presently being stored at the site.

In conjunction with this study, the Oregon State University group is also investigating pesticide container cleanup in Klamath Falls, Oregon. Attempts will be made to chemically clean the containers to such a level that they can be accepted for baling and placement in an electric furnace for scrap metal recovery. Facilities for this study have been constructed and cleanup investigations are presently underway. Liquids from the cleanup operation will either be used as a pesticide or disposed of at the Alkali Lake site. In order to make the container cleanup easier, the researchers have taken an active role in persuading pesticide users to rinse their containers with water or [illegible] the formulation they prepare, adding the rinse back [illegible] formulation. Laboratory tests have shown that rinsing a [illegible] container three times with several quarts of water reduces the residual pesticide content by 90 percent, affords the user a financial saving of [illegible] ounces if the pesticide costs $20/gallon, and greatly facilitates the container cleanup process.

Oceanic disposal of solid wastes, including pesticides and other toxic materials, may be an alternative to the sanitary landfill method; however, there are many questions to be answered before the Solid Waste Research Office could endorse ocean disposal. The report from a contract with the Applied Oceanography Branch of the Dillingham Corporation, San Diego, California, describes the nature and magnitude of present ocean disposal practices. In connection with the study, on-site surveys were conducted at 16 United States cities situated on or near the Atlantic and the Pacific coasts, and the Gulf of Mexico.

Data from the study reveal that some [illegible] million tons of waste are being disposed of at sea each year at a cost of $[illegible] million, including dredging spoils but excluding outdated munitions. Methods employed for disposal consist primarily of transporting the wastes in bulk or barrels aboard self-propelled or towed barges. The majority of wastes are disposed of in bulk form and discharged while the barge is underway. In several cases, highly toxic chemical wastes have been carried to sea aboard merchant ships as deck cargo. The containers were then discharged in undetermined areas once the ship was 300 miles from land. However, bulk industrial wastes are usually transported in tank barges certified for ocean waters by the United States Coast Guard. In addition, United States Coast Guard regulations regarding the bulk shipment of chemicals by water must be adhered to. The Sparkling Waters is just such a barge especially built to handle insecticides and other toxic chemical wastes off the New York coast.

Recently, a final report was received from [illegible] C. Shell, Inc. in Florham Park, New Jersey [illegible] decontamination and combustion of organic pesticide [illegible] containers. Work on this project has included:

1. Determining the temperature [illegible] pesticides burn in their pure form while [illegible] combustion gases for CO, CO_2, H_2O, and intermediate organics.

2. Incorporating the same pesticides in a number of materials such as sawdust, paper, burlap, cloth, polyethylene, and wood, and investigating the burning temperature and rate and determining the combustion products.

3. Low cost chemicals including nitrates and chlorates were incorporated in the pesticide and the pesticide-material mixtures above to facilitate decomposition.

The report indicated the structural and compositional requirements necessary for combustible pesticide containers and the possible use of polyethylene liners to aid combustion. It was shown during the course of the project that representative pesticides were virtually volatilized or sublimed when incinerated unless a binder was present to increase the residence time in the flame. By using polyethylene, which under heating or combustion conditions softens or degrades to products of lower molecular weights, the advantages of a liner and a binder were obtained with one material and the pesticides studied could be essentially destroyed at temperatures normally achieved by burning wood, paper, cardboard, etc.

In all the thermal studies performed, less than five milligram amounts of the pure pesticide chemical were used. Since some undesirable emissions were detected under these conditions, bench and field studies with larger samples need to be investigated before definite conclusions can be drawn.

Destructive distillation (pyrolysis) of pesticides shows great promise as a detoxification reduction method. It should leave an easily handled residue and should thermally degrade effluent gases to acceptable limits. Additional research is needed to verify the possibilities of this method.

A great deal of concern is being directed to recycling of waste material. Some of the present barriers to increased reclamation and recycling are technological in nature and others are economic. Success in overcoming these barriers has the dual advantage of reducing the amount of waste to be disposed of while conserving the nation's natural resources. Cellulosic wastes, including wood, bark, sawdust, oat hulls, corn cobs, bagasse, and other agricultural residues are generated in truly prodigious quantities. Little, if any, significant portion of these wastes is beneficially used and, since they are commonly burned, cellulosic wastes often contribute to air pollution in areas where they accumulate. Under a research grant, the Institute of Forest Products, University of Washington, in Seattle, is developing a unique means for utilizing cellulosic wastes which will at the same time allow safer and more efficient application of pesticides to the soil.

Some common properties of the wood and agricultural wastes are that they consist predominantly of polymeric cellulose macromolecules; they contain an abundance of replaceable hydrogen atoms, and all are biodegradable. Since these waste materials are polymers containing replaceable hydrogen atoms it should be possible to attach pesticides to these substrates in the same way that acetic acid, for example, becomes attached to cellulose in the manufacture of cellulose acetate. Research has shown that pesticides can be attached to such solid waste as sawdust, bark, and lignin by means of ester linkages. Herbicides have been combined with natural as well as synthetic polymers. The herbicides used were 2, 4-D, 2, 4, 5-T, 4(2, 4, 5)-TB, and Dalapon. It was found that each of these polymeric combinations prevented the germination of certain seeds longer than the herbicide alone under controlled laboratory conditions. Similar results have been obtained in field plots using herbicides and in Costa Rica using the insecticide carbofuran. In the Costa Rican study, it was found that a treatment with the pesticide-polymer combination was effective for eight weeks as opposed to one week for the pesticide alone. Plans are to repeat this study in Puerto Rico where environmental conditions are quite different.

The practical implication of the ability to chemically bond pesticides to cellulosic materials is that very large quantities of cellulosic wastes, so treated, could be utilized as a mulch for gardens and in agriculture. The pesticide in the mulch would be released in controlled fashion with distinct advantages over present procedures for applying pesticides to soils. Now, pesticides usually have rather short useful lives because they may be degraded by bacteria to inactive metabolites, or washed by rainwater into the subsoil where they are inaccessible to pests they are intended to control. Also, and more important from the public health standpoint, this leaching into the subsoil often means that some rather stable pesticides, or their degradation products, find their way into potable water supplies.

In contrast, if the pesticide were chemically combined with the polymeric solid waste, its useful life should be prolonged; attack by bacteria should be reduced; and the pesticide should not be leachable into the subsoil and hence will not pollute streams and rivers. As the solid waste-pesticide mulch lies on and in the soil, it will gradually decompose, continually releasing the active pesticide over a long period of time. With this technique the problems and potential errors of measuring and diluting liquid concentrates are eliminated. Spillages of solids are, of course, less likely than liquid leakages and are easier to rectify when they occur. Controlled releases of the pesticides may also allow lower dosages and fewer applications.

Another very important benefit from this project is the prospect it may hold for development and use of extremely short-lived biodegradable pesticides which, in combination with solid waste polymeric substrates, would be sufficiently stable for practical use. For example, many organophosphorous pesticides are liquid and are too dermally toxic to permit their use by anyone other than an expert. Combinations of these materials would perhaps render them safe, while not destroying their biological activity. The currently "unuseable" pesticides are often effective at much lower dosages than the superficially less hazardous products that are not used in relatively massive amounts.

Composting of municipal and agricultural refuse is not widely used as a means for solid waste disposal in the United States. However, there are several compost plants in operation and one may reasonably expect to see the continued composting of solid waste on limited scale in areas where the product is marketable. A research grant to the Western Research Laboratory of the National Canners Association, Berkeley, California, is supporting a study of the fate of insecticides in composted agricultural wastes. A substantial part of the fruits and vegetables received for preservation by canning or freezing is discarded as solid wastes. That portion of the raw product which is discarded--vegetable skin and rind--generally has the highest level of insecticide residue, and this fact has limited the use of such material as animal feed, and it also raises questions about possible harmful effects of spreading composted cannery wastes on agricultural lands. This concern is especially justified if toxic degradation or transformation products remain in the compost mixture.

The Canners Association study aims to obtain a better understanding of the mechanism by which insecticides are degraded by microbial or chemical action during aerobic composting, and also to obtain information which will make it possible to dispose of waste materials containing concentrated insecticide residues without hazard to public health. Insecticides selected for the study represent examples of the three principal classes: chlorinated hydrocarbons, organophosphates, and carbamates. The selection of specific insecticides was based upon the extent of usage in agricultural products, variety of chemical structure, and availability of reliable analytical methods. These included: dieldrin; parathion; Diazinon; p, p'-DDT; pentachlorophenol, and with further studies planned for Sevin and Zineb.

During the study, breakdown products of several insecticides have been identified and the varying effects of batch-type and thermophilic composting processes have been noted. The summary in a recent progress report contained the following information:

1. Concentration of Diazinon and parathion rapidly declined in both composting processes with the thermophilic process being the more efficient. Breakdown products identified for Diazinon were oxodiazinon and sulphotepp. Those identified for parathion were aminoparathion, p-aminophenol, and p-nitrophenol.

2. Continuous thermophilic composting caused some reduction in DDT whereas the batch process had little effect. No breakdown products have been identified.

3. Dieldrin was more efficiently degraded in the batch process and none of its breakdown products have been identified.

4. Following the active compost period (120 days), the curing or aging phase (180 days) of the process had little or no effect on the insecticides.

The consideration of pesticide disposal is one facet of hazardous waste disposal. In Section 212 of the Resource Recovery Act, Congress commissioned a study on the feasibility of strategically locating national disposal sites to safely process hazardous materials. The first phase of this two-year study has been initiated through a contract to the Booz-Allen Applied Research Company. Their responsibility is to make a survey and list the quantities, location, generation rate, and present disposal practices of our nation's hazardous wastes. Throughout all the phases of this study, pesticides will be given particular attention in hopes that some safe and effective means of their disposal can be developed.

INDUSTRIAL HYGIENE PRACTICE IN THE MANUFACTURE, FORMULATION, AND PACKAGING OF PESTICIDES

Clyde M. Berry, Ph.D.

In this presentation I shall define industrial hygiene as that art and science directed toward the anticipation, detection, evaluation, control and continued evaluation of untoward physiological response potentially associated with the manufacture, formulation and packaging of pesticides.

To establish a point of embarkation on a discussion of this kind a number of assumptions can be made. These are offered with no sense of chronological occurrence, of severity, of associated hazard or of feasibility.

1. Too much of anything may be deleterious to physical, mental or emotional well being.

2. Prudence indicates a need for a plant material balance. Pound for pound, ton for ton, the amount of total product, by-products and waste, should equate with the amount of all incoming ingredients.

3. A flow chart is an indispensable navigational aid in traversing the labyrinths of any plant product.

4. It is still necessary to "inquire locally". Ask questions, in-plant, about what happens, where, how and when.

5. Management may not know that operational changes are routine that are not a part of procedural specifications as detailed in process manuals.

6. Most chemicals are of technical grade and are usually not pure chemical compounds.

7. Many (most?) products and by-products are reaction mixtures.

8. People are required to build, maintain and operate equipment.

9. Machines do not get tired, become poisoned, make fewer mistakes.

10. Few engineers design with worker health and safety aspects taking priority over cost/performance.

11. New legislation (Example: Occupational Safety & Health Act of 1970) is going to force a re-ordering of priorities.

12. Inertia/tradition/pride can inhibit adoption of improved work patterns or process changes.

13. Legal, Public, and Employee Relations Departments are exquisetely sensitive with respect to safety and health verbiage.

14. Labor-management conflicts will sometimes be over safety/health items when these are not the basic issues at all.

Pesticides are used because they affect protoplasm, plant or animal. They can, and do, affect humans, usually deleteriously. To protect the in-plant workers some general principles can be stated:

1. Keep it inside the unit.

2. If it gets out, keep it as confined as possible.

3. Try to put it back in the process, if feasible.

4. Dispose of contaminated materials and wastes before they get into the general environment - and do it safely.

5. Keep it off (and out of) the worker.

One needs to know the toxicities of the materials to which a worker may be exposed, the clinical effects that may be produced, the threshold limits of exposure, how these can be measured, and the levels to which a worker may be exposed.

Some workers perform their job at a single location. Others move about. To make professional judgements on hazard potential it may be necessary to make three types of measurements:

1. At the source

2. In the general workroom air

3. The individual worker's exposure

Puddings may be proved by eating them. A successful industrial hygiene approach requires similar clinical proof of absence of injury, acute and chronic. There should be a plant physician, full time or on call. His contributions can be roughly categorized as follows:

1. Know the toxic effects of the materials.

2. Do pre-placement examinations to screen out susceptibles and avoid exacerbating existing conditions.

3. Be prepared to handle emergencies.

4. Do routine physical examinations.

5. Advise on transfers.

6. Authorize all returns to work after illness absences.

7. Maintain records that are epidemiologically useful.

8. Routinely tour the plant.

An industrial hygienist should be consulted early in the design of a facility for manufacturing, blending or packaging pesticides. Prevention, true prevention, begins here. Besides contact with toxic materials there are other aspects of worker exposure to be considered. Some of these would be:

1. Trauma
2. Heat extremes
3. Radiation (ionizing and non-ionizing)
4. Noise
5. Vibration
6. Personal services (as locker rooms and lunch rooms)
7. Ergonomics
8. Possibility of fire or explosion
9. Fatigue

The industrial hygienist will view each step in the process, each machine, each job against the backdrop of general control measures and their applicability. These would include:

1. Isolation
2. Remote control
3. General ventilation
4. Local exhaust ventilation
5. Enclosure
6. Personal protective equipment
7. Personal hygiene
8. Good housekeeping

Specific details will vary from plant to plant but the approach may be illustrated by viewing a hypothetical plant along the lines of the above. Let us assume that a large plant is involved which makes a pesticide that is highly toxic, can be absorbed via inhalation, ingestion and skin contact. It is a liquid. It is blended with a powder to a low percentage of active ingredient and then packaged in bags, boxes and drums. These are warehoused awaiting orders from jobbers and shipping is by rail and truck. On a departmental basis one might have industrial hygiene interests as follows:

Purchasing

Who are the suppliers?

How much of each material is purchased?

Has the supplier provided ... safety data sheet as required by law?

Is it appropriately labeled?

Receiving

If tank trucks, tank cars or barges, how is it transferred?

Will inclement weather produce (or exacerbate) problems?

Do the attendants have protective gear?

Are eye-wash and deluge showers present?

Is the area included in a disaster plan?

Can pneumatic conveying solve dust problems?

Would pressure transfer be preferred over pumping?

Storage

Are the tanks reasonably protected against damage by mobile equipment?

Do dikes (large enough to hold entire contents) surround the tanks?

If storage is inside is the lighting and ventilation adequate?

Is a regular check made for leaks and spills?

Are emergency preparations adequate? (lighting, personal protective equipment, neutralizing chemicals, etc.)

Manufacturing

Are the pumps of a type to minimize leakage?

Have covers and exhaust ventilation been provided at reaction vessels?

If the reaction is exothermic and could "run away" have quench tanks been provided?

Is the equipment durable, corrosion resistant and accessible for inspection and cleaning?

Has provision been made for equipment handling during turn-around?

Is there adequate general ventilation - and with tempered make-up air?

Are casuals kept out of high risk areas?

Has suitable personal protective equipment been furnished the operators? Is it kept clean and properly maintained?

Is housekeeping maintained at a high level?

Are hand washing facilities available and used prior to eating and toileting?

Can a batch method be changed to continuous mixing?

Is the actual blending done in an enclosed vessel, under negative pressure, with well designed hoods and ductwork to take away dusts, fumes, gases and vapors?

Are respirators, gas masks and/or other appropriate personal protective devices provided?

Do the workers wear clean clothing daily?

Packaging

Can it be more completely automated?

Are bottles checked for cracks and loose caps?

Is there any exterior contamination of bags or drums?

Will the labels meet ICC and other regulatory agency requirements - size, location, wording, coding?

Is there a printed warning against container re-use, except when returned for the same service?

Are all air contaminants controlled by effective ventilation at the point of discharge?

It will be apparent that the foregoing are just some of the points an industrial hygienist will keep in mind. He would extend this into the warehousing of the packaged product. He would similarly view shipping where he would seek maximum mechanization, minimum potential for container damage, applaud the use of experienced truck drivers, discourage mixed cargoes, etc.

The industrial hygienist will also find himself to be a candidate for service in additional capacities:

1. Advise the applicator on safe use of the formulated product.

2. Back-stop the physician if a Poison Information Center calls for information.

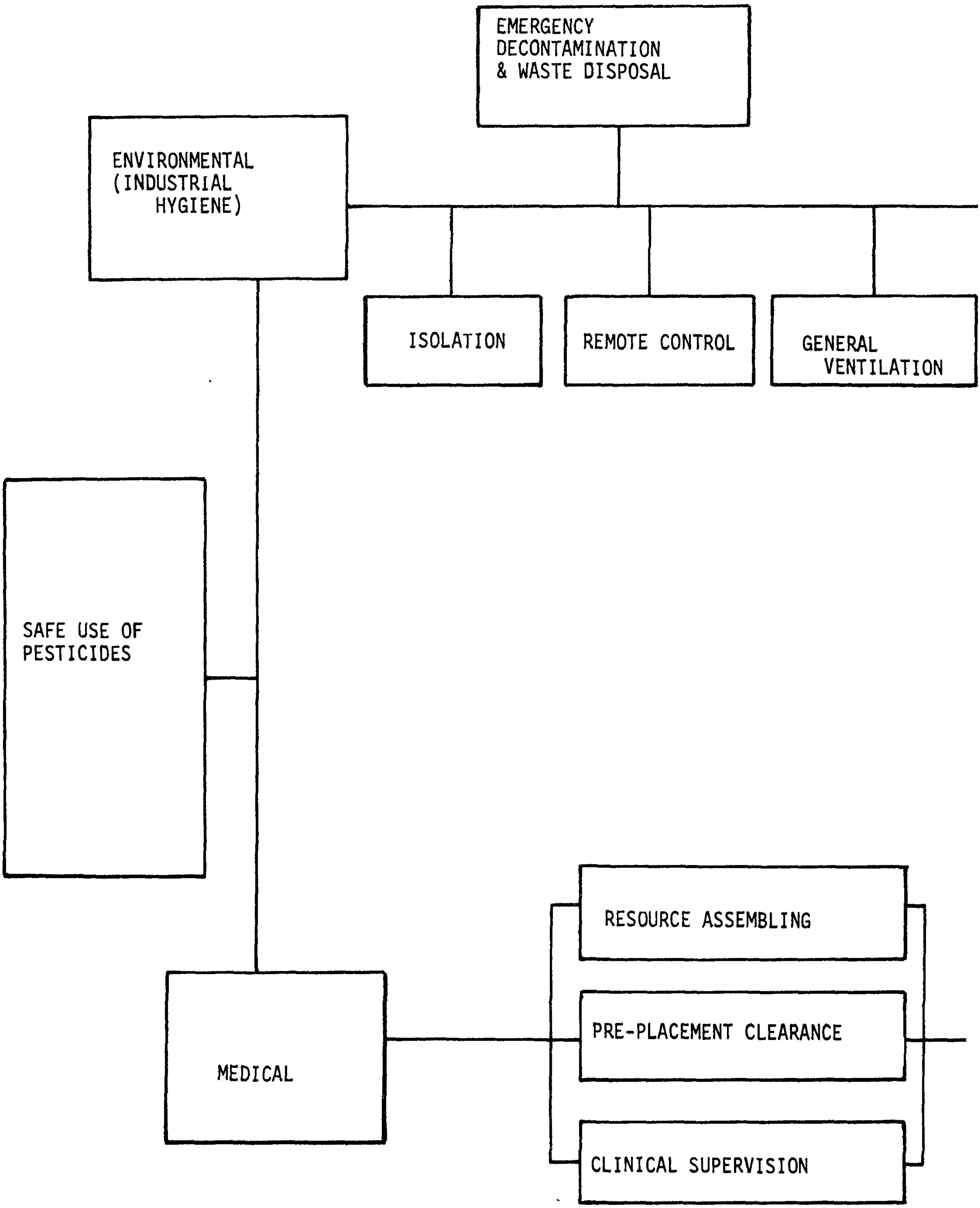
3. Participate in employee education programs on how to work safely.

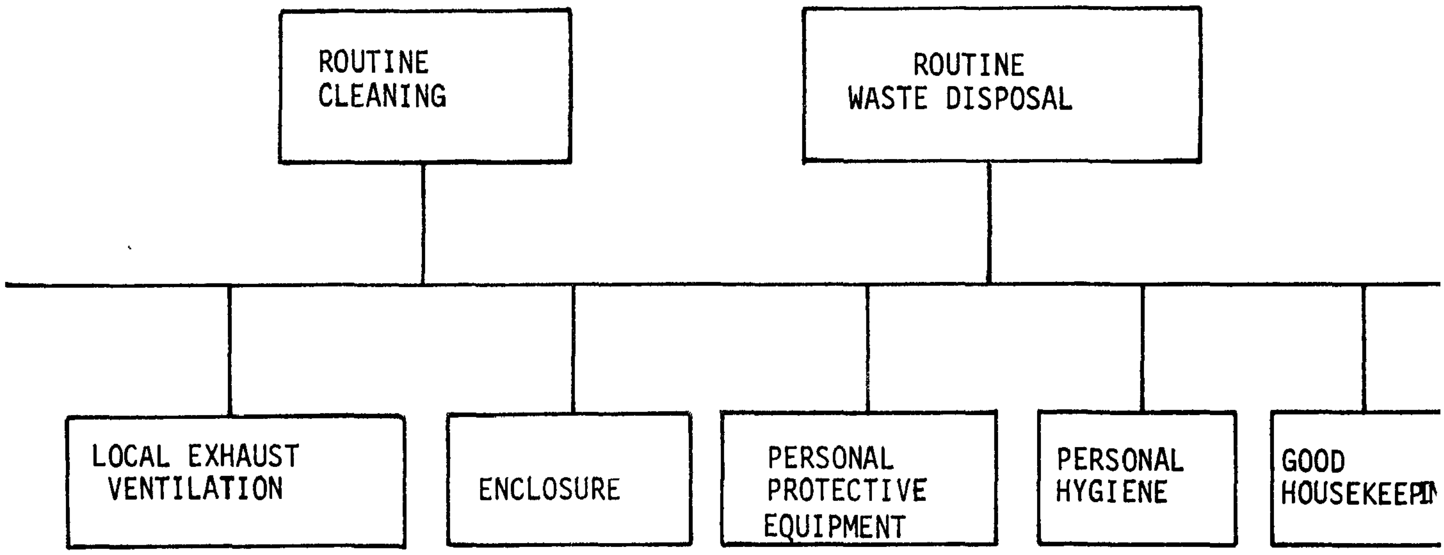
4. Work with plant personnel and management on

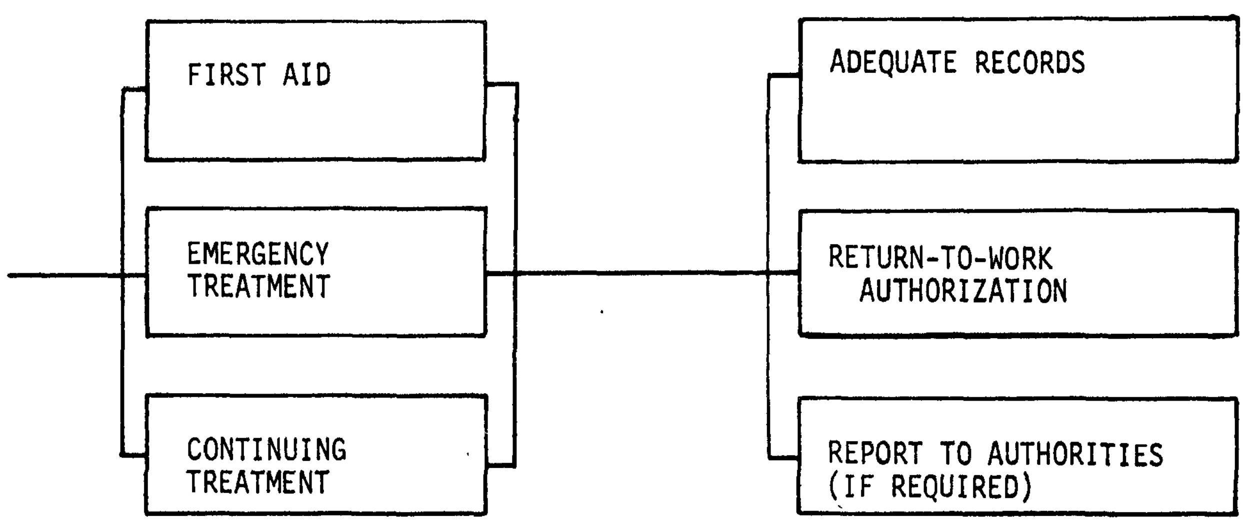
   a) Salvage operations
   b) Waste disposal
   c) Air pollution
   d) Water pollution
   e) Disaster planning

5. Share his knowledge and experiences

   a) With other industrial hygienists
   b) Physicians
   c) Safety engineers
   d) Regulatory personnel


EMERGENCY DECONTAMINATION & WASTE DISPOSAL
ENVIRONMENTAL (INDUSTRIAL HYGIENE)
ISOLATION
REMOTE CONTROL
GENERAL VENTILATION
SAFE USE OF PESTICIDES
RESOURCE ASSEMBLING
PRE-PLACEMENT CLEARANCE
MEDICAL
CLINICAL SUPERVISION


ROUTINE CLEANING
ROUTINE WASTE DISPOSAL
LOCAL EXHAUST VENTILATION
ENCLOSURE
PERSONAL PROTECTIVE EQUIPMENT
PERSONAL HYGIENE
GOOD HOUSEKEEPIN


FIRST AID
EMERGENCY TREATMENT
CONTINUING TREATMENT
ADEQUATE RECORDS
RETURN-TO-WORK AUTHORIZATION
REPORT TO AUTHORITIES (IF REQUIRED)

MINIMIZING FISH AND WILDLIFE
LOSSES DUE TO PESTICIDES

William E. Martin

Fish and wildlife are the barometers of our natural environment. If they are in trouble, we are in trouble.

I. Types of fish and wildlife losses due to pesticides

A. Direct or primary losses

1) Thallium/Eagles/Wyoming

A number of bald eagles and golden eagles are believed to have fed on antelope treated with thallium sulfate in Wyoming. Twenty-two of these birds are known to have died from thallium poisoning.

2) Azodrin/Birds/Arizona

At least 4,000 birds, 50% of which were dove and quail, were killed with Azodrin following its use to control pink bollworm in Arizona cotton fields.

3) Arsenic/Deer/Tennessee

Eleven deer, including some does carrying fawns, and some small game died from feeding on forage in an area treated with an arsenical herbicide to control Johnson grass.

4) Toxaphene/Fish/Nevada

Fish were killed after exposure to toxaphene used as a cattle dip to control scabbies.

5) Aldrin/Game Birds and Small Mammals/Illinois

Aldrin used for Japanese beetle control caused mortality within 3 weeks. Meadowlarks, robins, brown thrashers, starlings and grackles were virtually eliminated.

Populations of pheasants, quails, moles, shrews, and muskrats appeared to have taken severe losses.

6) Zinc Phosphide/Geese/California

At least 455 wild geese died from eating zinc phosphide-treated oat groats applied from mouse control on leased land at Tule Lake.

7) Fenthion/Songbirds/North Dakota

As many as 5,000 songbirds succumbed following a mosquito control application of fenthion in North Dakota. The spraying was done at the peak of a warbler migration; thus, exposing many more birds than would normally be affected.

8) Heptachlor/Bird and Small Mammals/Southeast

Early fire ant eradication efforts resulted in numerous incidents of losses of cottontail rabbits, bobwhite, other small game and many songbirds throughout the Southeastern United States.

B. Indirect or food chain losses

1) Diazinon/Grasshoppers/Fish

Grasshoppers treated with Diazinon hopped into streams during death throes. Fish gorged themselves on the insects and were subsequently poisoned.

2) Dieldrin/Aquatic Producers/Fish/Bald Eagles

Dead bald eagles known to have fed on fish containing dieldrin from the aquatic food supply had sufficiently high brain residue levels to indict dieldrin as the cause of death.

C. Losses through incapacitation

1) Mirex/Blue Crab and Shrimp

Very small quantities of mirex cause disorientation in certain crustaceans. The estuarine ecosystem is such that even slightly disabled individuals become easy prey.

2) Cholinesterase Inhibition in Birds

Birds depend heavily on their ability to react quickly to external stimuli when feeding and in escaping predators. When their nervous systems are not functioning properly they are severely handicapped.

D. Biological magnification/phenomenon/reproductive failure

1) DDT/Bald Eagles, Ospreys, Brown Pelicans, *et al*. DDT has been demonstrated to move through various food chains with increasing concentration as it is translocated upward through the trophic levels. Sublethal concentrations have been implicated in reproductive failures caused by physiological disruption leading to eggshell thinning in many species of birds at or near the top of aquatic food chains.

2) DDT/Lake Trout

Trout in Lake George, New York, continued to concentrate DDT in sac fry egg lipids until the last part of the sac was absorbed; at this point there was sufficient toxicant released in a single dose to cause death.

E. Habitat changes resulting from pest control efforts

1) Loss of food and cover for wildlife results from killing large tracts of sagebrush to "reclaim" rangelands.

2) Forest insect control spraying may seriously reduce food supply of canopy feeding songbirds.

3) Aquatic weed control may enhance the habitat for some organisms and make it intolerable for others.

II. Why losses occur

1) Monoculture croplands with related build-up of pests and need for pesticides.

2) Excessive application of pesticides ("Dressing-up" the edges).

3) Effects of pesticides are unknown prior to application (New "use-patterns" of established chemicals).

4) Pesticide applied to other than target area (Improper guidance; drift).

5. Effects may not be obvious immediately after application, but develop with time (Subacute physiological damage).

6) Pesticide known to have toxic effect, but alternatives are not available (Mosquito control using parathion because mosquitoes are resistant to other chemicals).

7) Industrial discharge or accidental spillage (Settling pond overflow; broken containers; improper handling of bulk).

8) Runoff (Application made prior to heavy rain or on steep or eroded slopes).

9) Improper disposal (Equipment washed out in streams; containers used for other purposes; dumping).

III. Who should be responsible for mitigating fish and wildlife losses

A. Manufacturers and distributors

1) Demonstration of efficacy and safety.

2) Extensive testing prior to marketing new products or methods.

3) Development and selling practices in the interest of long term benefits rather than immediate profit.

B. Federal and State Government agencies

1) Federal and State registration of chemicals and methods of use.

2) On-site regulation of accepted use patterns.

3) Field appraisals of non-target effects under operational conditions.

4) Monitoring of invertebrates, fish, wildlife, soil, water, vegetation, etc.

5) Technical assistance to manufacturers and prime users, and education of the general public.

C. Universities and associated organizations

1) Safe use and adverse environmental effects should be standard parts of any academic training in economic use of pesticides.

2) Education of the public a primary task.

D. Users

1) Choose the most selective chemical for the problem.

2) Read the label and act accordingly.

IV. Sources of information needed for forecasting potential fish and wildlife hazards

1) LD_{50}, LC_{50}, et al data from laboratory testing.

2) Simulated field studies under controlled conditions.

3) Field appraisals conducted under operational conditions.

4) Short term monitoring projects.

5) Feedback and extensive exchange of information between knowledgeable individuals and agencies.

6) Crystal Ball.

FUTURE TRENDS IN CHEMICAL AND NONCHEMICAL METHODS FOR PEST CONTROL (Safer?)

L.A. Richardson, Ph.D.

Insect pests are responsible for vast economic losses in the production, processing, distribution, and storage of food, fiber, and forest products. They assist in the transmission of diseases in animals, plants, and man, create intolerable annoyance problems, and effectively destroy items of beauty as well as those of man's basic needs. The annual economic loss due to insect activity over the period 1951-1960, has been estimated at 6.8 billion dollars. Consequently it might seem ideal to eradicate all destructive insects. However, while insects constitute one of man's most formidable enemies, they are essential in our complex ecological system. Insects function in the pollenation of many useful and ornamental plants and act as parasites and predators where they no doubt aid in reducing the potential transmission of diseases. In addition, experience has shown that single species eradication programs are successful only in limited geographical areas, usually are expensive, and are only temporary. Thus, the eradication of all insect pests is not only undesirable but, currently impossible.

Since insect species are both beneficial and harmful, the "balance of nature" philosophy is often suggested as the appropriate way of life. Insect pests at various stages in their life cycles, are subjected to disease, starvation, desiccation, natural enemies, and adverse environmental factors, all of which limit their reproduction potential. However, insects have great adaptability and readily adjust to adverse ecological conditions; develop resistance to diseases and man-made control methods; frequently tolerate parasitic infestations for sufficient periods of time to complete their mission and reproduce; and are, in most cases, highly mobile. It is currently estimated that 150-200 insect species frequently cause serious damage and that an additional 400-500 species may create problems from time to time. Thus in a man-insect confrontation, waged on a live-and-let-live basis, man is hopelessly outclassed.

Economic and cultural patterns, together with the requirements of a constantly increasing population, greatly complicate the development of pest management programs. Increased agricultural production must be accomplished on an ever decreasing percentage of the land area and the products therefrom transported, stored, and processed for use by high density urban populations. These two factors provide additional advantages to the insects. The shrinking rural area necessitates a high production density of specific crops and virtually eliminates many tillage practices useful in insect control. Simultaneously, through the assurance of a recurring and ample food supply in an area where little mobility is required, the potential for such crop-specific insects to reach devastating numbers is greatly enhanced. Specifically designed equipment and facilities of large capacity are necessary for the transportation, storage, and processing of agricultural products in order to supply densely populated urban areas. Such facilities and equipment provide a localized, constant, and ample food supply for insects and thus ideal destruction and reproduction potentials.

Densely populated areas create additional conditions which provide advantages to the insects. The potential for disease transmission, sensitization, allergic responses and general annoyance are greater in urban and recreational areas. Crowded conditions frequently create problems in waste disposal and general sanitation practices resulting in optimum conditions for insect reproduction.

In order for man to exist in a world where insects appear to have the advantage, it is necessary to modify this "balance of nature." Historically, both physical and chemical methods have been used, with the methods of choice being dependent upon economics, availability, and efficacy. Within the last thirty years chemical insecticides have been the principal means of effective insect control. Currently, the development of alternate control methods and the potential health hazards of chemical insecticides are under intense investigation. Pest control management programs are certain to change as a result of these investigations and the current general attention to ecological problems.

Chemical insecticides have been used in the struggle between man and insect since before the First Century AD. In the last thirty years, however, the development and use of such products has increased at a phenomenal rate. The efficacy, persistency, and economy of the early insecticides are undoubtedly responsible for virtually eliminating many insect-borne diseases and preventing starvation for untold numbers of people. Insecticides are currently our first line of defense in control of insect outbreaks. They are useful because they are highly effective, provide an immediate effect, are able to bring large insect populations under control, and can be employed as needed.

Unfortunately insecticides possess a number of disadvantages. The principal ecological problems are that all of the commonly used insecticides are broad spectrum agents and do not limit their destruction to the target organism, and all contribute to ecological pollution either as the parent compound or a degradation or reaction product thereof. From the standpoint of human and animal health and welfare, many of these agents accumulate in the tissue of man and animals and may be associated with chronic health problems. Others are acutely toxic and have brought serious illness and death not only to their users but to innocent bystanders. Development of insect resistance has severely hampered the utility of many useful and inexpensive chemical agents. Finally, additional disadvantages have accrued because of careless use and overuse to the complete ignorance, in many instances, of alternative or supportive methods of pest control.

Trends in the utilization of insecticides, both the agents and the means of application, have undergone noteworthy changes. During the last three decade era insecticide usage has shifted almost completely from the very persistent and toxic arsenic compounds, the organochlorines, are considered to be rather persistent, broad spectrum, contact and stomach poisons, which have the unfortunate characteristic of leaving cumulative residues in man and the environment. Insect resistance and general overuse initiated the trend toward the more acutely toxic and less persistent organophosphate compounds. Organophosphates, useful as contact, stomach, and systemic insecticides, were able to effect control of resistant insects and in addition, did not appear to leave toxic, cumulative residues. More recently, fear of human health problems and ecological considerations have tended to shift the usage patterns toward the relatively safer carbamate insecticides. In this move, organochlorines have been extremely limited in their usage and the phosphates have come under closer scrutiny.

A second trend has been to shift toward the use of the less persistent and less toxic compounds within these chemical groups. Methoxychlor, for example, has been used in certain applications instead of DDT because it is less persistent and has a lower mammalian toxicity. Malathion is preferred to other organophosphates, wherever it is an effective insecticide, due to a lower mammalian toxicity. More recently there has been a concerted effort to formulate certain of the common insecticides in such manner that they will rapidly degrade to ecologically safe chemicals.

While the ecology will benefit from the reduced usage of persistent insecticides, the cost of food production is destined to increase because of the necessity for more frequent applications of more expensive chemicals. Alternate methods of pest control hopefully will alleviate a portion of this problem. Currently, insecticide application by ultra low volume techniques is being used as an aid to improved distribution and thus a means of reducing the total quantities of insecticides required. A second technique, that of using encapsulated organophosphates in order to increase their persistence, has also been suggested. The development of insecticides which would effect eradication of the target insects with no persistence, toxic residues, or effect on other species has not as yet been accomplished.

Cultural procedures are the best known and most used alternate pest control methods in agricultural production. Basically, such procedures attempt to eliminate insect breeding areas by general sanitation practices and methods of exposure to the elements or to confuse the insects by altering production practices. Such practices as fall plowing, rotation of crops, strip cropping, changing planting time or plant spacings, and fertilizer and water management have been found to be effective in minimizing crop damage. Cultural control procedures require considerable planning and extremely good fortune in effecting complete control, however, safety and efficiency dictates that such methods be included in insect pest control programs for agricultural production.

Physical and mechanical methods include some of the oldest and most primitive control procedures as well as ones which will no doubt be used for many years. They consist of direct or indirect measures to destroy the insect, disrupt its normal activity, or modify its environment to an unacceptable degree. Physical and mechanical methods are most useful in the protection of people and products in structures. Techniques involved include temperature and humidity control, exposure to radiofrequency energy and sound waves, barriers and excluders, artificial environments, and traps and grids. Certain techniques such as hand picking, use of flame and heat, and mechanical trapping have been used in agricultural practices. Trapping, utilizing chemical attractants, are currently becoming more important as insect control methods in agriculture and forest conservation.

Various chemical attractants have been used in conjunction with mechanical trapping and poisonous baits. Successful eradication programs, utilizing traps for the Mediterranean fruit fly in Florida and a toxicant bait for the oriental fruit fly on a Pacific island, have been accomplished with attractants.

The most recent development in the area of attractants is sex attractants. To date sex attractants for twenty-one insect species are undergoing active field trials. Sex attractants fall within the broad category of pheromones, substances which are secreted to the outside by one individual and when received by a second individual of the same species, will elicit a specific response. Disparlure, the pheromone produced by the female gypsy moth, is the best known, and one of the most potent, of the sex attractants. Disparlure has been extensively studied and synthesized by U.S. Department of Agriculture scientists. This synthetic pheromone has been shown to attract male gypsy moths in field trials in the presence of as little as 0.1 nanogram, is an effective trapping aid at 1 microgram, and will outdraw the female moth at a concentration of 10 ug. Field trials, currently in progress, will attempt to so permeate the air that the odor signals of the female moths will be jammed. By this procedure it is hoped that complete control and eventual eradication can be acco -

Induction of sterility as a means of insect control has been under investigation for about thirty years. Perhaps the best known applications were the essential eradication of the screw-worm fly from the West Indies island of Curacao and the southeastern portion of the United States, and the eradication of the oriental fruit fly from Guam. This technique requires that insects be reared in captivity, sterilized, and released to compete in the natural population. Proper sterilization techniques generally do not interfere with the mating habits of insects, however, rearing in captivity severely limits the number of species to which this technique can be applied. Many species of insects are not suited to control by the rear-and-release method. Some are not adaptable to laboratory rearing and others would require excessive numbers to compete favorably with the large native population. In addition, certain species would be too hazardous, annoying, or destructive to release. Thus a second sterilization technique is available, the use of chemosterilants. Chemical agents, combined with mechanical trapping, allows the efficient sterilization of both males and females, at considerably less expense than irradiation. These agents are most efficient if placed in the food of the insect, however, they are effective if placed on the body. Chemosterilants are mutagenic and must be made available to the target insect in such manner that they will not endanger other insects, animals, and man.

Slightly over 30 years have been spent in the development of sterilization techniques for a very few insects. One would anticipate that a tremendous amount of time is needed to develop sterility techniques for the many insect species remaining. Such investigations and development will require the efforts of non-profit organizations since the profit potential is not currently visible. Insect control by sterility techniques depends to a large extent on mass action, is highly dependent on insect mobility and is a long-term method, relatively speaking, thus its principle benefit may be in eradication programs. Proponents are currently suggesting the use of a non-persistent insecticide followed by release of sterile males, to complete the eradication. Sterility techniques are safe, assuming chemosterilants are controlled, and should be useful in long-term insect control management programs.

One of the oldest and most natural insect control procedures is the use of so-called natural enemies, parasites and predators. The basic reason for incorporating these procedures into a pest control program is to maintain a pest species at a population below the point of economic importance. One of the chief problems in these programs is to control the predator-prey or parasite-host populations. Entomologists have predicted coincidental population cycles of both predator and prey, indicating that with those studied, the predator is totally dependent upon the target insect for food. Data are available, however, which show that such is not always true. Certain predators, while fastidious, are devastating numbers. On the other hand, ... tors may themselves become pests. With those species for which a stable predator-prey or parasite-host relationship can be maintained, below the economic threshold of the target insect, these control procedures are ideal. Such techniques do not leave toxic residues nor would they be expected to endanger other species.

Predator-parasite control procedures have been under study since about the middle of the 19th century. The accomplishments of these investigations emphasize the difficulty of locating and developing sufficient populations of specific predators and parasites. To date, the only successful man-made controls have evolved from immigrant insects. Control of the citrus cottony-cushion scale in California is an example of one of the earliest and most successful accomplishments. Importation of the Vedalia Beetle from Australia, the home of the citrus scale, is currently providing control of this scale problem. In addition to the difficulty of developing the proper predator-prey relationship one must also keep in mind that such control procedures are slow and must be carefully planned.

Control of insect pests by microbiological procedures are currently receiving considerable attention. Insect diseases have been recognized since the time of Aristotle and undoubtedly have been an unheralded weapon in man's survival. Scientists initiated studies designed to utilize microorganisms in insect control early in the 19th century. Bacteria and viruses, which cause insect diseases, are believed to be specific, do not constitute a known hazard to man or ecological components, and are biodegradable. The time element between application and effect is frequently much shorter than other alternate insect control methods and indeed approaches that of insecticides. Experience has shown that application of microbiological controls in the presence of insecticides does not reduce their effectiveness.

Microbiological agents, however, are plagued by some formidable disadvantages. They are considerably more difficult to produce than chemical insecticides and do not currently offer the profit potential. Thus the development of such agents have been, and will no doubt continue to be, in the domain of non-profit organizations. Their specificity dictates that a tremendously large number of species will need to be developed to effect control of the various insect pests in existence. Thus a long period of time will be required to make microbiological controls available for all destructive insects. In addition, the effectiveness of both bacteria and viruses are dependent upon precise time of application and environmental conditions.

The best known microbiological insect control agents, at the present, are Bacillus thuringiensis and the virus Viron/H, a virus effective against members of the genus Heliothis. Bacillus thuringiensis is the least fastidious and the most simple to produce of the two. However, it is most sensitive to environmental conditions and is ... This bacterium has been effective in field trials against ... caterpillars, cankerworms, cabbage loopers, and others. Viron/H, on the other hand, is most fastidious and very difficult to produce. It is much more stable to environmental conditions and has been found to be effective against the cotton bollworm, corn earworm, tobacco budworm, and tomato fruitworm, in pilot-plant applications. Both of these agents can be applied in spray or dust formulations.

The obvious logical answer to insect pest control in the future is integrated pest control management programs. Integrated control is the joint utilization of several suitable techniques to eradicate pests or to maintain their populations below the economic threshold. Such programs are not new but have been disregarded to a large extent in the presence of the very effective chemical insecticides. We are currently in a position such that, both by necessity and by opportunity, integrated pest control programs must be initiated. Ecological problems, insect resistance, needed improvements in pest control, and high application costs of non-persistent insecticides, dictate that we take advantage of alternate control methods. Recent developments in attractants, sterility techniques, microbiology, and cultural procedures, which ... used ... together with, or following the ... of ... insecticides, will assist in pr... the necessary control. Integrated programs are desirable but difficult to achieve on a universal basis. The development of such programs will require the combined knowledge of the agricultural, chemical and biological scientists and the cooperation of all people concerned with insect control.

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WHY SOME CHEMICALS FAIL TO CONTROL

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The success or failure of an attempt at chemical regulation depends on the ability of the operator to distinguish the factors affecting pesticidal action and to take advantage of them. Because of the diversity of chemicals, pests, and environments, however, there is often insufficient information available to allow firm statements to be made. It must be realized that variables frequently interact with each other and in consequence deliberate alteration of one may not have a simply predictable effect. Nevertheless, an understanding of environment-pest-pesticide interactions and the specification of some of the parameters controlling field performance is therefore an essential step towards increasing the reliability and effectiveness of pesticides.

Resistance: Many experts in pesticidal work consider the phenomenon of pest resistance to pesticides as one of the biggest problems posing their profession. This phenomenon has been a real source of worry since the introduction of DDT and its many companion insecticides. Within 2 years after DDT was available to Government workers for laboratory tests, a strain of houseflies resistant to it had been selected. By the late 1940's the reason for the houseflies resistance to DDT was known. The degradation of DDT to DDE was more rapid in the resistant insects than in the susceptible insects.

Brown lists 171 species, divided into two general categories of agriculture and public health, which are now resistant to one or more insecticides. A 1969 publication raises this number to 224. The first instance of resistance in the U.S. was noted in 1908, when the San Jose scale resisted lime-sulfur sprays in certain orchards of Washington State.

When an insect population develops resistance to a given material, it is usually cross-resistant to related chemicals. But developed resistance to DDT, for example, does not necessarily involve a cross-resistance to cyclodien derivatives or lindane, and vice versa, and none of these resistances carries a cross-resistance to organophosphorous compounds. Therefore, in order to controlthe resistant population, an insecticide in a different class must be selected or a different method of control should be used.

Plants can also develop resistance to a pesticide. 2,4-D, the oldest of the systemic herbicides, was developed only about a quarter of a century ago. Yet as a result of the widespread use of this herbicide (about 100 million acres annually), shifts in weed population are evident. Weeds that are resistant to 2,4-D, such as the grasses and certain species of broadleaves,are becoming more prevalent. At the same time, the development and spread of ecotypes and races of "resistant" weed species is becoming encouraged. For example, it is now possible to grow several ecotypes of bindweed and to selectively control all but one ecotype by spraying with 2,4-D. This process of resistance is comparable to that which occurs in insects but it takes longer in plants for two reasons: (1) Insects may reproduce several times within a year but plants form seeds only once a year, and (2) the susceptible plant population is constantly being renewed by seeds buried in the soil which germinate over long periods of time.

Specificity: Although many insecticides are effective against a broad spectrum of insect types, a particular pest species is often more effectively controlled with certain insecticides than with others. Some exceptions to this are the systemic insecticides which may be incorporated in the soil. This is true of some herbicides as well.

Whatever specifity a given pesticide possesses usually derives from its relative ease of entry into the pest and to the active sites of poisoning. Nicotine was a specific for aphids because it was a potent contact insecticide and readily penetrated the nervous system, while Paris green was the choice material for the Colorado potato beetle because it was a suitable stomach poison. DDT is particularly effective against houseflies and adult mosquitoes because it is a residual insecticide, and against mosquito larvae and catepillars because its toxicity is caused by contact as well as stomach action. Many beetles, however, that have heavy cuticular defenses, require the cyclodiene derivatives as chemical control agents on nonedible crops, e.g., the boll weevil on cotton.

The most widely used and best known herbicides are chlorophenoxy compounds. Characteristic of the group is effectiveness against many broadleaves and consequent selective use in cereals and grasses. TCA and dalapon, the chlorinated aliphatic acids are selective against grasses. Barban, a carbamate herbicide, is specific against wild oats in spring cereals. The stage of growth is very critical. The oats must be at about the two-leaf stage for best results, and the wheat at about the same stage. Oats become less sensitive as they grow older, but the cereal may be more severely affected.

Life Cycle and Timing: The development stage of a pest influences its susceptibility to pesticides. In general, larvae and nymphs are easier to kill than pupae and adults, and the early instars are often more susceptible than the later ones. Eggs are usually most susceptible just before hatching.

Behavior of the insect pest sometimes dictates modifications in treatment timing. The need for insecticidal treatment against the European corn borer, for example, is based primarily upon evidence of leaf feeding by young larvae. At this time the larvae population feeding in the corn whorls may threaten the crop, but due to natural mortality, only a fraction of the original larval population may actually become established as borers and injur the plants. The treatment, however, is effective only when applied before the larvae bore into the stalks and become invulnerable to insecticidal control. Thus, a treatment at this late stage will result in a failure.

In lepidoptera, the damaging stage is larva - control practices are always aimed at this stage with little effort toward control of other stages. Early instar larvae are most susceptible to chemical control. Pupae are often protected in soil and adults seldom feed.

The timing of the treatment is also of prime importance in herbicidal applications. In general, susceptibility often decreases with age or maturity. The coast fiddleneck is very sensitive to 2,4-D in the rosette stage but becomes resistant as soon as the plants start to flower. Tansy ragwort, a biennial, is moderately susceptible to 2,4-D in the first year. In the second year, when it begins to flower, it is much more difficult to kill. Unfortunately, in the first year, it is relatively inconspicuous, in the second year, when it is conspicuous because of its bright yellow flowers, it is then recognized as a serious problem but it is too late to spray effectively.

Plant responses may differ between chemicals also for example, pepperwort becomes decreasingly susceptible to MCPA as the growing season progresses, yet shows an increasing susceptibility to 2,4-D until flowering time, followed then by decreased susceptibity.

Generally speaking, plants that grow rapidly - i.e. those that grow under optimum conditions of adequate moisture, warmth, and nutrients - are most susceptible. Seedlings of perennial weeds should be treated within a few days after germination before the plant has begun to compete seriously with the crop or before it has established an extensive root system that will enable it to withstand chemical treatment.

Dosage: Correct dosage is very important, since less than the correct dosage will surely result in failure to control the pest, and more than the correct dosage may injure plants or animals or cause excessive residue. It appears that a sufficient amount of most chemicals will be lethal, a lesser amount harmful, a still lesser amount stimulatory, and an even smaller amount of negligible effect. The chemical or its metabolic products must persist on or in the pest in a toxic form and in sufficient amount for as long a time as necessary for the killing action to take place.

Computing dosages requires simple arithmetic. Error usually arises from the variety of ways in which dosages are given and from carelessness.

Dosages are often given as a range. Sometimes the treatment is intended to control two or more species, one of which might inherently be more tolerant of the pesticide than the others. When this tolerant species is absent from the complex, the lower dosage will suffice; when the tolerant species is present, the higher dosage is necessary.

<u>Formulations</u>: Treatment effectiveness is much governed by the choice of formulation. The effectiveness of an insecticide, for example, is enhanced by a formulation that concentrates the initial deposit of insecticide at the critical site, or by a formulation that yields a more persistent residue. To illustrate granular formulations were invented to carry mosquito larvicides into water covered by dense foliage that shielded the water from dusts or sprays. Granules also concentrate insecticides in the whorl of corn where the larvae of several insects habitually feed. The coarse particles roll down the corn leaves and are funneled into the throat of the plant whorl. In both examples, the effective initial deposit is multiplied by this particular formulation. Herbicides in granular form for soil application also have several advantages over spray or dust applications. It is possible to modify the properties of the granules so that the rate at which the pesticide is released can be controlled.

The elemental makeup of a pesticidal formulation is also important in the effectiveness of a treatment. The esters of 2,4-D, for example, are generally considered more toxic to plants than the amine salts. This greater toxicity is probably due to their compatibility with the cuticle and leaf waxes which they may be able to penetrate more readily. Also, they have greater wetting ability because of the oil-like nature of the ester. The oil carrier may aid penetration of the stomates and volatility permits entry of the vapors through the stomates.

<u>Compatability</u>: Pesticides are often applied in conjunction with other pesticides, or with plant nutrients and it is important that the separate ingredients of these multicomponent sprays or dusts do not reduce the biological efficiency of any of the other components, i.e., that they are compatible. Incompatibility may be the result of chemical reaction between the individual components of the mixture - either the chemicals themselves or their formulating agents - or it may be caused physically, as in the flocculation of suspensions by oil emulsions and in the preferential adsorption of one toxicant on the carrier of the other. There are many examples of chemical interaction: pyrethrum, rotenone, and - to a lesser extent - DDT, are inactivated by lime sulfur. The orgonophosphorus insecticides such as parathion, malathion, and phosdrin are rapidly hydrolyzed by the alkaline bordeaux wetting agents; a cationic fungicide such as dodine can react with anionic wetting agents. To aid practical spray application, numerous compatibility charts have been prepared by official and commercial organizations. These charts are invaluable for determining gross compatibility characteristics but it must be remembered that the rate and extent of any chemical reaction is a function of the concentration of reactants and that the property of the formulation supplements, such as wetting and emulsifying agents, are not usually considered in the construction of these tables.

Reactions - either chemical or physical adsorption displacement - involving the surface-active agents which stablize the suspension or emulsions in the tank mixture can destroy the formuation and therefore the pesticidal properties of pesticides.

<u>Environmental Factors</u>: An invaluable property of an ideal pesticide would be complete independence of environmental conditions: the capacity to be fully selective and fully active against pests irrespective of temperature, rainfall, light intensity, humidity

environmental conditions do alter effectiveness of pesticides. The rate at which a pesticide is absorbed into the pest body and its subsequent translocation and metabolic breakdown are affected by the temperature. Thus the most effective temperature conditions for a successful kill are a high temperature to get the poison inside the insect followed by low temperatures which slow the rate of detoxification. Some chemicals (DDT, methoxychlor, and TDE) are an exception to this rule in that they are most effective at continual relatively low temperatures. Usually the quick-acting poisons are more effective at higher temperatures and the slow-acting poisons at lower temperatures. In herbicidal treatments, high temperature before and after spraying appears to increase weed susceptibility and mortality, but supraoptimal temperature may reduce herbicidal entry by causing wilting, closure of stomates, and rapid drying of spray deposits.

Rains wash off water-soluble sprays, but many pesticides (insecticides and fungicides) now in use do not fall into this category. Wind and rain cause the "weathering" of the less tenacious portions of spray deposits. The effect of rainfall depends on the quantity of rain and its timing. In the case of foliage - applied herbicides, for example, rain during or closely following spraying can reduce or nullify toxicity. Rain before spraying may increase leaf wettability and hence susceptibility to a herbicide. Granular lawn herbicides should be applied to a wet foliage to be more effective.

Sunlight causes breakdown of pesticides for as long as residues remain exposed. This phenomenon, the disappearance of the chemical from the surface in regions of high light intensity is termed photodecomposition. It has been shown that the effectiveness of many pesticides applied to soils exposed to bright sunlight and little rainfall might be drastically reduced due to photodecomposition. The formative and growth responses of plants to light which in turn affect the performance of a pesticide should also be kept in mind.

Low relative humidities have a deleterious drying effect on the fine mists produced in spraying. Penetration might cease with droplet desiccation.

Many pests are controlled most readily by application of pesticides to the soil. The consequences of this are that the toxicant may persist in the soil for periods ranging from a few hours in the case of fumigants and unstable materials to several years in the case of residual compounds. Like foliar-applied chemicals performance of soil-applied chemicals is conditioned on many factors. Adsorption, leaching, decomposition, and volatility are among these factors.

When one considers all the factors that can influence the response of pests to pesticides and hence the effectiveness of a pesticide application, it is perhaps surprising how often pesticidal treatment is successful.

Treatments, as we all know, occasionally fail to fulfill expectations. The practice of pest management and control is an art, and herein lies room for mistakes in judgment and execution. One precaution however, is to allow sufficient time for maximum effort, and here familiarity with the chemical is imperative. A nonresidual contact pesticide causes maximum mortality quickly; a systemic pesticide may not produce maximum mortality for days, although indication of probable results is usually visible sooner.

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FEDERAL LEGISLATION - ITS IMPACT ON PESTICIDE SAFETY

Emerson R. Baker, J.D.

A. Occupational Safety and Health Act of 1970 [Public Law 91-596]

An act to assure safe and healthful working conditions for men and women; by authorizing enforcement of the standards developed under the Act; by assisting and encouraging the states in their efforts to assure safe and healthful working conditions; by providing for research, information, education, and training in the field of occupational safety and health; and for other purposes.

Contents:

B. Federal Environmental Pesticide Control Act of 1971

Senate Bills

232 - (Prohibits sale or shipment of aldrin, chlordane, DDD/TDE, dieldrin, endrin, heptachlor, lindane, toxaphene)
272 - (Prohibits sale or shipment of DDT)
660 - "National Pesticide Control and Protection Act"
745 - "Federal Environmental Pesticide Control Act of 1971"

House Bills

26 - (Prohibits importation of certain agricultural commodities to which pesticides have been applied)
1077
1722
4152 - "Federal Environmental Pesticide Control Act of 1971"
4596
5182
6576
6761

House Committee Print 3 (July 13, 1971)

This document represents current thinking of the House Committee on Agriculture after hearing testimony from many different individuals. It varies considerably from H.R. 4152, which was drafted by EPA and submitted by the administration. Nearly 1,000 pages of testimony were printed by the House Committee and almost an equal amount by the Senate Subcommittee on Agricultural Research and General Legislation. Probably an equal volume of material was presented to the committees and placed in their files.

Section 1. Short title and table of contents.
Sec. 2. Definitions
- (e) Certified pesticide applicator, etc.

Sec. 3. Registration of pesticides.
- (d) Classification of pesticides
  - (1) Classification for general use, restricted use, or both.

Sec. 4. Use of restricted use pesticide; certified applicators.
- (a) Limitation on use.
- (b) Certification procedure.
  - (1) Federal certification.
  - (2) State certification.

Sec. 5. Permits for experimental use.
- (a) Issuance.
- (b) Use under permit.
- (c) Temporary tolerance level.
- (d) Studies.
- (e) Revocation.

Sec. 6. Cancellation and suspension of registration of pesticides.
Sec. 7. Registration of establishments.
Sec. 8. Books and records.
Sec. 9. Inspection of establishments, etc.

Sec. 10. Protection of trade secrets, etc.
Sec. 11. Standards applicable to pesticide applicators.
(a) In general.
(b) Separate standards.
Sec. 12. Unlawful acts.
Sec. 13. Stop sale, use, removal; and seizure.
Sec. 14. Penalties.
(b) User or applicator.
Sec. 15. Indemnities.
Sec. 16. Administrative procedure; judicial review.
Sec. 17. Imports and exports.
Sec. 18. Exemption of Federal agencies.
Sec. 19. Disposal and transportation.
(a) Procedures.
Sec. 20. Research and monitoring.
Sec. 21. Solicitation of public comments.
Sec. 22. Delegation and cooperation.
Sec. 23. State cooperation, aid, and training.
Sec. 24. Authority of States and political subdivisions.
Sec. 25. Authority of Administrator.
Sec. 26. Severability.
Sec. 27. Authorization for appropriations.

C. Other Pesticide Related Legislation

1. Poison Prevention Packaging Act of 1970 [Public Law 91-601]

The following information has been extracted from the March 1971 issue of FDA Papers:

"Among the important bills signed into law...during the...91st Congress was the Poison Prevention Packaging Act of 1970 (P.L. 91-601), which will be administered by FDA. The basic concept of the legislation is to protect children from accidentally ingesting toxic substances by requiring safety closures and other safety packaging.

"FDA has already acted under the Federal Hazardous Substances Act against certain liquid drain cleaners containing more than 10 percent sodium or potassium hydroxide by publishing a proposal to require child-resistant packaging. Products failing to comply would be classified as banned hazardous substances.

"The legislation is aimed specifically at protecting children under five years of age.

"Coverage of the Act extends beyond that of the Federal Hazardous Substances Act and includes all hazardous substances, economic poisons, foods, drugs, cosmetics, and household fuels in portable containers...(and)... to items customarily stored around the household even when such products may not be destined for use around the household.

"The bill authorizes the Secretary of Health, Education, and Welfare to establish special packaging standards for virtually all household substances after consultation with a technical advisory committee.

"One of the major controversies that had arisen over this legislation...related to the exemption permitted for the benefit of the elderly and handicapped. The Senate, recognizing this contingency, provided that one size of a product could be marketed in noncomplying packages for this purpose if such packages bore a label stating that the noncomplying packages are intended for households without young children.

"Establishment of a technical advisory committee of up to 18 members by the Secretary is mandatory under the Act and consultation with the committee prior to making findings and in establishing standards is required.

"The legislation provides for accomplishing enforcement by amending the misbranding sections of the Federal Insecticide, Fungicide and Rodenticide Act; the Federal Food, Drug, and Cosmetic Act; and the Federal Hazardous Substances Act."

2. Hazardous Materials Transportation Act of 1970 [Public Law 91-458]

3. Federal Food, Drug, and Cosmetic Act

4. State use and application laws and regulations

PESTICIDE POISONING: A MEDICAL EXAMINER'S VIEW

Joseph H. Davis, M.D.

The diagnosis of poisoning is usually considered in terms of characteristic symptoms corroborated by specific laboratory findings. However, the first step in a diagnosis is to think of the possibility. The next step is to carry out the necessary investigations. In order to achieve the ultimate in accuracy in poison death or injury investigation, the physician, or investigative agency, should possess the following:

1. A high index of suspicion

2. A background knowledge of the community

3. Familiarity with the variables of clinical manifestation

4. Facilities for careful initial and subsequent scene investigation

5. Facilities for prompt use of laboratory testing, bearing in mind the limitations of such procedures

Only by knowledge of community experience may the physician be alert to the possibilities of pesticide causing an illness or fatality. In Dade County, Florida, a ten-year review of over 1000 poison deaths investigated by the Office of the Medical Examiner has revealed that pesticides comprised approximately 9.7 per cent of the total of all poison deaths including accidents, suicides, and homicides. If intentional poison deaths are excluded, leaving 313 accidental cases, pesticides comprised 11.8 per cent of the cases. With children under 5 years of age, a total of 45 deaths in 10 years, pesticides comprised 49.0 per cent, 22 cases. This was double the number of deaths due to medications, the majority of which were salicylates.[(1)]

Of all the pesticide deaths and injuries studied in this one community, organophosphates, usually parathion, were the most common and produced the greatest number of clinically observed cases.

The clinical manifestations of organophosphate pesticide poisoning are well described and include miosis (constricted pupils), weakness and collapse, muscular fasciculations (twitchings), cutis anserina (goose flesh), diaphoresis (sweating), pulmonary edema, nausea, vomiting and diarrhea. Unfortunately, not every patient follows a set pattern of clinical response when initially viewed by the physician. The clinical signs may be confused with encephalitis, brain injury, hypertensive encephalopathy, pneumonitis, gastroenteritis, asthma, and congestive heart failure, to name a few.

Clinical laboratory data might confuse the clinician. In a local study of 60 hospitalized parathion cases, one-third has glycosuria in the acute phase of poisoning. This could lead to a misdiagnosis of diabetes. Leukocytosis coupled with pulmonary edema could easily lead to a diagnosis of infectious pneumonitis. Miosis, constriction of the pupils, has been frequently emphasized as a diagnostic sign. However, it was noted in only 50 per cent of the series of hospitalized cases. Another recent review of hospitalized cases revealed 6 out of 44 who had mydriasis (dilation of the pupils) instead of miosis.(2)

Specific laboratory tests for organophosphate poisoning may be confusing unless all circumstances are carefully considered. For example, the bromothymol blue screening procedure for cholinesterase activity may be "normal" due to the blood having an initial acid pH or a very high hematocrit. This may lead to an error in diagnosis in what would otherwise be considered an organophosphate poisoning or death.(2)

Examples of the problems of diagnosis, investigation of circumstances, and treatment are typified in the following cases:

Case I (63-1713) A 5-year old child developed diarrhea and foaming at the mouth while playing in the backyard. He was dead on arrival at a nearby physician's office. Poison was suspected in the form of some palm leaves with which the child was playing. The postmortem appearance of miotic pupils, watery foam from the mouth, and rapid onset of symptoms and death indicated an organophosphate poisoning. Police were directed to search for parathion which was subsequently found in a whisky bottle from which the child drank under the mistaken belief that it was eggnog.

Case II (63-1485) This 70-year old vagrant, whose home consisted of a discarded packing crate, was found dead. Because of the agricultural area in which he lived, the autopsy study was directed along the lines of organophosphate poisoning with resulting positive results. This type of case could easily be misdiagnosed in view of the age of the victim, his social status and the additional fact that he was beginning to decompose.

Case III (61-1854) This 31-year old female was admitted to a hospital unable to speak due to pulmonary edema. She wrote a note to the nurses indicating that her soft drink had been poisoned. Despite this she was treated with antibiotics for pneumonia and died 4 hours after admission. Her boyfriend was charged with murder.

Case IV (62-1602) This 53-year old male became ill while drinking beer in a saloon. He died in a taxicab on the way home. Small pupils, coupled with the fact that he died in association with a saloon, led to an investigation of organophosphate. Parathion was detected. The police arrested a woman who confessed to putting a drop of 80 per cent parathion into his beer "just to make him sick."

Case V (64-343) This 16-month old Negro child collapsed to the ground while playing. Ineffectual small doses of atropine were given. Twitching of muscles (fasciculations) were treated with Dilantin. Head trauma was suspected.

He died the following morning. The postmortem appearance, small pupils, pulmonary edema, suggested an organophosphate. Chemical tests for parathion and its metabolic by-products were negative. Subsequently it was found that the family used Guthion concentrate as a fly spray in the bedroom of the child. Empty pesticide containers were being used in profusion throughout the community as utility cans for water, kerosene, gasoline, garbage, etc.

Case VI (65-2103) This 18-year old male was found unresponsive and admitted to a hospital with a story of having drunk from a soda pop bottle containing turpentine. He died 3 hours and 45 minutes after admission. The stomach contained a chemical having similar characteristics to the contents of the soft drink bottle. Red cell cholinesterase activity was markedly depressed. The contents of the bottle were found to be Zectran-2E, a carbamate insecticide obtained from his place of employment.

It was initially assumed, because the family said so, that the material in the soft drink bottle was turpentine. A significant part of the initial determination of the type of poison is a scene search and knowledgeable interrogation of witnesses. This is difficult to do on an emergency basis in view of the usual lack of community facilities for this type of investigation.

Case VII (Acc. 61) A small child was admitted to a hospital. The physicians suspected poisoning but ruled out pesticides because the family acknowledged only that the house had been fumigated. Subsequently it was found that the "fumigation" consisted of having an unlicensed door-to-door "structural pest control operator" sprinkle "roach powder" in the home. The physician had assumed that fumigation meant the classical tent fumigations. The family thought the word meant what had occurred in its home the day before. Fortunately the father had enough concern to bring some of the powder to the laboratory where it was immediately determined to be parathion. The physicians were alerted, and energetic therapy with atropine and PAM led to a speedy recovery.

Case VIII (66-924) This small child was found playing with some powder obtained from a container marked D-Con whose label indicated it to contain 0.023 per cent warfarin. A physician called on the telephone, assumed the label to be correct and advised no therapy was needed. The child died. In view of the circumstances the death was erroneously certified as being due to warfarin poisoning. With subsequent interest in civil litigation the body was exhumed and transported to a distant medical examiner laboratory for study. Material from the container as well as from the embalmed body revealed parathion. In this case the source of confusion was due to the substitution of one insecticide for another.

Case IX (Acc. 68) This man was admitted to a hospital and stated that he had been poisoned. He had dilated pupils. A physician commenced treatment for organophosphate poisoning. Initial chemical tests were confusing due to the presentation of late stomach washings to the laboratory, rather than the initial stomach content. Energetic therapy over a period of several days, coupled with an equally energetic epidemiological background investigation, led to the proper solution of the case. The victim had drunk approximately 2 ounces of concentrated Guthion shortly before admission to the hospital.

Case X (Acc. 59) Moonshine still operators have found that pesticide barrels are useful for fermenting mash.

REFERENCES

1. Davis, Joseph H., The Changing Profile of Fatal Poisonings, Ind. Med. Surg. 36:340-346, May, 1967.

2. Davis, Joseph H., Davies, John E., and Fisk, Arthur J., Occurrence, Diagnosis and Treatment of Organophosphate Pesticide Poisoning in Man, Biological Effects of Pesticides in Mammalian Systems, New York Academy of Sciences, To be published.

SAFETY IN TRANSPORT AND STORAGE OF PESTICIDES

James F. Byrne

A discussion of the above topic must necessarily consider pesticide containers; Department of Transportation regulations; protection of the public, workers, and environment in handling pesticide spills; and, finally, manufacturers' assistance to provide such protection.

A discussion on containers should be limited to those designed for pesticide products which if released would represent an immediate hazard to human life. The higher the degree of hazard, the more urgent the problem. Parathions, for instance, are a case for urgency, whereas DDT or CHLORODANE are not.

Hazardous liquid pesticides are transported in steel containers, lined and unlined, from one-gallon size up to 55-gallon drums. Glass, though an excellent container, is fragile and represents a hazard in itself. Hazardous pesticides are not known to be packaged in plastic containers.

Failure in steel containers can be grouped in two general areas: (a) failure due to abuse in handling, and (b) failure due to structural defects in manufacturing the container. It can also be stated that the rate of failure attributable to manufacturing increases as the container gets smaller. Conversely, the rate of failure attributed to abuse climbs as the container gets larger.

Aside from exposure to a larger volume of product as a result of a larger container leaking, the knowledge does exist on how to reduce these leakers significantly. These failures (leakers) occur largely through mishandling in loading, transportation, and warehousing, which can be reduced through education.

Failure due to manufacturing defects or inadequacies are a serious problem related to small containers. Despite years of investigation, the problem still exists in the one-gallon container. Aluminum, glass, plastics and copolymers, combinations, and composites still have not replaced steel pails and manufacturers continue having difficulty fabricating a one-gallon can without damaging the lining as well as properly sealing flex spouts.

The Department of Transportation, of course, is concerned over the transportation of hazardous materials, in particular, on movement of Class B Poisons with food stuffs, which is banned.

Since special tariff regulations apply to the transport of certain classifications of poisons, an explanation of these several classes follows: extremely dangerous poison - Class A, less dangerous poison - Class B; tear gases or irritating substances - Class C; radioactive materials - Class D.

Class A Poisons are listed specifically as to the name and chemical make-up of the product. Thirteen such poisons are listed by the tariff. Some materials so classified are Bromacetone, Diphosgene (Phosgene), Nitrogen Peroxide, and Mustard Gas.

Class C Poisons are those materials, liquid or solid, "which upon contact with fire or when exposed to air give off dangerous or intensely irritating fumes." Some materials so classified are Monochloroacetone (stabilized), Tear Gas grenades or candles (without ignition elements or fuses), and Chlorocetophenone.

Radioactive materials are designated as a Class D Poison, however, the regulations concerning packaging and transportation of radioactive material differs from the regulations covering toxic materials and would not pertain herein.

Class B Poisons, to which this discussion is addressed, are described by the tariff as "those substances, liquid or solid...other than Class A or Class C Poisons, which are known to be so toxic to man as to afford a hazard to health during transporting or which, in the absence of adequate data on human toxicity, are presumed to be toxic to man on the basis of tests conducted on laboratory animals. If a product meets any of the lethal dose criteria, it must be classified as a Class B Poison and carry a flammable "DOT" label. Although products may have the characteristics of a Class B Poison, tariffs stipulate that the products which meet the requirements to be classified as more than one class of Dangerous Article, must be labeled with the classification designating the highest degree of danger. In other words, the products' flammable aspects take precedence.

Further, with respect to Class B Poisons, a Motor Carrier regulation specifies that "material marked or known to be poison (Class A or B) must not be transported in the same vehicle with material known to be food stuffs, feeds or any edible material intended for consumption by humans or animals." Nothing is said about poisons of less than Class B potency but still dangerous, or a mixed personal use cargo, such as clothing, that might be contaminated by Class B Poisons and also hazardous to the user.

As of December 31, 1970, the Department of Transportation has required each carrier transporting hazardous materials to report by telephone to the DOT at the earliest practical moment after an incident in which as a direct result of hazardous transporting, a person is killed, hospitalized, property damages exceed $50,000, or a continuing danger to life exists at the scene of the incident. Transportation regulations include, as well, loading, unloading and temporary storage. Written reports of such incidents involving highway or railroad accidents are required of the carrier within 15 days of the discovery of the incident. Also required are reports of any "unintentional release of hazardous materials."

It is obvious from the above that the carrier plays a significant role in protecting the public from Class B pesticide exposure and cannot delay reporting and seeking assistance when he has an upset or discovers a leaking container. Responsible manufacturers of pesticides provide the necessary warning information of their products being transported.

Safe pesticide storage or "warehousing" is a matter of prime importance. There are no government rules or regulations on warehousing. Pesticide manufacturers as well as the National Agricultural Chemicals Association do publish storage guidance with respect to the several classifications of pesticides. The only general or non-specific collection of rules for safe pesticide storage, known to this author, was prepared by Cornell University in Supplement II of its Northeast Pesticide Information Manual. Chapter V of this Supplement is quoted as follows: "Rules for safe pesticide storage: Identify pesticide storage with prominent waterproof signs over each entrance, including windows if present and on all sides of building. Keep locked when not in use. Inform police, fire department, and public health officials in writing of the location and layout of the storage, types of materials stored, and hazards involved. Leave phone numbers of persons responsible for storage with fire chief. Fire companies should map the locations of pesticide chemical storages in their respective areas. Inform local physicians and hospital of potential hazards and be sure they know how to treat and that antidotes are on hand. (The U. S. Public Health's Clinical Handbook on Economic Poisons should be available.) Antidotes should include an adequate supply of atropine sulfate and 2-PAM (Protopam chloride). Post list of chemicals (organophosphates, carbamates, herbicides, chlorinated hydrocarbons, flammable solvents, etc.) on outside of building, along with storage plan. Obtain desirable firefighting equipment, familiarize yourself and your help with its operation. Be sure it works. Keep pesticide containers, particularly glass, away from windows and out of sun so they will not be subject to heat and ignition. Do not store partly empty containers of pesticides containing chlorates. Keep combustibles away from steam lines and heat. Read label for information on flammability and store accordingly. Store highly toxic pesticides in one area. Store herbicides separately from other pesticides to prevent cross-contamination and to prevent mistakes in choice of material. Dispose of unlabeled pesticides. Treat them as highly toxic. Keep a quantity of hydrated lime on hand for detoxification of spills."

Major pesticide manufacturers normally provide information on safe storage and handling as well as on site decontamination kits at their own and public warehouse locations.

With respect to assistance rendered in the event of a pesticide spill endangering the general public, workers and the environment, major manufacturers are, for the most part, prepared to assist immediately on notification of a spill of one of their products. To better ensure that complete national coverage is provided by all major manufacturers, the National Agricultural Chemicals Association has sponsored membership participation in a national network of trained safety teams, designed to minimize the risk arising from the accidental spillage or leakage of pesticide chemicals in the Class B Poison category. This network began operation on March 9, 1970. More than 38 teams were initially involved in the NACA program known as the Pesticide Safety Team Network, and many more have since joined.

Each participating company has been assigned one of 10 specific areas in the United States within which it will act as the Area Coordinator. The Area Coordinator is notified by Telephone Central, which operates monitors on a 24-hour basis in Cincinnati, Ohio, reports of any accident involving a Class B Poison pesticide occurring in his area. After receiving such an emergency message, the Area Coordinator immediately will attempt to communicate with the manufacturer or producer of the involved product and agree on a procedure to be followed. The and advised on what immediate steps to take. If a safety team is needed, it is dispatched to the scene of the accident by the Area Coordinator from a roster of teams in his area, or by the manufacturer.

In the first year of operation, 47 cases were handled by the Network, and as its existence has become better known, reports of spills have increased accordingly

At this point, the question naturally arises as to the purpose and responsibilities of pesticide decontamination teams. Essentially, a pesticide team attempts to minimize hazards to people from exposure to hazardous chemical spills; to minimize damage to plant property and animal life, to better confine the effect of the immediate incident by guarding against its extension or the occurrence of secondary incidents; to provide appropriate coordination and return to normalcy at the site of the incident; to provide for discriminate release of information on the incident to avoid undue public speculation and hysteria.

In meeting the above objectives, the teams will recommend to local authorities that the contaminated area be roped off and confine entry to those persons who are properly protected. If there is visible spread of hazardous material, recommend to local authorities to evacuate all residents in the path of spread and maintain a close check of wind conditions and direction until the hazard abates. Recommend prompt medical attention of persons known to have been exposed or suspected of having been exposed to poisonous materials. Advise local, state and Federal health authorities of possible contamination of water supplies, if such a hazard appears to exist.

The teams will then advise local workers on decontamination, removal and safe disposal of residue, ensuring all the while their personal protection. As is often the case, the team members will themselves perform many of the manual chores required in the decontamination process.

No two situations are the same, therefore, the technical ability and maturity of the individual team member is carefully considered before his assignment.

The team captain, under most circumstances, will be a plant manager at a pesticide basic manufacturing or formulating plant. He must possess the ability to make intelligent on-the-spot judgments. He must be able to take charge of an emergency situation and formulate a plan of action which will insure maximum safety to the public. He must be willing to carry out the plan and go to any length necessary to insure himself and any authorities which may become involved that the situation has been rendered safe.

The following listing of qualifications are considered to be of utmost importance and essential in the selection of team captains to meet the high standards which must be established by the PST Network. First-hand experience working with toxic pesticides preferably gained from previous and/or present responsibilities in a plant or plants manufacturing or formulating Class B Poison pesticides. Extensive knowledge of the safe handling and operational precautions of toxic pesticides to be able to give special advice, direction, and guidance in the case of a spillage incident. Extensive knowledge of requirements and limitations of protective clothing and equipment for working with toxic pesticides. Sufficient knowledge of personal hygiene, signs and symptoms of intoxication by toxic pesticides, and first aid treatment to insure maximum safety to all persons possibly exposed to toxic pesticides until such time as a physician is contacted.

The National Agricultural Chemical Association and its participating members have been gratified by the results of its efforts. Future success should continue so long as cooperation continues between all interested parties, the

CALIBRATION OF EQUIPMENT

Robert D. Black

A. Nozzle Types and Uses

There are basically 8 different types of broadcast spraying for use with all the spraying and metering techniques employed in the farm chemical spray field. It is recommended that all nozzles are designed and fabricated under quality control methods to assure precise calibration. Most nozzles are available in a choice of materials to meet requirements of application. These include brass, aluminum, stainless steel, and nylon. In addition, it is recommended that these nozzles be of the material that offers the greatest resistence to corrosion and erosion relative to the chemical used.

The 8 methods of broadcast spraying are:

1. Overlapping Boom Spraying Nozzles
   a. Tee-jet
   b. Flood-jet
   c. Vee-jet
2. Ban Spraying Nozzles
   a. Even Spray Nozzles
3. Boomless Spraying Nozzles
   a. Doc-jet
   b. Boom-jet
   c. Field-jet
   d. Off Center
4. Row crop nozzles
   a. Cone-jet
   b. Disc type tee-jet
5. Fertilizer and Fumigant Metering and Spraying Nozzles
   a. Vee-jet
   b. Tee-jet Flow Regulators
6. Spray Gun Applications
   a. Gun-jets
7. Airplane and Helicoptor Spraying Nozzle
   a. Diaphragm tee-jet
8. Misblower Nozzles
   a. Whirl-jet
   b. Disc type tee-jet

B. Manipulations of properly calibrated equipment (lbs./ozs./acre-verses nozzle)
   1. Graft (will show slides and explain 80° Tee-jet Nozzles)

C. Determination of accuracy of application. Because conditions in farm areas vary with each locality, it is recommended that the individual follow the directions given by local specialists from chemical manufacturers, universities, and the USDA. Also, before applying chemicals, read the label and follow all safety instructions.
   2. Show graphs on useful information.

After useage the spray tip may clog or wear; thereby resulting in improper, often costly, chemical application. It is most important to clean your equipment and spray tips and check the flow rate before each use.

USEFUL INFORMATION

CAPACITY TABULATIONS BASED ON SPRAYING WATER

Water weighs 8.34 lbs. per gallon. When spraying solutions are heavier or lighter than water, multiply tabulated gallonage figure by factor shown below.

Weight of Solution	Specific Gravity	Conversion Factors
7.0 lbs. per gallon	.84	1.09
8.0 lbs. per gallon	.96	1.02
8.34 lbs. per gallon—WATER	1.00	1.00
9.0 lbs. per gallon	1.08	.96
10.0 lbs. per gallon	1.20	.91
11.0 lbs. per gallon	1.32	.87
12.0 lbs. per gallon	1.44	.83

G.P.A. TABULATIONS FOR BOOM SPRAY NOZZLES

The spacing of nozzles is illustrated and stated in nozzle tabulations of this catalog. Where spacing of noz: on a boom is other than listed in the tabulations, multi the tabulated G.P.A. coverages by one of the follow conversion factors that applies.

Where Tables Are Based On 20" Nozzle Spacing									
Other Spacing	8"	10"	12"	14"	16"	18"	22"	24"	
Conversion Factor	2.5	2	1.67	1.43	1.25	1.11	.91	.83	

Where Tables Are Based On 40" Nozzle Spacing									
Other Spacing	28"	30"	32"	34"	36"	38"	42"	44"	
Conversion Factor	1.43	1.33	1.25	1.18	1.11	1.05	.95	.91	

USEFUL FORMULAS

$$\text{G.P.M. (Per Nozzle)} = \frac{\text{G.P.A.} \times \text{M.P.H.} \times W^*}{5940}$$

$$\text{G.P.A.} = \frac{5940 \times \text{G.P.M.}}{\text{M.P.H.} \times W^*}$$

*W—Nozzle spacing (in boom spraying) or spray swath (in boomless spraying) in inches.

ABBREVIATIONS

G.P.A.—Gallons per Acre
G.P.M.—Gallons per Minute
G.P.H.—Gallons per Hour
M.P.H.—Miles per Hour
N.P.T.—Tapered Pipe Thread
P.S.I.—Pounds per Square Inch (gauge pressure)

MISCELLANEOUS CONVERSION FACTO

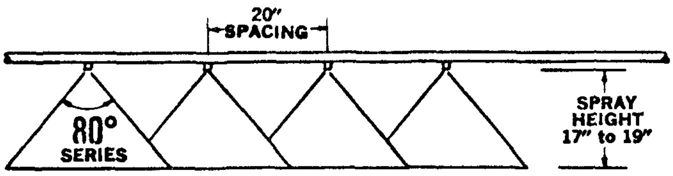
One Acre—43,560 square feet
One Mile—5,280 feet
One Gallon—128 fluid ounces
—8 pints
—4 quarts
One Foot Head—.43 pounds per square inch
25.4 microns—.001"

TRACTOR SPEEDS

Speed/MPH	Time Required in SECONDS to Travel a Distance of: 100 Feet	200 Feet	300 Feet
1.0	68	137	205
1.5	45	91	136
2.0	34	68	102
2.5	27	55	82
3.0	23	45	68
3.5	20	39	58
4.0	17	34	51
4.5	15	30	45
5.0	14	27	41

RATES OF FLOW

G P M	Seconds To Collect 1 Quart	G P M	Seconds To Collect 1 Quar
.05	300	.175	86
.06	250	.20	75
.07	214	.225	67
.08	188	.25	60
.09	167	.30	50
.10	150	.325	46
.11	136	.35	43
.12	125	.40	38
.13	115	.425	35
.14	107	.45	33
.15	100	.50	30



FLAT SPRAY Teejet Tip No.	Liquid Pressure in p.s.i.	Capacity 1 Nozzle in G.P.M.	GALLONS PER ACRE 2 M.P.H.	3 M.P.H.	4 M.P.H.	5 M.P.H.	7.5 M.P.H.	10 M.P.H.
	20	.05	7.0	4.7	3.5	2.8	1.8	1.4
	25	.055	7.8	5.2	3.9	3.1	2.1	1.6
800067	30	.06	8.6	5.7	• 4.3	3.4	2.3	1.7
	40	.067	9.8	6.6	4.9	4.0	2.6	2.0
4.3 GPA	50	.07	11.0	7.4	5.5	4.4	3.0	2.2
(100 MESH)	60	.08	12.0	8.1	6.0	4.9	3.3	2.5
	20	.07	10.5	7.1	5.3	4.3	2.8	2.2
	25	.08	11.8	7.8	5.9	4.7	3.1	2.4
8001	30	.09	12.9	8.6	• 6.4	5.1	3.4	2.6
	40	.10	14.9	10.0	7.4	6.0	4.0	3.0
6.4 GPA	50	.11	16.7	11.2	8.3	6.7	4.5	3.4
(100 MESH)	60	.12	18.2	12.2	9.1	7.4	4.9	3.7
	20	.11	15.7	10.5	7.8	6.3	4.3	3.2
	25	.12	17.5	11.7	8.8	7.1	4.7	3.6
80015	30	.13	19.2	12.9	• 9.7	7.7	5.2	3.9
	40	.15	22	14.9	11.1	8.9	6.0	4.5
9.7 GPA	50	.17	25	16.7	12.4	10.0	6.7	5.0
(100 MESH)	60	.18	27	18.2	13.6	10.9	7.4	5.5
	20	.14	21	14.0	10.5	8.4	5.6	4.2
	25	.16	23	15.7	11.8	9.4	6.3	4.7
8002	30	.17	26	17.2	12.9	10.3	6.9	5.2
	40	.20	30	20	14.8	11.8	7.9	5.9
12.9 GPA	50	.23	33	22	16.5	13.2	8.8	6.6
(50 MESH)	60	.25	36	24	18.1	14.4	9.7	7.2
	20	.21	32	21	15.7	12.6	8.4	6.3
	25	.24	35	23	17.6	14.1	9.4	7.1
8003	30	.26	38	26	19	15.4	10.3	7.7
	40	.30	45	30	22	17.8	11.8	8.9
19 GPA	50	.34	50	33	25	20	13.2	10.0
(50 MESH)	60	.37	55	36	27	22	14.4	10.9
	20	.28	43	28	21	16.8	11.2	8.4
	25	.32	47	31	24	18.7	12.5	9.4
8004	30	.35	51	34	26	21	13.7	10.3
	40	.40	59	40	30	24	15.8	11.9
26 GPA	50	.45	66	44	33	27	17.7	13.3
(50 MESH)	60	.49	73	49	36	29	19.4	14.6
	20	.35	53	35	26	21	14.0	10.5
	25	.40	59	39	29	23	15.7	11.7
8005	30	.43	64	43	32	26	17.2	12.9
	40	.50	74	49	37	30	19.8	14.9
32 GPA	50	.56	83	55	42	33	22	16.6
(50 MESH)	60	.61	91	61	45	36	24	18.2
	20	.42	63	42	31	25	16.9	12.6
	25	.47	70	47	35	28	18.7	14.1
8006	30	.52	77	52	39	31	21	15.5
	40	.60	89	59	45	36	24	17.8
39 GPA	50	.67	100	66	50	40	27	20
(50 MESH)	60	.73	109	73	55	44	29	22
	20	.56	84	56	42	34	22	17
	25	.63	94	63	47	37	25	19
8008	30	.69	103	69	52	41	27	21
	40	.80	119	79	59	48	32	24
52 GPA	50	.89	132	89	66	53	35	27
(50 MESH)	60	.98	145	97	73	58	39	29
	20	.70	105	70	53	42	28	21
	25	.78	117	78	59	47	31	24
8010	30	.86	128	86	64	51	34	26
	40	1.00	148	99	74	59	40	30
64 GPA	50	1.11	165	111	83	66	44	33
	60	1.22	181	121	91	73	49	36
	20	1.06	157	105	79	63	42	32
	25	1.23	176	117	88	71	47	35
8015	30	1.30	193	129	97	77	52	39
	40	1.50	222	148	111	89	59	45
97 GPA	50	1.67	248	165	124	100	67	50
	60	1.83	272	181	136	109	73	55
	20	1.41	209	140	105	84	56	42
8020	25	1.58	235	156	117	94	63	47
	30	1.73	257	171	128	103	69	51
128 GPA	40	2.00	297	198	149	119	79	59
	50	2.23	331	221	166	132	88	66

Addendum

Study Book for the Training Course

SAFETY AND PESTICIDE USAGE

1971

Table of Contents

*See enclosed Service Letter 1249 of the National Pest Control Association - Good Practice Statements.

ENVIRONMENTAL PROTECTION AGENCY
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ERRATA:

1) Page 6, Table #1, should read:

Sales in thousands of pounds

1968	130	318	511	960
1969	124	311	493	929

2) Page 29, Example: Make 96 gallons of chlordane...

Gallons chordane 8 lb/gal E.C. to use = $\frac{8.33x96x.5}{100x8}$ = .5 gal

3) Page 100, reference No.2 should read:

2. Davis, Joseph H., Davies, John E., and Fisk, Arthur J.: Occurrence, Diagnosis, and Treatment of Organophosphate Pesticide Poisoning in Man, Biological Effects of Pesticides in Mammalian Systems Monograph in Ann. N.Y. Acad. Sci., 160 (1): 383-392, June 23, 1969.

4) Page 102, paragraph beginning with "Class B Poisons...," 8th line, "ICC" should read "DOT."

HAZARDS ASSOCIATED WITH DIFFERENT METHODS OF APPLICATION

W. E. Yates and N. B. Akesson

Pollution of pesticides in our biosphere has resulted in widespread public concern during recent years. The magnitude of the problem has increased tremendously during the past decade due to the development and expanded use of synthetic organic pesticides. In the period 1964 to 1967, the U. S. sales of synthetic pesticides rose from 6.9×10^8 lb. to nearly 9×10^8 lb. California accounts for approximately 20% of the total U. S. pesticide useage. From 1964 to 1969 the area treated by licensed pest control operators in California increased from 8.4 to 13.1 million acres with aircraft operators accounting for over 75% of this acreage. If the estimated area treated by California farmers is added to the above figure for 1969, the total area treated would be 17.9 million acres.

Although there are many routes by which pesticides pollute the environment, one of the major routes is through the air. For example, the Panel on Monitoring Persistent Pesticides in the Marine Environment by the National Research Council Committee on Oceanography (1) concluded "It is at least plausible that the atmosphere is the major route for transfer of DDT residues into the oceans." The panel estimated that 26,000 tons of DDT residues (25 percent of the annual production) enters the air by drift when pesticides are applied and vaporize from water, plant or soil surfaces. They further concluded that the residues in the air may travel great distances before they eventually fall into the sea, are washed out by rain or precipitated as dry particles.

This paper discusses the major factors affecting the drift or movement of pesticides in the air to nearby nontarget areas as a result of pesticide applications. A potential hazard exists during every spray or dust application since current techniques releases a certain fraction of material as fine particles or gases of the pesticide formulation directly into the atmosphere. The inhalation of gases and fine particles of pesticides as well as collection of larger particles on exposed skin and on clothing poses a potential health hazard, particularly to application crew, to farm workers or others nearby. Large area applications may produce enough aerosols during certain stable atmospheric conditions to significantly contaminate areas within several miles or possibly within a given air basin. The drift of pesticides onto edible crops near harvest times and into water and soil resources poses a health hazard as a direct contamination of our food and water supply or indirectly through the contamination of our meat or milk supplies. Also low levels of drift residues may have serious long term effects on wild life, agri-eco systems, and estuarine food chain. To protect the consumer each pesticide is registered with a specific tolerance or maximum limit on specified foods and feed products that go to market. For example, the tolerance for Parathion on dry alfalfa is 1.0 ppm. Since this is an extremely small level to visualize it may be more graphic to state that this is equal to the distribution of one tablespoon of technical Parathion distribution over 10 acres. As another illustration of the potential drift hazard, consider the treatment of a cotton field with an equal size alfalfa field adjoining it on the downwind side. In this case, if 99.8% of the spray remained on the target crop, the remaining 0.2% of the pesticide would represent enough Parathion to contaminate an equal area of alfalfa to a level of 1.0 ppm.

Specific research on the drift and deposit of pesticide chemicals have been conducted by our group at the University of California, Davis, with support in part by PHS grants during the past 10 years. Results from this program have been reported in numerous publications (2,3,4,5,6). Fig. 1 illustrates the general field layout for the drift experiments. Most of the aircraft applications were made with a Stearman aircraft flown 1-5 feet above crop level. Each spray mixture contained a tracer or a pesticide material. Six to eight passes were made over a single marked course at least 1/2 mile long and oriented perpendicular to the wind. Drift fallout samples were collected on Mylar sheets placed near the top of the crop. The air burden was assessed at strategic locations with high volume Staplex air samplers and the particle size measure from collections with Unico cascade impactors. All deposits were corrected to a common basis of micrograms per square foot per pass and for an equivalent of 1 pound active material released in 1320 ft. of travel.

Figure 2. illustrates typical results of drift recoveries plotted on log-log axis. As shown, the fallout residues drop very rapidly and at a distance of 1 mile downwind are approximately 1/10,000 the concentration under the aircraft. Figure 2 also shows that at a distance of 1 mile downwind the concentration of material collected by the air samplers was over 100 times as much as the fallout at that distance.

This paper summarizes the basic effects of the following five physical factors on the potential drift hazards; (a) Type of application equipment and operating techniques, (b) Nozzle types and operating conditions, (c) Physical properties of the formulation, (d) Microweather factors, and (e) Field size and dosage.

TYPE OF APPLICATION EQUIPMENT

The type of application equipment plays a significant role with respect to the number, size, velocity and location of particles released in the atmosphere. For example, fixed wing aircraft produce characteristic wing tip vortices that have a major affect on the movement of fine particles released from an aircraft. Theoretically, for a simplified rectangular spanwise loading of a wing the circulation is proportional to the weight of the aircraft and inversely proportional to the aircraft velocity. A few years ago a study was conducted to measure the effect of air currents on fine particles released at various locations on an aircraft. Motion-picture cameras were used to record the trajectories of small gravitationally balanced balloons released from cages along the boom on the aircraft. Figure 3 illustrates the trajectories and velocity of balloons released from a high wing monoplane. To avoid severe entrainment of fine particles in the vortices, nozzles should not be located near the wing tips. A helicopter produces a similar wake behind its rotary wing. The major difference is that it is capable of flying at a lower forward speed and can consequently produce stronger circulation patterns. Figure 4 illustrates the theoretical velocity field while Figure 5 shows the velocity and trajectories of balloons released from a Bell helicopter operating at a 15 mph forward speed. It is obvious that the circulation is stronger than that produced by a fixed wing aircraft. Thus, it is particularly important that the nozzles be located as far forward as practical and only in the central area in order to reduce the amount of fine particles that may be entrained in the vortices.

Air blast ground sprayers are frequently used for orchard applications and may produce an initial air velocity of over 100 mph near the machine. If fine spray particles are introduced into the air curtain a serious amount of material may be carried well above the tree level and likewise drift a significant distance downwind. Ground boom type or broadcast type sprayers have a potential of producing a minimum amount of drift since the vehicle doesn't produce any vertical air currents. However, it should be recognized that if a very fine spray is used, the terminal velocity may be extremely low and consequently the atmospheric wind velocity and turbulence may produce significant drift residues downwind. However, Figure 6 illustrates the potential reduction in drift residues with the use of a large drop size emitted from a ground broadcast sprayer. As shown the ground sprayer produced 1/6 to 1/10 the spray residue of an aircraft sprayer.

NOZZLE TYPES

The particle size distribution is one of the major factors influencing the potential drift residue hazard. The basic problem is that presently available nozzles suitable for agricultural sprayers produce a wide spectrum of drop sizes. Figure 7 illustrates typical hydraulic nozzles used for pesticide applications. From left to right, the first is a simple circular orifice or jet used on aircraft to produce a large droplet size, the second and third are two types of hollow cone nozzles commonly used for aircraft applications, the fourth is an eliptical orifice that produces a flat fan pattern frequently used on ground sprayers, and the last nozzle is a bi-fluid (air and liquid) nozzle commonly used to produce a very fine or coarse aerosol spray at very low flow rates.

Figure 8 shows the drop size distributions for various types of nozzles. The curves reveal that a wide range of different drop size spectrums can be selected for special requirements. However, it should be noted that the slope of all spectrums are similar which means the uniformity or coefficient of variation is nearly the same for all nozzle types. Drift could be significantly reduced if an atomizer was available that could eliminate or reduce the percent of drops less than 100 microns. One recent development that looks promising is the use of small nonturbulent jet stream atomizers. A system developed by Amchem Products Inc., called the Microfoil™ utilizes over 3000 needles with a 0.013 inch ID for use on a helicopter. With the jets directed back and in line with the relative air velocity a very uniform drop size of approximately 800 microns is produced. Figure 9 shows the very significant reduction in spray drift fallout that can be achieved with this system operating at a forward speed of less than 60 mph on a helicopter. It should also be noted that the 800 micron droplets aren't stable when introduced into a 100 mph airstream of a fixed wing aircraft. Consequently, the drift from the Microfoil and conventional D6 jet are similar if used on a fixed wing aircraft.

The maximum stable droplet size for a shock exposure of 100 mph air velocity is 390 microns. Thus we are currently attempting to develop a jet stream nozzle system that will produce a uniform drop size of 250 to 300 microns. The system will incorporate a 0.005 inch orifice along with an electromagnetic oscillator to provide a control of the critical oscillation of from 6000 to 1000 Hertz. We hope to field test this system later this year.

PHYSICAL PROPERTIES OF THE SPRAY FORMULATION

The physical properties of the spray fluid are important variables that may be utilized to reduce the number of fine particles and also to control the evaporation rate of the droplets. Numerous adjuvants are available to modify the viscosity of the spray to reduce the number of particles. Commercially available materials include; invert emulsions, water swellable polymers or particulate spray (NORBAK,Dow Chem.Co.), hydroxyethyl cellulose (VISTIK, Hercules Powder Co.), and thixotropic gel (DACAGIN, Diamond Alkali Co.). Figure 10 shows a comparison of drift residues from a conventional normal emulsion application and a thickened particulate spray. A dramatic reduction in drift is evident, with approximately 1/7 as much residue for the first few hundred feet downwind. This is of particular importance in right-of-way applications, where a sharp cut-off will reduce the brownout zone from herbicide applications.

The evaporation rate can be controlled by the type of solvent or carrier used to dilute the toxicant. Although water is frequently used, fine sprays may require a low volatile carrier to achieve satisfactory recoveries in the target area. It should also be recognized that the use of a lower volatile carrier may also increase fallout recoveries in the immediate downwind area. Figure 11 shows a direct comparison of the drift fallout residues from an application with a normal oil in water emulsion and an application with 100% diesel oil. The greatest difference in fallout occurred at approximately 1000 ft. downwind with the drift from the diesel oil application producing more than 4 times as much residue as the normal emulsion application.

MICROWEATHER FACTORS

The field drift tests have shown that one of the most important factors affecting drift residues is the atmospheric turbulence or stability. Further, it has been found that the stability ratio is a convenient index of atmospheric conditions that can be related directly to drift fallout residues. The stability ratio is defined as:

$$\text{Stability Ratio} = \frac{T_{32} - T_8}{\overline{U}^2} \quad 10^5$$

where T is the air temperature in degrees Celsius at 32 and 8 ft. elevations and $\overline{U}$ is the mean horizontal wind speed in cm/ sec. at 16 ft. Thus the temperature gradient with respect to height and the wind velocity are basic measurements that can be combined to predict the drift fallout residues.

Table 1

Range of microweather and classification of atmospheric stability

temperature gradient (T_{32} - T_8)	-1.7 to 5.7 degrees F
wind velocity	3.0 to 19.0 mph

atmospheric stability	stability ratio
unstable	-1.7 to-0.1
neutral	-0.1 to 0.1
stable	0.1 to 1.2
very stable	1.2 to 6.0

Table I shows the range of microweather conditions that have occurred during our tests along with the classification we have used in reference to different calculated stability ratios. Figure 12 illustrates the important relationship between the stability ratio and the drift residue pattern. Although the regression curves of the drift fallout were nearly the same for the first 100 to 200 feet the curves are quite divergent and at a 1/2 mile distance the residues were over 13 times as great during very stable conditions as during neutral conditions.

It should be mentioned that the above results are attributed to greater vertical mixing during conditions with a lower stability ratio. Another important factor that may be related to the concentration of pesticides remaining in the air is the depth of the inversion layer. We have plans for investigating the vertical profile, (up to several thousand feet in height) of pesticide contamination and temperature gradients in an effort to identify the fate of 100% of the material that is emitted by the pesticide applicator. Figure 13 shows a typical inversion layer and lapse conditions that varies diurnally during the summer months in the central California valley.

Another technique that we are investigating is the use of a sigma meter to directly indicate the standard deviation of wind direction fluctuations. This may provide a useful field technique for an immediate indication of drift hazards during applications. Figure 14 shows the response of the sigma meter during very stable (S.R.= 6.0) and unstable (S.R. = -0.7) conditions.

FIELD SIZE AND DOSAGE

Figure 15 illustrates how the exposure to drift increases when the number of progressive swaths or size of treatment area increases. The 20 swath application (equivalent to 40 acres with a swath width of 33 ft. and a 1/2 mile field length) indicates that at a distance of 1/4 mile downwind the residue is 0.34 ppm on dry alfalfa. If the swaths were doubled to 40, the residue at 1/4 mile goes up to a maximum of 0.6 ppm., and at 80 swaths, extrapolated data indicate the residue would mount to 1.0 ppm, or a three-fold increase from the 20 swath to 80 swath application. Also, if a field were exposed to the drift of more than one hazardous chemical or to additional nearby applications, the total of these are additive.

The above values of contamination in ppm on alfalfa are based upon a upper 99% confidence limit. This means that, statistically, 99% of the time the residues would be below the stated value.

References

(1) Panel on Monitoring Persistent Pesticides in the Marine Environment, E. D. Golberg-Ch.; Chlorinated Hydrocarbon in the Marine Environment, National Research Council Committee on Oceanography, 1971.

(2) Yates, W. E. and N. B . Akesson, Fluorescent Tracers for Quantitative Microresidue Analysis. ASAE Trans. 6(2) 104-107.

(3) Akesson, N. B., and W. E. Yates. Problems Related to Application of Agricultural Chemicals and Resulting Drift Residues, Annual Review of Entomology, 9, 285-318, 1964.

(4) Yates, W. E., N. B. Akesson and H. H. Coutts, Evaluation of Drift Residues Resulting from Aerial Applications. Trans. of ASAE 9(3) 389-398, 397, 1966.

(5) Yates, W. E. N. B. Akesson and H. H. Coutts, Drift Hazards Related to Ultra-Low-Volume and Diluted Sprays Applied by Agricultural Aircraft. Trans. of ASAE, 10(5) 628-632, 638, 1967.

(6) Yates, W. E., N. B. Akesson and K. Cheng. Criteria for Minimizing the Hazard of Drift from Aerial Applications. ASAE Trans. No. 67-155 June, 1967.

This study was supported in part by PHS research grant FD 00261 from the Consumer Protection and Environmental Health Service, Food and Drug Administration, Washington, D. C.

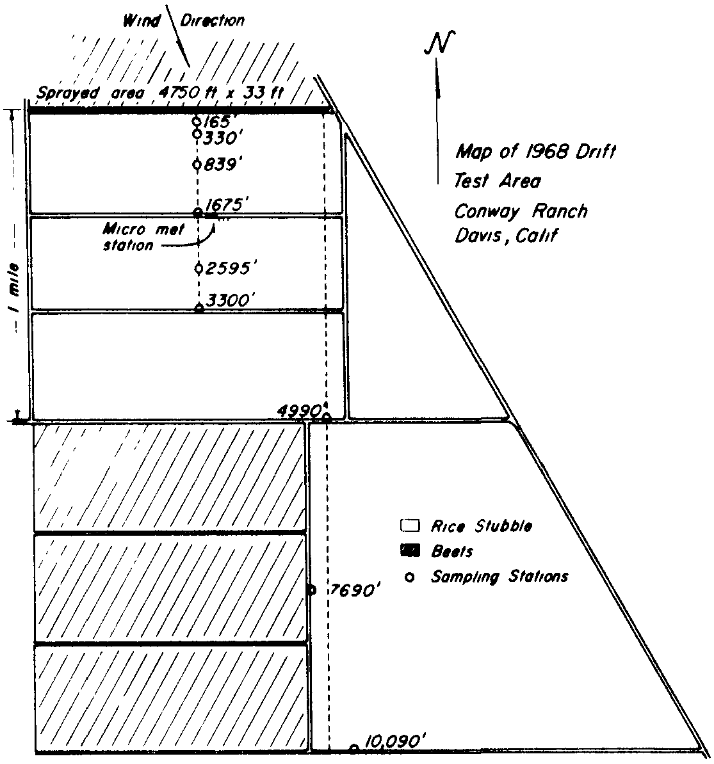
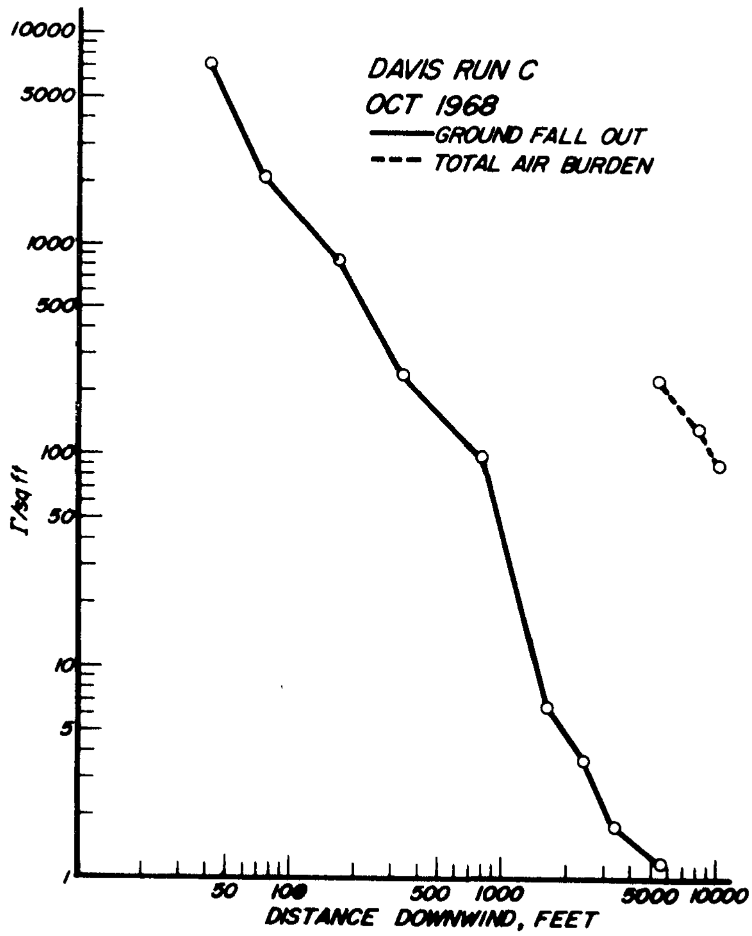


Fig. 1 Spray line and downwind sampling locations for drift tests.



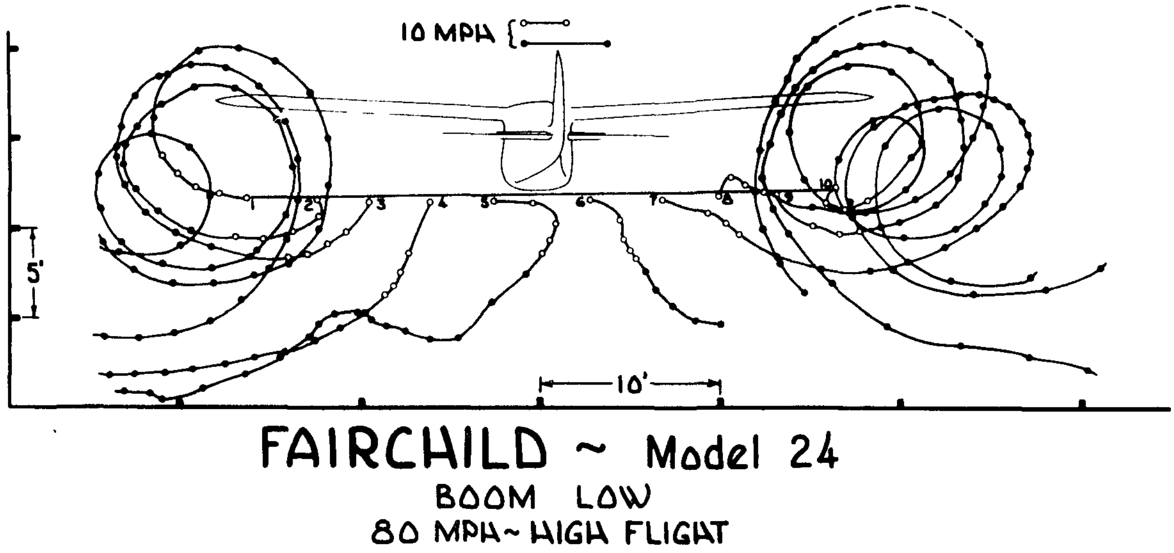
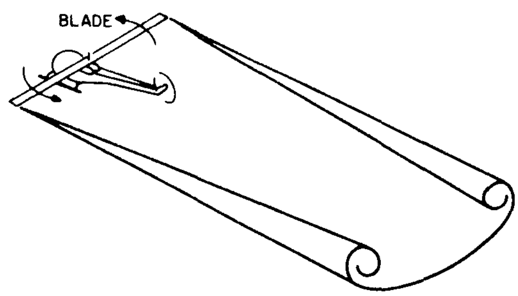
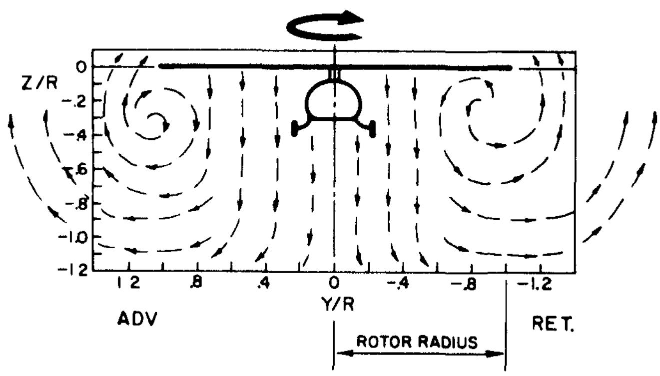


Fig. 3 Trajectories of hydrogen filled balloons released in wake of fixed wing aircraft.





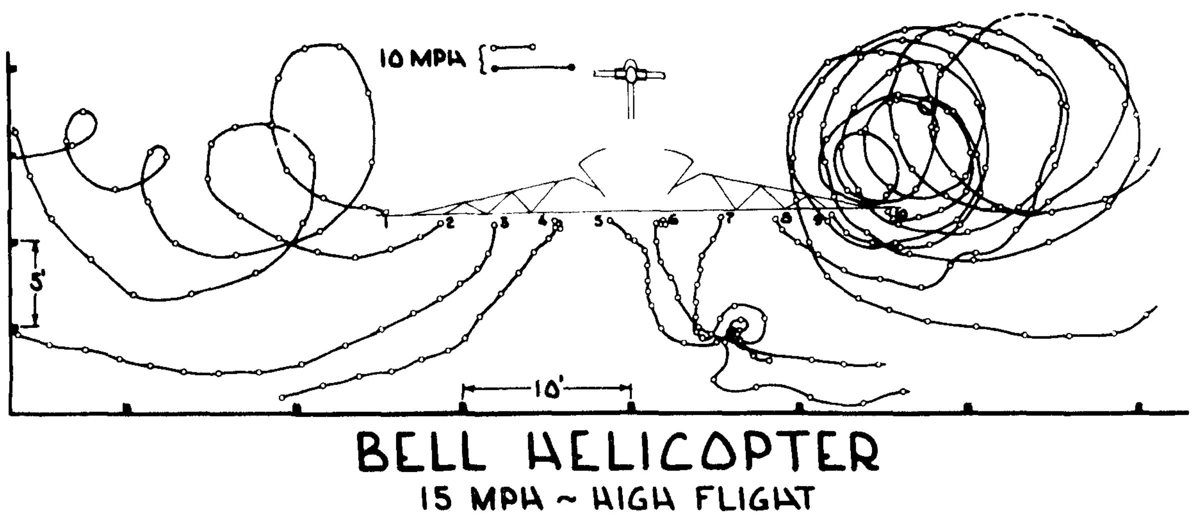
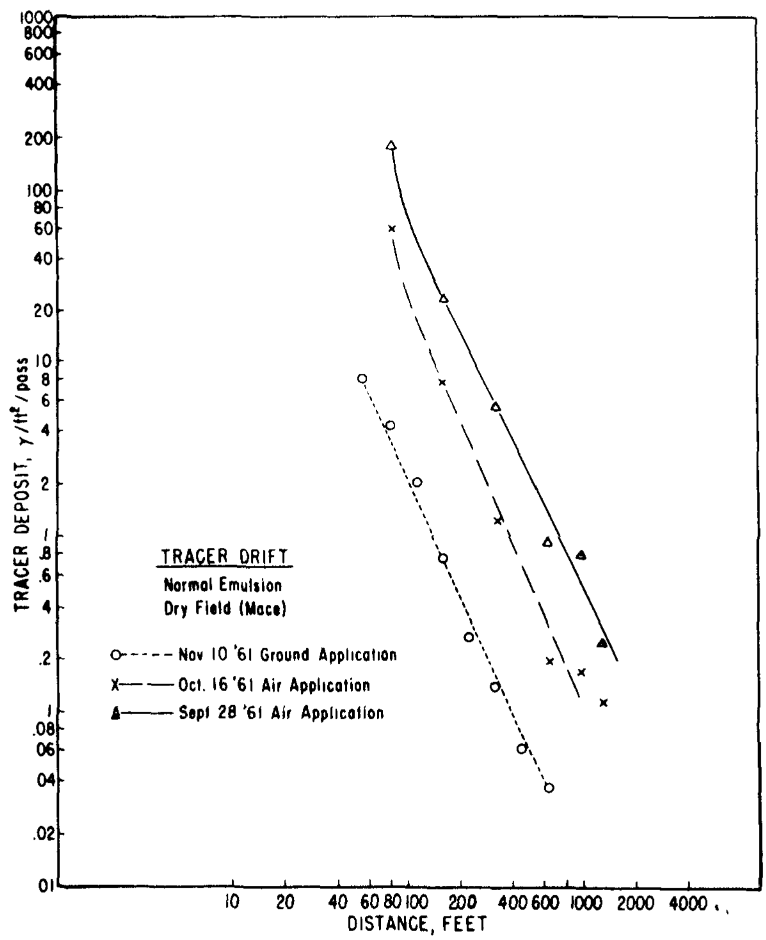


Fig. 5 Trajectories of hydrogen filled balloons released in wake of a helicopter.



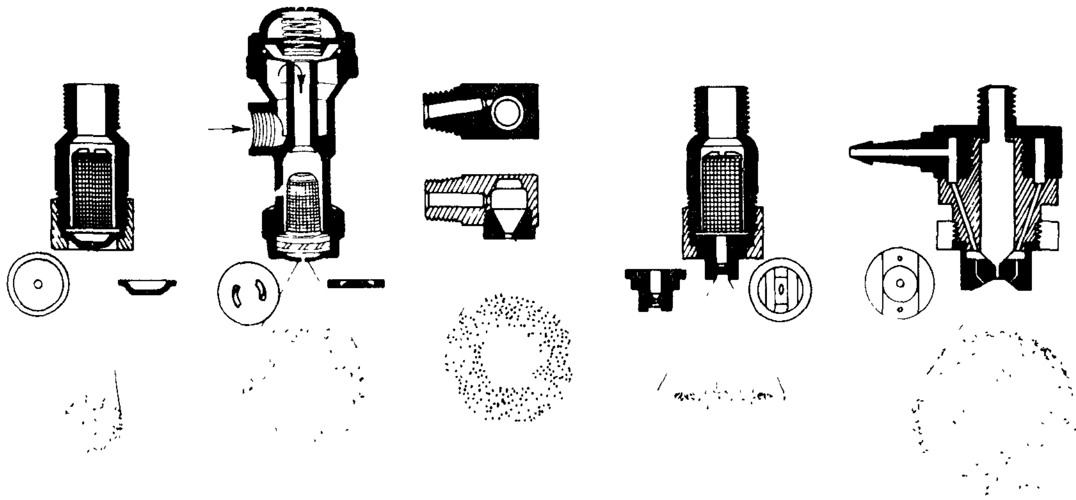
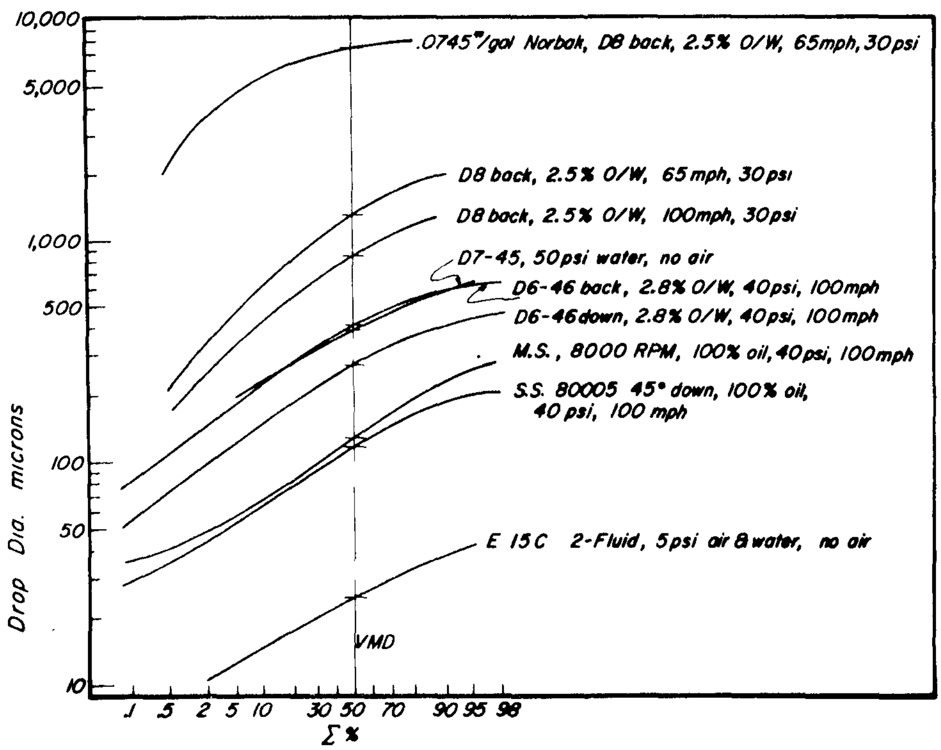


Fig. 7 Typical hydraulic nozzles used for pesticide applications.



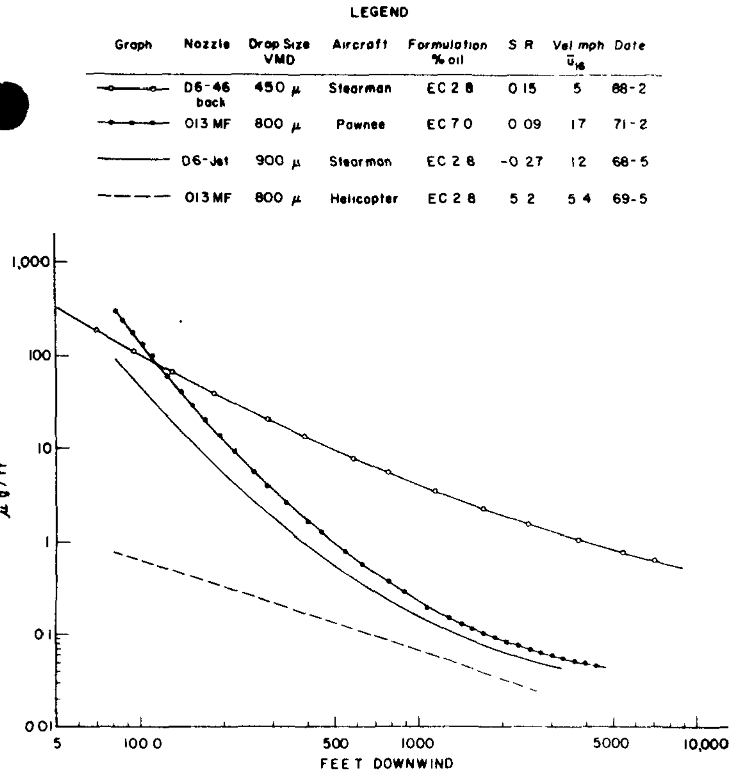


Fig. 9 Effect of nozzle types on drift residues.

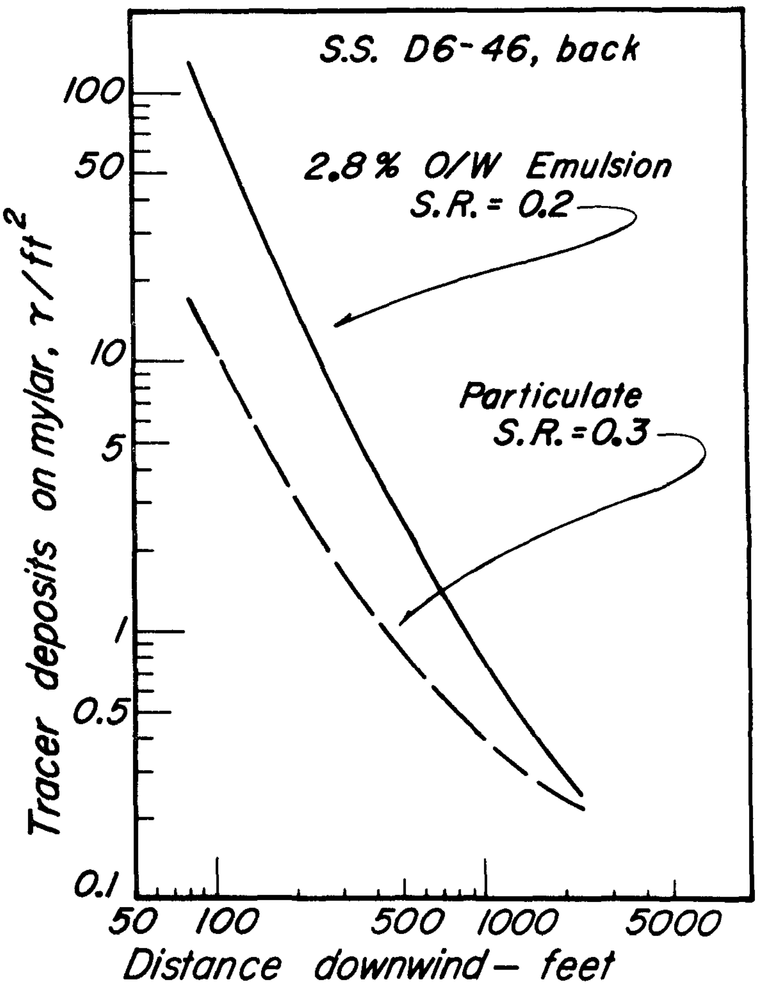


Fig. 10 Effect of a water-swellable polymer (Norbak) on drift residues.

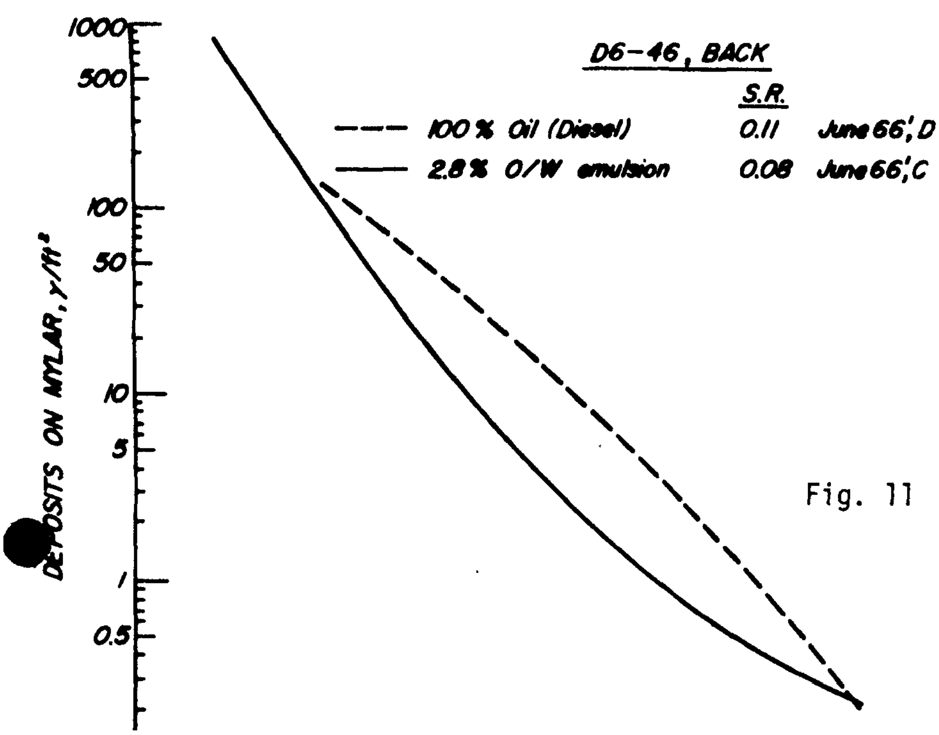


Fig. 11 Effect of controlling rate of spray evaporation on drift residues.

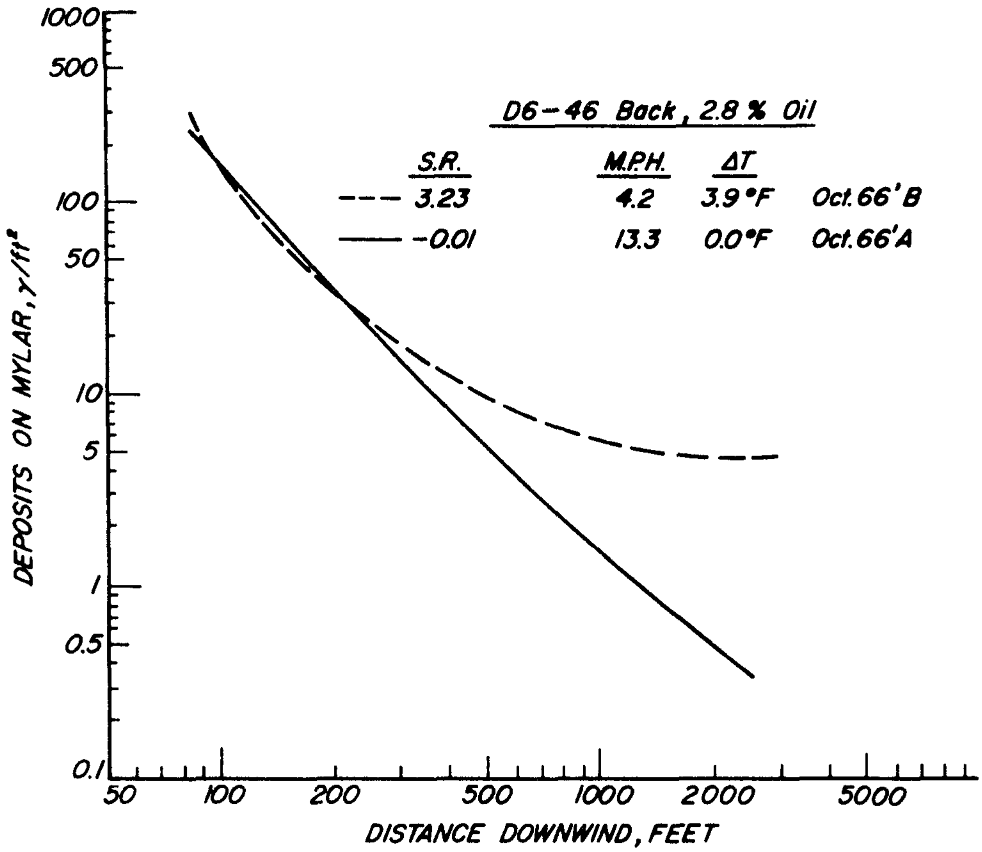


Fig. 12 Effect of very stable and nearly neutral conditions on drift residues.

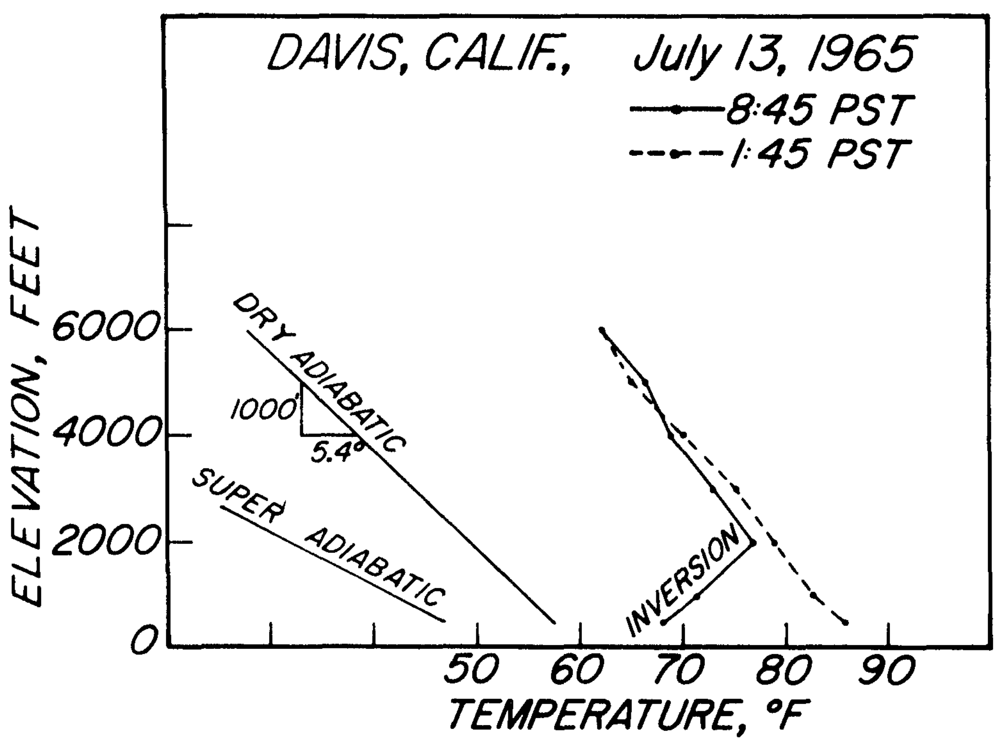


Fig. 13 Typical atmospheric temperature inversion and lapse conditions during summer

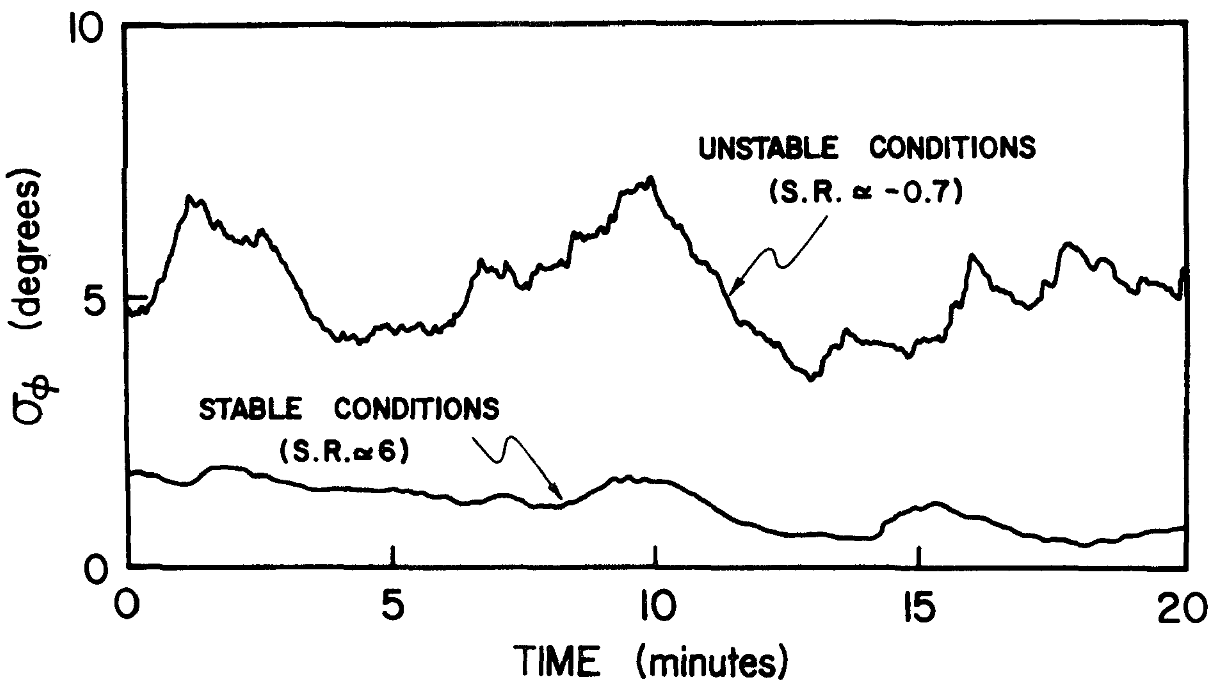


Fig. 14 Standard deviation of the variation of the elevation angle with a 30-second sample time for two weather conditions.

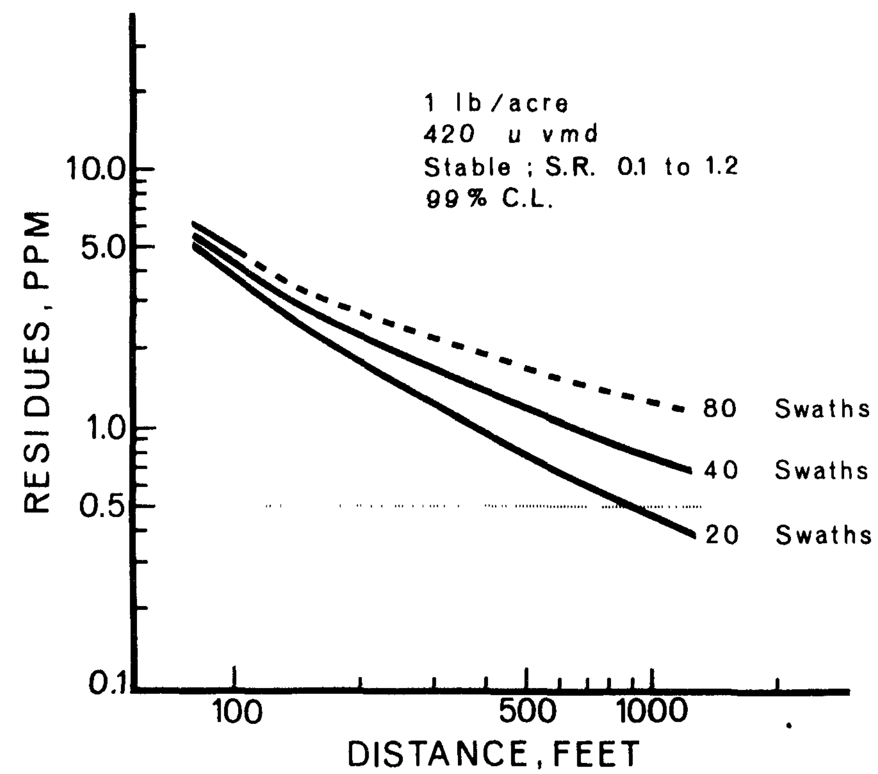


Fig. 15 Upper 99% confidence limits on the cumulative residues that could be expected on dry alfalfa for different sizes of treatment areas.

Service Letter

National Pest Control Association INC

A NON-PROFIT MEMBERSHIP ASSOCIATION

THE BUETTNER BUILDING
250 WEST JERSEY STREET
ELIZABETH, N. J. 07207
201-354-3738

NUMBE
124

DATE
3/18/

GOOD PRACTICE STATEMENTS

Good Practice Statements of the National Pest Control Association are officially adopted documents which provide practical guidelines to safe and effective pest control work. They are developed by committees and undergo careful review by experts and by the general membership of the Association so as to reflect the best current knowledge and skills of the Pest Control Industry.

The significance of Good Practice Statements is indicated by the following statement accepted by the Board of Directors in 1969:

> "Good Practice Statements of the National Pest Control Association describe activities of a prudent, well-informed pest control operator. They are intended to guide:
>
> the Pest Control Industry as to what members of NPCA consider generally acceptable as a safe and effective practice;
>
> the Public as to the service they may reasonably expect from members;
>
> the Association if it asks a member to justify departure from generally accepted practice when such departure endangers persons, property or the Industry image."

The Good Practice Statements are guidelines - not standards. They are for guidance - not for enforcement. An important reason that our Good Practice Statements are not standards is that pest problems are not standardized. If an unusual pest problem is encountered, a PCO may deviate from the details of the Good Practice Statement if he is able to take adequate safeguards to protect the public, property and the environment. The operator's experience should enable him to determine the needed additional safeguards and to justify their adequacy.

(Over)

NPCA's Good Practice Statements should be incorporated into every pest control company's operations. They should become an essential element in servicemen's training programs. In both cases they will need to be used in conjunction with other related and reliable sources of information such as NPCA Technical Releases. PCO's expanding the scope of their operations will find Good Practice Statements as valuable guides based on the experience of veteran, knowledgeable workers.

There will be numerous uses for Good Practice Statements in informing the public and various official agencies concerning acceptable procedures in pest control. Distribution to firms outside the NPCA membership is encouraged. As indicated on the attached order form the non-member price is $6.00, while the price to members is $3.00.

We believe that the importance of NPCA's Good Practice Statements will increase as they become known and used. It is anticipated that there will be increased pressure from within and without the industry to comply with good practice. As their importance grows, members and outsiders as well will give greater weight to them. An expected result is that existing statements as well as those under development will receive increasingly careful review. As new information, equipment or skills become available, existing statements can be revised to reflect current Good Practice.

ORDER FORM

1971 COMPILATION, NPCA GOOD PRACTICE STATEMENTS

The 1971 Compilation of Good Practice Statements contains the 17 statements listed on the reverse side of this sheet, plus an Introduction and Table of Contents. They are attractively bound in a plastic-covered Duo-Tang binder into which additional statements can be inserted as they become available. The price is $3.00 per copy to members of NPCA and Public Agencies engaged in regulatory, educational or research activities related to pest control. For others the price is $6.00.

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NPCA GOOD PRACTICE STATEMENTS

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EVALUATION OF PESTICIDE APPLICATIONS

Norman B. Akesson and Wesley E. Yates

The use of various pesticide chemicals, and pathogens to control weeds, insects and plant disease as well as application of defoliants, fertilizers and trace nutrients constitutes a highly complex practice, and a significant factor affecting the total system of agricultural, forest, and rangeland culture and ecology. The effect on the immediate environment surrounding the area of application, or in the areas that are a part of the air and water basin systems involved, can be examined and in many instances the effects of chemicals on the non-target crops and on human and animal habitat have been drastic and dramatic. But the effects on the more distant or total environment, which includes the wildlife areas, is not easily examined and little if any reliable data exists on the extent and damage done to this overall environment by the use of various plant protection, pesticides and nutrition chemicals.

A great deal of speculation has been made with regard to pesticide pollution of the air, water and soil systems, and including global dispersion; but good data on the actual numerical losses of these materials from the fields and areas being treated during the following specific treatments is lacking. Observers have indicated these losses may vary from 5 percent to as high as 70 percent, but depending primarily on particle size and formulation of the applied material and weather factors at the time of application.

The basic purpose of most of the applications being made is for either plant protection or nutrition. Along with the question being raised about the losses to the environment is a basic question of the efficiency and dosage requirements to control specific weed, disease and insect pests, and how this efficiency can be improved. The materials used include the great variety of pesticide chemicals, certain plant materials such as pyrethrum and rotenone, as well as the more recently available pathogens, such as bacilli and viruses. In addition, the basic fertilizer chemicals, nitrogen, phosphorus and potassium as well as a host of trace nutrients, can and have become contaminants in differing degrees.

Thus, the type of material, the extent of its use, and its specific effects on sensitive organisms determines not only the fundamental use being made of the material but also its potential hazard as a contaminant. The basic toxicity to the animals and plants which it could possibly contact as well as its effectiveness and requirements or modes of action on the target organisms will not only control which material is to be used, but also indicates the relative hazard of use and safety precautions that need to be followed when it is applied.

The concerns expressed over large scale environmental pollution caused by agricultural chemicals have come from wildlife and conservation-minded forces. Of much greater impact on the local agricultural, forest or rangeland community is the immediate damage done to crops, ornamental and esthetic planting, by actual plant destruction or disfigurement, and to contamination of foods and feeds by unwanted and illegal residues on edible portions. These damages are generally within the community concerned and do not become a rallying point for the conservation interests. However, they do result in widespread damages and frequently in lawsuits where farmer A sues farmer B, his applicator and the chemical company producing the material, for losses sustained either through direct crop damage or from seizure of crops due to illegal residue. A more subtle form of widespread damage characterized by the troubles with cotton insect control over most of the world has been the result of the increased use of broad spectrum insecticides which knock out predator and parasites in cotton that would normally provide protection from economic insects. Thus, excessive and sometimes careless use, as well as poor techniques of application have resulted in actual crop reverses and even the abandonment of cotton culture in certain areas. However, it must be pointed out that newer practices such as integrated control where reduction and withholding of early chemical treatments are advocated will quickly help to restore the normal insect population and make possible rational cotton insect control programs.

Operational Responsibilities

The primary base of discussion, inasfar as application of agricultural chemicals is concerned, must start by identifying the chain of responsibility and the roles played by each group in relation to the overall crop, chemical, pest and application problems.

Chemical Manufacturers

The responsibility of the manufacturers starts with his development of the chemical, the series of tests and data required to obtain registration labeling, and finally to the sales and field service representatives who are the basic advisors to the applicators and farmers on the use of the particular material and its relation to crops and pests. There is increasing concern for the obvious conflicts of interest that a chemical salesman has in trying to objectively evaluate a grower's need and still maintain a brisk sales program. Thus, we are seeing more restrictions on field people as well as required licensing of these in some states such as California. The salesman must not only have knowledge of the chemical, pest and plant complex but also be able to advise regarding the best means of application. Again a conflict of interest arises because application techniques which provide the greatest degree of safe use or least loss hazard are also restrictive in use, such as: (1) hours of the day or night when they can be applied safely, (2) limits of particle size dispersed, where coarsest sprays are safest, but not most effective in control, and (3) formulation restrictions where granular materials being the safest from a loss viewpoint cannot always be used due to lack of coverage or contact with plants and pests.

The chemical company field man will have to revise his thinking in terms of application methods and direct his thoughts more to safe application and less to control efficiency. In this regard, the farmer and commercial applicator must also share the burden of decision for chemical safety which is difficult to do when a crop is in jeopardy from a pest complex.

Commercial Applicator

The commercial applicator shares some of the same legal responsibilities as does the manufacturers, but since he takes the manufacturer's product and makes the actual application, he takes on that specific responsibility of safety as well as control efficacy, which again introduces the basic conflict of interest between these concepts. The commercial applicator is usually licensed by the state and it is through this license that regulation of the commercial applicator takes place. If trouble occurs, he will receive a suspension or loss of license in accord with findings of a State regulatory office. Thus, because of this and his key position in the application, the operator--either ground or aircraft--becomes the most significant person in the application picture and must be knowledgeable and prepared to consider all facets of his job, particularly the hazards not only to his pilots and handling crew but to nearby crops and to the overall environment.

Farmer or Crop Advisor

The grower and his representatives, foremen, advisors and crop consultants are also part of the legally responsible chain along with the operator and chemical manufacturer. But here the conflict between use efficacy and loss hazards, as well as worker safety, come into sharpest conflict. The farmer must protect his crop and to do so will frequently demand application practices from the operator and chemical men that can and do lead to damages, lawsuits and financial disasters, not to mention over-reactive regulations enforced by state agencies who are held accountable to legislative bodies for the misuse of pesticides by the farmer.

It should be evident from this analysis of the viewpoints of the three principal groups involved that further licensing and other qualification regulation, as well as specific application control, will likely be seen at all levels of chemical use since competitive practices both in growing crops and selling chemicals virtually make it impossible for these people to regulate themselves.

Application Techniques and Machines

The machines and methods used to apply crop protection materials can be reviewed in brief, with consideration for factors of safety in use as well as effective pest control. Since the physical/chemical formulation greatly alters the application machine, it would be well to first examine the various alternatives in this area.

Formulations

Formulations or physical forms of the chemical materials have evolved over the many years of use and in general consist of (1) dry materials as dusts and granules (Table I) and (2) liquids as solutions, suspensions or emulsions with a wide range of basic particle size generated at the time of application of the liquids. This may range from aerosols to very coarse sprays as shown in Tables II and III.

Dry Materials: Dusts and Granules

This is a particle size definition and carries the broad identification of dusts as consisting of particles manufactured to a size range such that 85 to 90% of the particles are under 25μ (microns) major diameter, while only a few percent are above 44μ or can be passed through a 325 mesh screen. The granulars range in size from 1 to 6 mm (millimeters) or 1000 to 6000 microns. Considerable differences exist in the mode of action of the various sizes as well as in the machines used to apply them. Table I gives the sieve size, the opening size in mm, the average number of particles per pound (and gram) and the coverage or distribution of these in a ft^2 (or m^2) basis when 10 pound (or 1,200 g/ha) are applied. It can quickly be seen that if we are going to need to contact an immobile insect or fungi on plants, a granular formulation is not the answer. So we would use a very finely divided dust instead which has the tremendous coverage potential that the millions of small particles (under 20μ) gives. Granular formulations of translocated chemicals are available and where useable, constitute a very effective and safe application means.

Spray Materials

Table II presents data on water droplets but would be largely applicable to solid particles as well, with some changes needed if the particle density is varied greatly from water. As can be seen in Table II, the terminal velocities of the particles goes up rapidly as their size is increased. Thus, up to a 20 micron drop, the terminal velocities are extremely low (less than 4×10^{-2} ft/sec.) and even a 50μ drop settles only at 3 inches per second. However, far more importantly, these are all for still air and in a normal atmosphere, the air movement as indicated by horizontal and vertical measurement will show that only under unusually quite temperature inversion (warmer air overhead than at the ground level) condition, is the vertical motion likely to be less than 3 inches/sec. This means that particles under 50μ (as an arbitrary identified aerosol size) do not settle out under normal atmospheric conditions, and can be transported for considerable distances with any air motion. Conversely the settling rate of 2000μ (2mm) size particles, such as granules, is 21 ft/sec. and settling is very rapid and positive.

Further data in Table II indicates the coverage capabilities of small particles and drops if the spray were all one particle's size range. That this is not true in normal atomization, has been pointed out; and in fact, a spray atomization or grinding process actually produces a normal distribution of sizes covering a range of perhaps 10 to 1000μ for a given atomizer setting.

As in the case of the larger granules, the smaller particles (1000 oz/A or approx. 7.8 gals/A) show a rapid increase (related to the cube of their diameter) as size is reduced. The last column of Table II is for the air burden in a depth of 65.6 (20 M) in particles/M^3 of air at the particle size shown, and if the volume of 7.8 gals/acre applied were all atomized to that stated size. This illustrates the necessity for using very small drops as aerosol when contact with adult forms, such as flying mosquitoes is desired. When a given volume of material is used, a reduction of particle size will result in a vastly improved contact with insects or fungi on plant surfaces, or with the plants themselves in the case of herbicides.

However, where material is applied to the soil and is worked in, as in the case for weed control or soil insects and disease control, the fineness of the material is not as much of concern. Similarly material applied to water, as in the case of certain rice insect and weed control materials, is disseminated by the water and control is effective with quite low concentrations of active chemical, as little as 6 ppm in case of certain insect pests.

The spray materials may be made with as large particles as the granulars, but a significant difference exists. This is the fact that the dry materials may be air screened to remove all particles below a certain size. Thus, the mesh ranges of Table I do specify that a high percent (95 - 98%) of the material in a 30/60 mesh range will pass a 30 mesh screen and be retained on a 60 mesh size. When spray materials are made very coarsely (see Fig. 1) a special low turbulence type nozzle, such as the Microfoil device (registered by Amchem Corp.) can be used to achieve almost uniform, large drops of 800 to 1000μ size. However, such a nozzle is limited to the low turbulence wake of a helicopter at less than 60 mph, and as has been pointed out, when used with a fixed wing aircraft the higher speed tends to break up the large drops into smaller ones. The lower nozzle of Figure 1 indicates a jet type device which consists of a simple orifice with no whirl plate or other spreading mechanism in the jet stream. The drop size produced is of the order of 600 to 900μ VMD (volume median diameter, which is the drop size that precisely divides the drops produced into two equal halves by volume). This means that the normal distribution (usually slightly skewed toward the small drop end) prevails and a wide size range of drops are produced. Figure II shows two nozzles in a 80-100 mph air stream of a fixed wing aircraft. Both are hollow cone types which have a whirl plate and chamber behind the orifice which swirls the spray stream and creates considerable more break up of drops than what the straight jet does. The nozzle on the left is directed with the 100 mph airstream and if this were a D6-46* hollow cone nozzle operated at 40 psi (pounds per in.) the VMD would be around 420μ. The right hand nozzle (the same as the first) is directed across the airstream at 90 degrees, which causes the spray to be broken into drops of about 300μ VMD.

Drop sizes finer than this may be created by (1) increasing the liquid pressure, (2) decreasing orifice size, or (3) decreasing the whirl plate size which speeds the whirl and atomizes more thoroughly. However, practical

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*The D6-46 hydraulic nozzle designation is Spraying Systems Co. hollow cone type. D6 stands for 6/64 in. orifice dia. and 46 is an arbitrary designation for the largest whirl plate to give coarsest drops. Smaller plates have limitations control these effects and in order to go below 100μ VMD extraordinary measures need to be taken, such as twin-fluid or other special powered atomizers. Rotary screen, grid, and gauze type devices have also been used, but the same lower limit of around 100μ VMD also appears with these. Table III gives a very rough approximation of the recoveries of spray in a 1000 ft distance downwind under near neutral (no strong inversion or strong turbulence) conditions of weather. As can be seen, the amount lost from a field being treated (to 1000 ft downwind) can be as high as 85% when a highly transportable aerosol of less than 50μ VMD is applied by aircraft at 10 ft. altitude. However, when the Microfoil boom is used, the recovery can be as high as 99% of the released spray. The drop size ranges in between represent the need to balance the requirement for coverage with the losses by drift that would occur. For example, because of the increasing difficulty in confining the sprays to the fields being treated, the University of California pest control recommendations do not advise drop sizes smaller than 300μ VMD as produced by a D6-46 nozzle directed 90 degrees to the airstream and operated from a fixed wing agricultural aircraft using at 40 psi liquid pressure.

Ground Equipment

The discussion thus far has centered on use of aircraft principally because in California, the use of agriculture, forest, range-land and vector control probably averages out with aircraft applying 75 to 85% of all materials applied commercially. Of this, the helicopters constitute less than 15% of all aircraft used in agriculture in California.

Ground equipment is used for orchard spraying and to a limited extent in field crops, and perhaps to 50 to 60% of the vegetable crop work. A very few ground rigs are used for rice spraying and a considerable number for vector control work, particularly in urban and suburban areas.

Ground equipment for dusting has practically disappeared, but a considerable number of machines are used for distributing or injecting various soil applied liquids and granulars.

It has been suggested that use of ground equipment would eliminate problems of drift losses of chemicals during treatment. However, air carrier and high pressure, fine atomizing hydraulic nozzles on ground rigs can be equally as guilty of causing air pollution by losses of material as can the aircraft. The distinct advantage of the ground rig in this case is in its relative unobtrusive appearance, not easily spotted by the passersby, and its relatively low rate of acreage treated or amount of material discharged in a given day. Refinement of application machines in California would appear to be moving toward more helicopter use rather than toward ground rigs. While helicopters cost 1/3 to 1/2 more than a fixed wing aircraft, the helicopter productivity and ability to work in small fields and also to land close by, puts its productivity close to the fixed wing aircraft. In terms of cost per acre treated, all aircraft at around 2.00/A. (application alone) for a 5 gal/A. application rate compares very favorably with ground rig costs. This, plus the ability to fly over irrigation checks, ditches and even the crop itself, plus the rapidity of treatment, as much as 200 A/hr of usual agricultural work, gives a sharp competitive edge to aircraft use. Tests of helicopter use in orchards and vines show that at low speeds (under 20 mph) the effectiveness of coverage can be adequate for many control problems, particularly of fungi as dormant period sprays. Precision of application with the helicopter makes the machine more competitive with ground equipment rather than with fixed wing aircraft.

Spray Additive

Aside from the wide variety of emulsifiers, stickers and spreaders used in spray formulations to obtain better contact and greater persistence of deposit, there have been many materials introduced into the spray formulation for thickening and thereby causing very large drops to be formed during atomization. The earliest of these were phase crowded emulsions and since the discontinuous phase had to be of the order of 85 to 90% of the mixture this was best achieved by putting water (as a discontinuous phase) into a petroleum oil as the continuous phase. This is the reverse of the normal w/o emulsion and is called an invert emulsion, or o/w. This technique while producing very coarse up to 10,000μ VMD drops does not eliminate small drops due to viscosity reduction under stress when passing through the nozzle. Consequently, these and other thickening agents, such as cellulose, seaweed and plastics, will not eliminate small drops causing drift but do cause very large drops to form thus requiring large applied volumes in order to obtain coverage. However, for spraying weeds on canals, roadsides and power line rights of way, the large drops using translocated herbicides are very effective and produce only low drift levels.

More recently another additive as a form agent has been introduced, which causes very large drop formation (Fig. 3) of hollow drops. The action of this formulation is such as to reduce the volume of liquid while maintaining the bulk collected particle size. If air buoyancy is not too much increased by the hollow drops, this may offer a logical means to reduce liquid volume while still maintaining coarse collected drop size.

Electro-Static Charge

The promise of attracting particles, liquid or dry, to plant surfaces from the application machine has intrigued researchers for at least 40 years. Laboratory and closed system studies where atmospheric conditions can be controlled and distances are limited have shown the tremendous capabilities of this technique. However, the practicability of these systems has yet to be proven either by ground or air. A system is presently under study for aircraft use and has shown considerable promise. However, its success is related to an initial, very fine (coarse aerosol) spray, and if all of this is not captured by the charging process, a certain amount of highly transportable spray particles would be released.

Application techniques and machines, along with adherence to safety in use as a primary objective can spell the difference in continuing the use of plant protection and nutrition materials or being forced to reduce and abandon these in increasing numbers, particularly of the pesticide chemicals. While the farm growers have been able to manage continued crop production under increasing restriction, it is not being accomplished without changes and displacement of crops as well as increased costs of production. Since the three groups involved with pesticide chemicals have almost equal legal responsibility, it should follow that they should also stand together and accept the responsibility for supporting better application means which research now indicates can result in near 100% confinement of materials to the target fields.

TABLE I

Mesh or Sieve Size	MM Opening	Average Granules per lb	Average Granules per gram	10 lb/A or 11204,g/ha granules per ft^2	10 lb/A or 11204,g/ha granules per M^2
8/16	2.36/0.99	$145x10^3$	$0.32x10^3$	30	323
16/30	0.99/6.465	$1150x10^3$	$2.5x10^3$	260	2800
18/35	0.749/0.417	$2708x10^3$	$6.0x10^3$	620	6674
25/50	0.673/0.283	$7722x10^3$	$17.0x10^3$	1770	19050
30/60	0.52/0.246	$12,500x10^3$	$27.0x10^3$	2820	30355

TABLE II

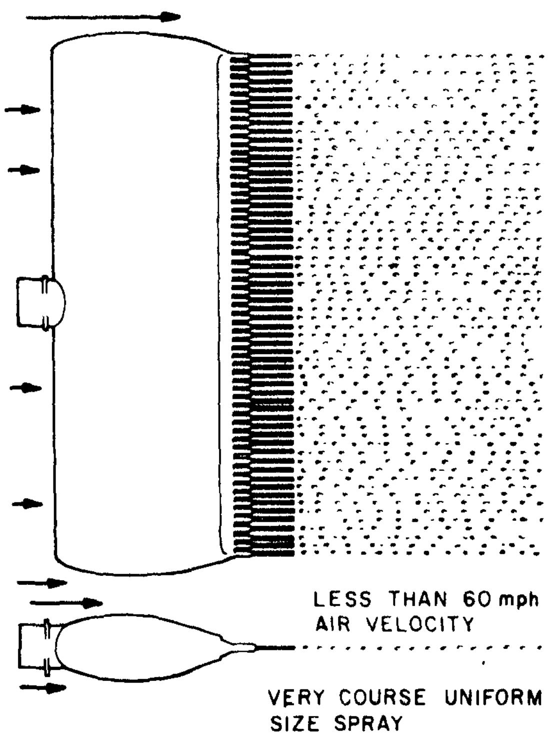
Terminal Velocities of Water Drops and Numbers per Given Volume in Relation to Unit Area and Air Volume

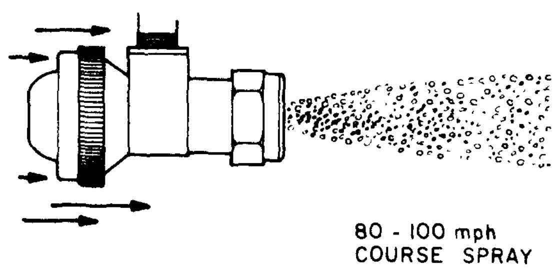
Drop Dia. Microns μ	ft/sec	m/sec	No. of drops at applied rate of 1000 oz/A (12,000 cc/ha) on flat (7.8 gal/A) surface: Per in^2	Per cm^2	In air to depth of 65.6 ft. (20M) per cm^3 air
1	$.01x10^{-2}$	$.033x10^{-3}$	$9000x10^6$	$1400x10^6$	$7000.0x10^2$
5	$.25x10^{-2}$	$.76x10^{-3}$	$716x10^6$	$11x10^6$	$55.0x10^2$
10	$1. x10^{-2}$	$3.0 x10^{-3}$	$9x10^6$	$14x10^6$	$7.0x10^2$
20	$4. x10^{-2}$	$12 x 10^{-3}$	$1.1 x10^6$	$17x10^6$	85
50	0.25	.076	$710.x10^2$	$110.x10^2$	5.1
70	0.4	.12	$265.x10^2$	$41.x10^2$	2.1
100	0.9	.27	$90.x10^2$	$14.x10^2$	0.7
150	1.5	.46	$27.1x10^2$	$4.2x10^2$	
200	7.0	2.13	70.	11.	
1,500	13.	4.0	8.8 Per ft^2 1267	1.36	

TABLE III

Spray Drop Size

General Description	Size Range Microns μ VMD	% est. Recov. in 1000 ft. Release not Swath Height 10 ft. Neut. Wea.	General Use
Aerosols (airborne) Special Atomizers	<50	<15	Adulticiding Vector Control; not recom. for aircraft use.
Fine Sprays - Cone, Fan or Rotary	120-200	35-50	Large area programs. Low toxicity material low dosage.
Medium Sprays - Cone	250-300	60-75	Low toxicity Agr. Spr demanding best covera
Coarse Sprays - Cone	400-450	75-85	All Toxic Agr. Sprays restricted materials.
Min. Drift - Jet	600-900	85-95	Translocated, highly toxic, residual larvaciding in water
L.T.N. (Microfoil on helicopter)	800-1000	99	Highly toxic herbicid as 2,4-D paraquat, propanil





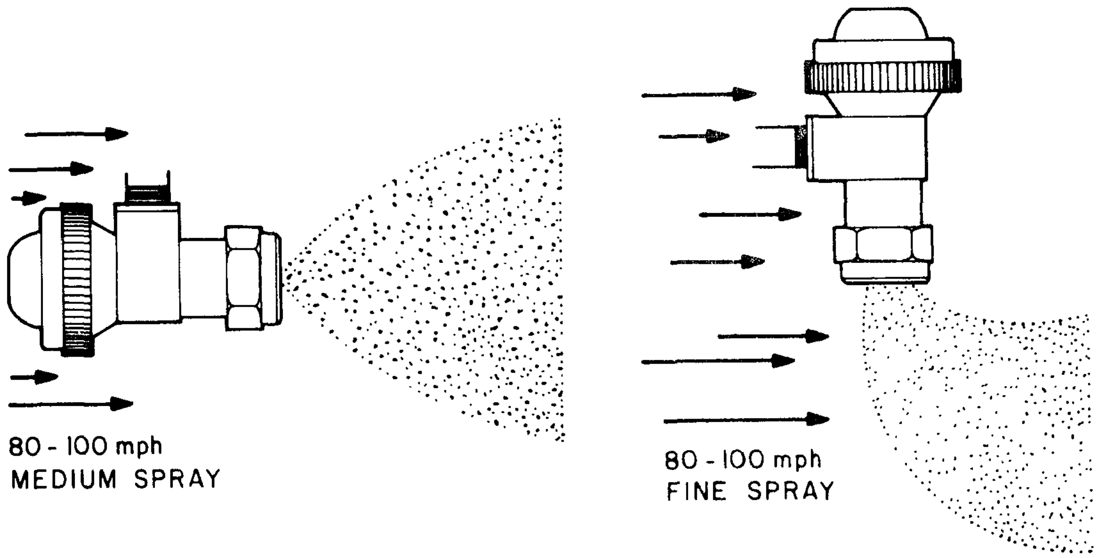


Figure 2

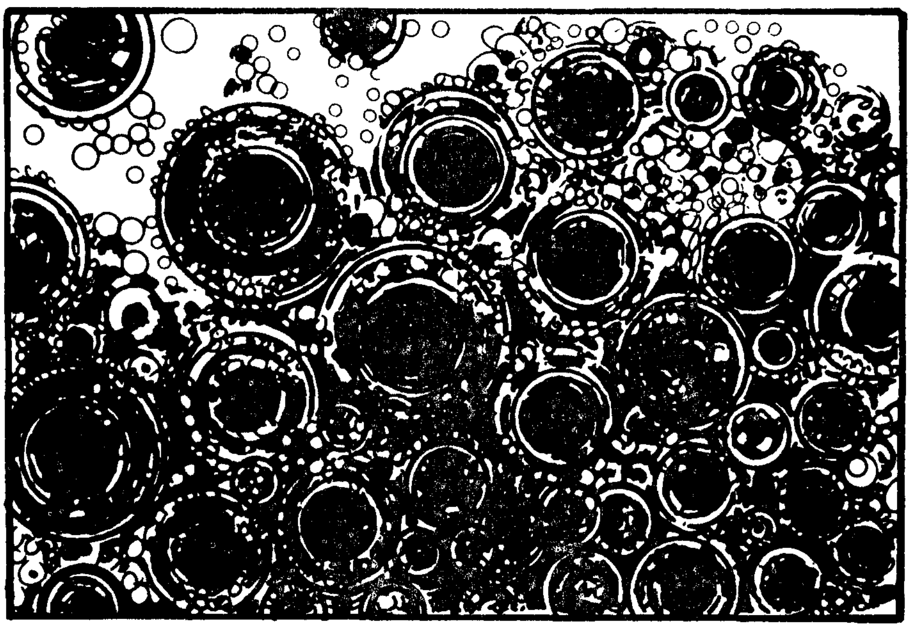


Figure 3

HERBICIDES--WHAT WE KNOW, WHAT WE NEED TO KNOW, AND WHERE DO WE GO FROM HERE

Virgil H. Freed

Of the chemicals for pest control, those used for control of plants were the slowest to be developed. This is not at all remarkable in view of the fact that the problems caused by insects and the crop losses resulting from fungal disease are much more dramatic than the problems posed by unwanted plant species. However, as our knowledge developed particularly from the mid-1940's, the discovery and use of herbicides have grown dramatically. Herbicides now are the number one pest control chemicals having surpassed insecticides a few years ago. Appreciable tonnages of a wide variety of chemicals are now being used as herbicides on crops, right-of-way sterilization, and other purposes.

The effect of common inorganic chemicals on living systems was known even to the ancients. Chinese, Greek, and Roman writings indicate their awareness that such things as sulfur and certain of the heavy metals were toxic to organisms. Far back into antiquity, man of course attempted to apply chemicals in medicine. It wasn't until the mid-19th century, however, that more systematic studies of the use of chemicals for control of pests were attempted. At this time, it was demonstrated that compounds known in that day would control insects, were effective against plant diseases and were capable of killing unwanted vegetation. In the latter half of the 19th century, particular attention was directed to the discovery of chemicals capable of controlling man's insect enemies. Parallel but less intensive efforts were concerned with fungal diseases of plants.

During the last few years of the 19th century and the beginning years of the 20th century, a few plant scientists engaged in the development of chemical tools for the control of weeks. Inorganic compounds, such as iron or copper sulfate, sulfuric acid for selective weed controls, sodium chlorate, the arsenicals and borates for non-selective weed control resulted from these early investigations.

From the period of 1920 to the early 1940's, some attention was given to organic compounds with the result that such things as petroleum oils and phenols were discovered and used for weed control. In the mid-1940's came the discovery of the herbicidal properties of 2,4-D and other phenoxy acetic acids. This ushered in a whole new era part by intensive search for new and more effective herbicidal compounds and the value of their application. Today we have as a result of all that activity a hundred or more highly active and widely used chemicals, many more whose herbicidal activity is known and occasionally used.

A wide variety of different classes of organic compounds show a remarkable activity against one or more species of plants. Similarly, a number of organometallic as well as inorganic compounds exhibit valuable herbicidal activities.

Herbicides are used in a wide variety of ways to achieve control of an unwanted vegetation. First there is the use of these materials in crops to destroy competitive species. Selective control, that is differentiating between the weed species and crop, takes advantage of a number of factors. Among these factors are differences in growth habit and morphology of the plant as well as purely biochemical differences. Advantage may be taken also of differential location of roots in the soil horizon or ability of the plant to absorb the chemical.

On the other hand, general control of the vegetation may not be concerned with differential toxicity to species, often rather the objective will be control of all types of species in a given area. It is important to note that very often a chemical, used at a lower rate of application for selective weed control, when the dosage is increased is able to kill wider range of species. This, it may be observed, is another example of dose-response relationship that, despite recent assertions to the contrary, seems to be a valid and widely encountered phenomenon. On the other hand, there are some chemicals that by virtue of a broad spectrum of activity is toxic to many commonly encountered species.

General vegetation control may range from control of a single brushy species to what is termed soil sterilization or complete vegetation control. The control of a singular or small number of brushy species, is usually accomplished by foliage application of the phenoxy acetic acids or similar growth regulating products. Only occasionally is it effected through use of a soil active chemical. On the other hand, it is often desired to kill all vegetation, as for example along a right-of-way of a highway or utility or around an industrial site. To accomplish this, one of the several soil active and persistent chemicals may be employed. In early days inorganic materials such as sodium chlorate and arsenic were used but today more reliance is placed on triazines, ureas and uracils. Depending on the dosage, type of soil, climatic conditions and species, vegetation control may last anywhere from one to three years.

The variety of chemicals used as herbicides has been mentioned several times. Inorganic chemicals such as the arsenicals, sodium chlorate and borates, were indicated as having been developed very early and still enjoy some use. The organo-arsenicals are the primary representatives of the metalo-organics employed as herbicides. On the other hand, the purely organic substances cover a wide range of classes. It starts with the simple petroleum hydrocarbons, ranges through alkyl acids to a large number of aromatic and heterocyclic compounds. The tables given as an appendix illustrate the wide variety of organics that are used.

In order not only to use the chemicals most effectively, but to evaluate their effects and hazards as well, one needs an appreciation of the behavior and fate of the chemical once applied in the environment. Fortunately, the behavior of chemicals in the environment and to some extent their fate or persistence can be interpreted in light of known physico-chemical principles. Thus, having some knowledge of the properties and chemical reactions of the material, we are able to predict with some confidence the probable persistence and mobility of the chemical in the environment and assess its possible hazard to non-target species.

Before describing some of the principles that are applicable, it is necessary to discuss the matter of formulating these chemicals.

The formulation or condition of the chemical as it's used often has an important bearing, particularly during the application operation. Chemicals range in properties from being gases or liquids to high melting solids. Chemicals also vary widely in solubility characteristics. Many chemicals, particularly the salts of compounds and simple molecules are usually soluble in water. Other chemicals dissolve only in certain types of organic solvents and others show a resistance to dissolving in almost any solvent. Further chemicals are markedly different in their vapor characteristics or tendency to change into gases.

In the application of chemicals, one wants as concentrated amount of chemical as possible. This makes for ease of handling, cheapness of transportation, and small volume for storage. Ideally of course one would use the technical chemical; but because of lack of solubility and difficulty of distribution, it may not be amenable to distribution in the spray, dust or granular form. It becomes necessary then to formulate the chemical or put it into a form that is readily used.

One of the simplest formulations is that of a dust. Here the chemical is ground with an inert filler such as a clay to a degree of fineness that makes distribution easy. The dust, though simple to formulate and easy to apply, has notorious disadvantages. One of the disadvantages is that the mixture with the clay often reduces the activity of the compound. The other is that dust, because they are fine particles, will often drift during the application.

Another common formulation is that of the emulsifiable concentrate. Here the chemical is dissolved in organic solvent and an appropriate surface active agent added. Mixed with water, the concentrate will then emulsify. In recent years there has been developed emulsifiable concentrate that instead of providing an oil in water, it provides water in oil emulsion. The water in oil emulsions are thicker, have a higher viscosity, and offer advantages in reducing drift during application.

The third type of formulation that might be mentioned is that of the granular. The granular is prepared much as the dust with the chemical being ground or mixed with an appropriate inert carrier, but here the formulation is prepared in particles or granules of an appreciable size. Granules are then distributed over the surface of the area to be treated and through moisture or some other mechanism, the chemical is released for activity. As is readily apparent the dust and spray applications are much more fraught with problems or drift than would be granular applications.

Turning back now to behavior and fate of the chemical during and following application, we find that drift of the dust or spray particles is a common occurrence during the application. This is true of any chemical and for any method of application. The amount and distance of drift depends on the variety of factors including particle size, particle weight, wind speed, height above ground at release and in the case of a liquid particle, rapidity with which the diameter changes due to volatility. Studies have shown as high as 80% of the material released or as little as 10% may reach target. Drift from the target area may be a matter of just a few hundred yards up to several miles, again depending on conditions and the material being applied.

Once the chemical has lighted on the target area, it comes in contact with a variety of surfaces. It may be the surface of an insect or a plant, or it may be the soil. In any event, there is an interaction with the surface. If it happens to be the waxy cuticle of a plant, the chemical may dissolve it. On the other hand, if it is a soil particle, the material will be sorbed. This interaction is extremely important for a variety of reasons. For example, if the chemical interacts with a soil particle, its rate of movement by water, its ability to volatilize and its accessibility for biological action are all reduced. It has been found in recent years that there is good correlation between certain fundamental characteristics of the molecule and the strength with which it will be bound. The tighter the binding or adsorption, the greater the reduction and availability for biological action.

Another phenomenon in behavior of chemicals in the environment is the movement with water--particularly, through the soil profile. This is really analogous to chromatography and many of the same principles apply. Each chemical will move in a characteristic fashion with water as it moves through the soil and the rate of movement will be modified by the character of the soil through which it is moving. Chemicals strongly sorbed by soil are only poorly leached. A striking example of this is the insecticide DDT which is leached poorly or almost not at all by water.

Vapor behavior of the chemical is also very important. All chemicals have a measurable tendency to change from either liquid or solid state to a gas, but the rate and amount varies widely depending on the nature of the compound. It is a common experience with more volatile substances such as the herbicide EPTC to experience a substantial loss of the chemical in the early hours after application. It has been found that these losses can be minimized by immediately incorporating the chemical into the soil where two different phenomenon are operative. The first phenomenon is that of the adsorption of the chemical by the soil, thereby rendering it comparatively unavailable for vaporization. The second phenomenon is the operation of Raoult's Law which states in essence that if you reduce the amount of surface of the evaporating species the amount of chemical being lost is thereby reduced. Even though a chemical may be only poorly volatile, when spread out over very large surface areas, appreciable amounts of the vapor can be lost. Many have postulated the premise that extensive if not even universal contamination of the world eco-system has insued from the use and wide distribution of certain pesticides and industrial chemicals. Certain evidence just now coming to light brings this postulate into question.

It is of considerable interest and importance to know how long a chemical will persist at biologically significant concentrations. Some chemicals we class as persistent, others as relatively non-persistent depending on the rate at which the biologically significant concentrations disappear. We attribute the difference to the rather more rapid breakdown of the non-persistent chemical. All chemicals once released into the environment are subject to a breakdown. It starts with the breakdown by ultraviolet light of the chemical exposed to that agent, through chemical reactions mediated by the surface on which the chemical may reside, to biological breakdown or metabolism. The rate at which this breakdown occurs determines the degree of persistence.

Persistence of the chemical in the environment in part determines the availability of that chemical for transport. With chemicals that breakdown rapidly to less than biologically significant concentrations, we see little or no evidence of its transport even though it may occur. Mechanisms or transport include those of drift during the application, volatilization and transport as a vapor or the transport of the chemical sorbed to a dust particle. This latter mechanism of transport may be accomplished either by wind or water erosion of the particle. There is some evidence to suggest that perhaps the matter of erosion of the contaminated particle is one of the principal means by which the chemical appears in non-treated areas far removed from the point of use. Certainly it would appear that the principal contamination of our water systems in continental United States is most probably through a water erosion of contaminated soil.

Herbicides bring about effects on plants by a variety of biochemical mechanisms. In all cases the effect of the chemical can be shown due to the result of the interaction of the chemical with the biochemical processes of the plant. It should be emphasized that very few chemicals act through a singular event, but rather that they effect a number of different processes in the living organism with perhaps one process being slightly more evident than others. Thus, for example, the ureas, triazines, and certain other herbicides are known predominantly for their effect on the photosynthesis of plants. The chemicals such as the growth regulators appear to have a fundamental mode of action at the level of the nucleic acids.

While the chemical is effecting metabolic processes of the plant, many plants in turn are metabolizing the chemical. There are many cases of selectivity known where the ability of the resistant plant to rapidly metabolize the herbicide accounts for its resistance.

The type of metabolism of herbicides carried on in plants is parallel to the type of metabolic actions seen in animals. The chemical may be hydrolyzed, oxidized, reduced, conjugated or otherwise altered by the metabolic processes. Usually this metabolism results in a compound of less biological activity than the parent substance.

Of particular importance in light of the large quantities of chemicals used as herbicides, the question is, "What hazards may arise from these chemicals?" Such hazards may be classified into two large categories; namely, toxicological hazard to man and important animals species and secondly, ecological hazards. It must be remembered that there is a distinction between intrinsic toxicity of a compound and the hazards it affords. Materials such as mercury we know to be toxic, but when it is in the form of the ore cinnaber, we do not consider it as a particular hazard. The same is true of many other substances. Hazard as contrasted to toxicity is dependent on the following factors: (1) the spectrum of organisms affected, (2) the intrinsic toxicity, (3) the resistance of the chemical, and (4) mobility of the chemical.

Fortunately, among the herbicides there are very few materials having a very high mammalian toxicity. Many of these compounds have LD 50s greater than 100 mg/kg of weight and some running into as high as three to four thousand millograms per kilo of body weight. There are materials like the herbicide paraquat that have a realtively higher order of toxicity. This compound has the unique feature that when ingested, causes a fatal overgrowth of lung tissue. Some herbicides, notably 2,4,5-T, may have reaction by-products that contaminate the material and have a high order of toxicity. The dioxin which is a by-product in the manufacture of 2,4,5-T is such a chemical. Considerable concern is generated over 2,4,5-T as a result of a study that indicated that it was a possible mutagenic agent. The issue was confused by the presence of dioxin though subsequent studies purported to show that 2,4,5-T alone was capable of mutagenesis. The whole problem has recently been reviewed by an expert panel, the majority opinion of which was that properly purified 2,4,5-T used in good agricultural practice would afford little if any hazard.

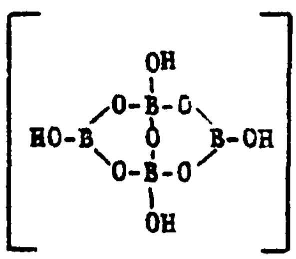
Herbicides by virtue of their ability to affect plant growth possess potential for ecological effects in non-target areas. We have seen instances of this in the result of spray drift, the evidence that use of herbicides is causing problems from latent transport however is rather scant.

Because of our knowledge on many of these chemicals is still incomplete, proper care and precaution should be exercised. It would be suggested that best exercise of prudence would be to insure that only knowledgeable individuals have access to their use. The recent proposal to license applicators on the basis of training and knowledge is commended as reasonable step toward this end.

References

1. Oregon Weed Control Handbook (Pub. yearly), O.S.U. Coop Bookstore, Corvallis, Ore.
2. Herbicide Handbook, 2nd Ed., Weed Soc. of Am.
3. Principles of Weed Control - NAS/NRC (Principles of Plant and Animal Pest Control Series)
4. Organic Pesticides in the Environment - Adv. in Chem #60, Am. Chem. Soc.
5. Montgomery, M. L. & Norris, L., Res Notes PNW for a Range Exp Sta. #116

Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
INORGANICS		
1. Arsenous oxide	Arsenic trioxide	197.2 As_2O_3
2. Sodium meta Arsenite	Sodium Arsenite	129.9 $NaAsO_2$
3. Ortho-arsenic acid Hemihydrate	arsenic acid	141.9 H_3AsO_4
4. Sodium chlorate		106.4 $NaClO_3$
5. Sodium tetraborate	Borax	201.3 as $Na_2B_4O_7$

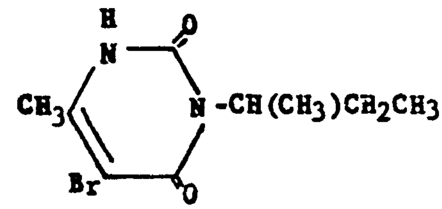
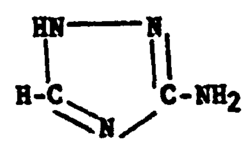
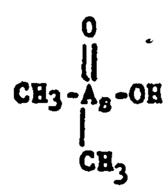
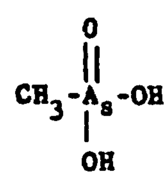


-2 $\cdot 8H_2O$

$2Na^+$

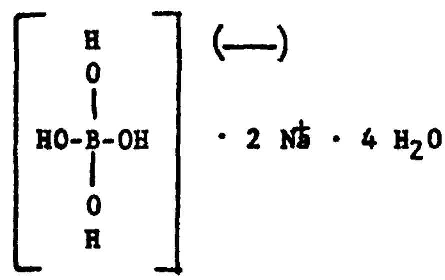
	MP	VP mm Hg	Solubility			Comments
			Solvent	G/100ml	°C	
1.	subl		water	1.2	0	oral LD_{50} rats 138 mg/Kg ΔH solution -7.5 Kcal/mole
2.			water alcohol	v.s. sl.s.		oral LD_{50} various animals 10-50 mg/Kg
3.			cold water	14		intravenous LD_{50} rabbits 8 mg/Kg ΔH solution -0.4 Kcal/mole
4.	248 decomp		water	81	0	oral LD_{50} rat 12 g/Kg dermal LD_{50} 20 g/Kg LD_{50} man 15-25g LD_{50} child 1 yr old 2g ΔH solution -5.6 Kcal/mole
5.	742		water methanol acetone glycerol (93.5%)	1.3% 4.7% 11.2% 18.6% 0.6% 52.6%	0 20 40 25 25 20	0.1 M solution pH 9.25 oral LD_{50} male rat 5.6 g/Kg ΔH solution -25.8 Kcal/mole

Freed

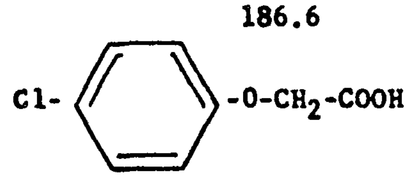
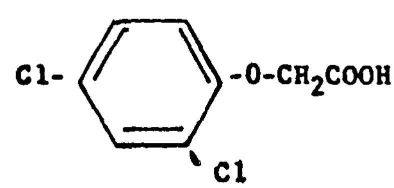
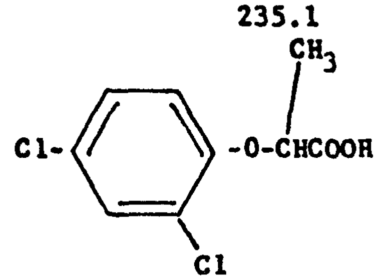
	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
	URACILS		
6.	3-sec-butyl-5-bromo 6-methyluracil	bromacil#*	261.1 
	AMITROLE		
7.	3-amino 1,2,4-triazole	amitrole# ATA	84.1 
	ORGANOMETALLICS		
8.	Dimethylarsinic acid	cacodylic acid	138.0 
9.	Methylarsinic acid	MAA	140.0 

	MP	VP mm Hg	Solubility: Solvent	G/100 ml	°C	Comments
6.	158-159		water	815 ppm	25	oral LD_{50} male rat 5.2 g/Kg
			benzene, methanol, acetone, acetonitrile	s.		
7.	153-154		water	28	23	oral LD_{50} rat 25 g/Kg
			water	53	53	pk 11.0
			ethanol	26	75	
			acetone	sl.s.		
			pyrrolidone	v.s.		
			ether	insol.		
8.	200		water	190	25	oral LD_{50} rat 800 mg/Kg
			(Ca salt in water)	75		
9.	106		water	28	25	oral LD_{50} rat 1.3 g/Kg
			(Ca salt in water)	100 ppm		

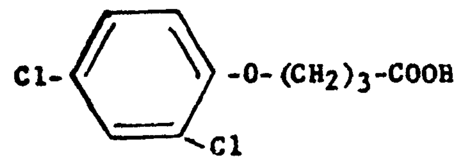
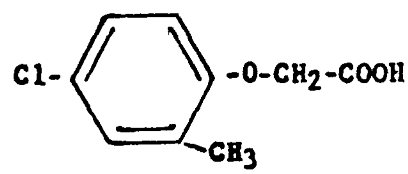
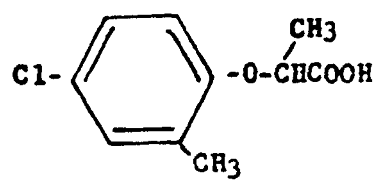
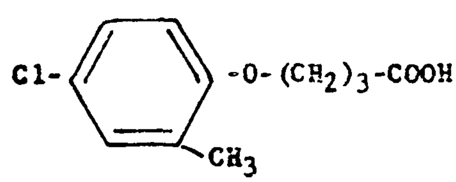
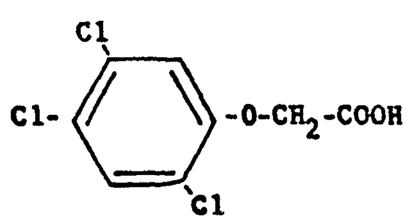
Freed

	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
10.	Ammonium sulfamate	AMS	114.1 $NH_4 \cdot O-\overset{O}{\underset{O}{\overset{\parallel}{\underset{\parallel}{S}}}}-NH_2$
11.	Sodium metaborate	Sodium 1:1-borate	131.6 as $Na_2B_2O_4$ 

PHENOXYALKANOIC ACIDS

	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
12.	4-Chlorophenoxy acetic acid	4-CPA #*	186.6 
13.	2,4-Dichloro-phenoxyacetic acid	2,4-D #*	221.1 
14.	dl 2-(2,4-dichloro-phenoxy) propionic acid	dichlorprop* 2,4-DP#	235.1 

	MP	VP mm Hg	Solvent	G/100ml	°C	Comments
10.	132		water	57%	0	oral LD_{50} rats 3.9 g/Kg
11.	965 ($Na_2B_2O_4$)		water	21%	20	0.073 M solution pH 11.2 oral LD_{50} Male rat 3.2 g/Kg ΔH solution -23.8 Kcal/mole
12.	159-160		water	797	25	oral LD_{50} 850 mg/Kg UV absorption maxima at 195, 227, 279, 289 mu ΔH solution 3.5 Kcal/mole pk 3.10
13.	140.5		water	620ppm	25	oral LD_{50} mice 375 mg/Kg UV absorption maxima at 201, 230, 283, 291 mu pk 3.31 ΔH solution 6.1 Kcal/mole
			CCl_4	0.1		
			ether	27		
			acetone	85		
			ethanol	130		
14.	118		water	180-350 ppm	20	pk 3.28

	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
15.	4-(2,4-Dichloro-phenoxy) butyric acid	2,4-DB #*	249.1 
16.	2-Methyl-4-chlorophenoxy acetic acid	MCPA #* MCP	200.5 
17.	dl 2-(2-methyl 4-chlorophenoxy) propionic acid	Mecoprop * MCPP 2-MCPP	214.7 
18.	4-(2-methyl 4-chlorophenoxy) butyric acid	MCPB #*	228.6 
19.	2,4,5-Trichloro-phenoxy acetic acid	2,4,5-T #*	255.5 

	MP	VP mm Hg	Solubility Solvent	G/100ml	°C	Comments
15.	119-120		water	53ppm		pk 5.0
			ethanol			
			chloroform	s.		
			benzene	s.		
			hexane	si.s.		
16.	119		water	825	25	UV absorption maxima at 199,229,279 mu pk 3.4 ΔH solution 8.2 Kcal/mole
17.	94.5		water	620ppm	20	oral LD_{50} 700-150mg/Kg
			water	895ppm	25	UV absorption maxima at 287 mu
			acetone	s.		pk 3.38
			ethanol	s.		
			ether	s.		
18.	100		water	44-48ppm		pk 4.86
19.	158		water	251ppm	25	oral LD50 dogs 100 mg/Kg pk 3.17 ΔH solution 8.4 Kcal/mole

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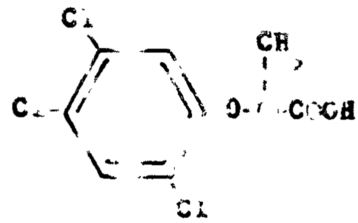
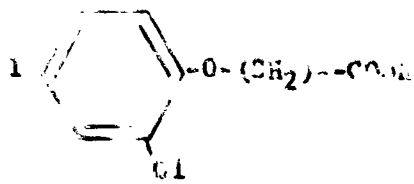
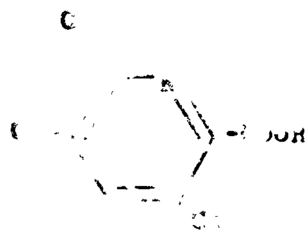
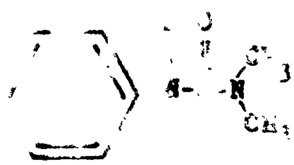
	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
20.	dl 2-(2,4,5 - Trichlorophenoxy) propionic acid	Silvex # [illegible] Fenoprop* 2,4,5-TP	269.6 
21.	4-(2,4,5-Trichlorophenoxy) butyric acid	2,4,5-TB#*	283.6 

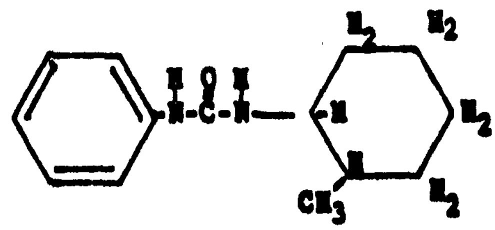
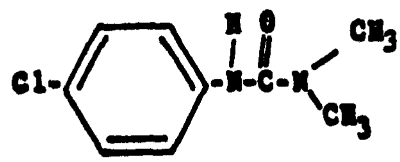
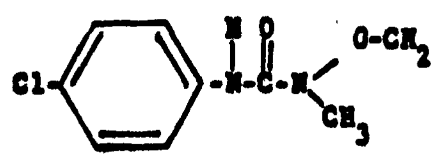
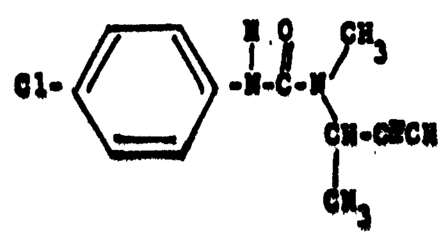
PICOLINIC ACID

22.	3,5,6-trichloro 4-aminopicolinic acid	Picloram*	241.5 

UREAS

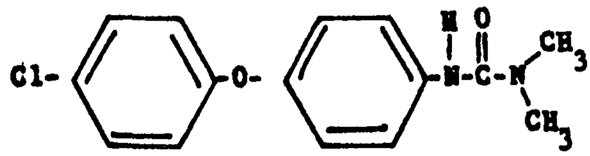
23.	NN-dimethyl-N'-phenyl urea	Fenuron#	164.2 

	MP	VP mm Hg	Solubility Solvent	G/100ml	°C	Comments
20.	181		water	140ppm	25	oral LD_{50} rats 650 mg/Kg
			CCl_4	0.095		pk 3.1
			benzene	0.47		
			methanol	13.4		
			acetone	18.0		
21.	114-115		water	42ppm		pk 4.78
22.	233	$6.1x10^{-7}$ (35°C)	water	450ppm	25	oral LD_{50} rat
		$1.07x10^{-6}$ (45°C)	benzene	200ppm	25	8.2g/Kg-rabbit 2g/Kg
			ether	0.12	25	pk 2.94
			acetonitrile	0.16	25	ΔH Solution 1.6 Kcal/mole
			isopropanol	0.5	25	
			ethanol	1.0	25	
			acetone	2.0	25	
23.	130		water	0.4	25	Oral LD_{50} rat 3.9 g/Kg-rabbit 1.5 g/Kg UV absorption maxima at 240 mu

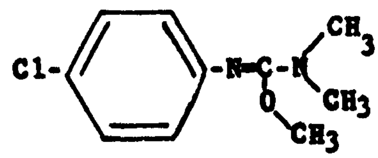
	Chemical Name	Common Name WSSA *BSI	M.W. Structural Formula
24.	1-(2-methyl-cyclohexyl)-3-phenyl urea		232.3 
25.	N'-(4-chlorophenyl) N,N-dimethyl urea	Monuron* CMU	198.7 
26.	N'-(4-Chlorophenyl) N-methoxy-N-methyl urea	Monolinuron*	214.7 
27.	N'-(4-Chelorphenyl) N-isobutynl-N-methyl urea	Buturon*	236.7 

	MP	VP mm Hg	Solubility Solvent	G/100ml	°C	Comments
24.	133-138		water	18ppm	25	oral LD_{50} male rat approx 5 g/Kg
			ethanol dichloromethane, dimethylacetamide, dimethylformamide	>10		
25.	170.5-171.5		water	161ppm	25	oral LD_{50} male rat 3.5g/Kg UV absorption maxima at 245 mu
26.						
27.						

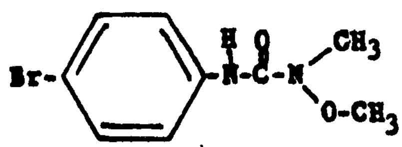
	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
28.	N'-4(4-Chloro-phenoxy)-phenyl-N,N-dimethyl urea	chlorox-uron	290.7



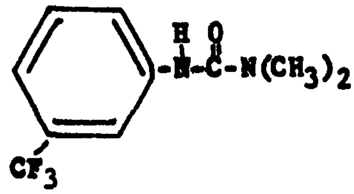
	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
29.	N'-(4-chloro-phenyl)-O,N,N-trimethyliso urea	trimeturon#*	212.7



	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
30.	3-(4-bromophenyl)-1-methyl-1-methoxy urea	metobromuron#*	259



	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
31.	1-(3-trifluoromethylphenyl)-3,3-dimethyl urea		213.2



	MP	VP mm Hg	Solubility Solvent	G/100ml	°C	Comments
28.			water acetone	3.7ppm s.	20	oral LD_{50} male rat 3.7g/Kg mouse 1.0g/Kg dog 10g/Kg
29.						
30.	95.5-96		water acetone, ethanol, chloroform	320ppm s.	20	oral LD_{50} rat 3 g/Kg
31.	163-164.5		water ethanol, acetonitrile acetone, chloroform ether, hexane	60-70ppm s. sl.s.	25	

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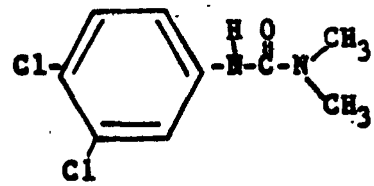
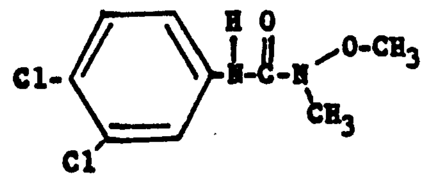
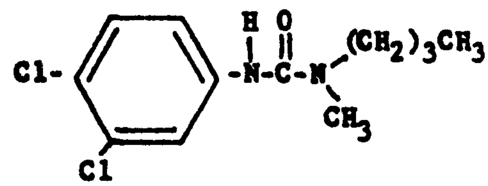
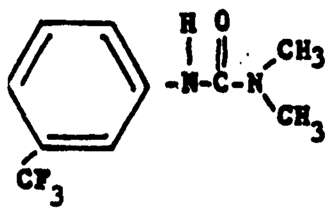
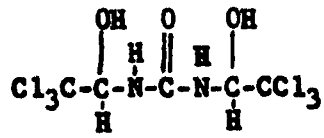
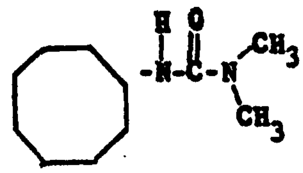
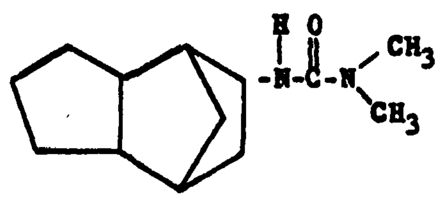
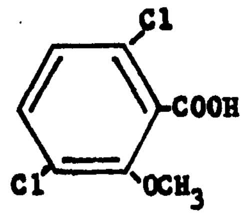
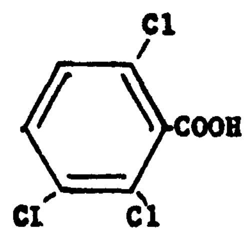
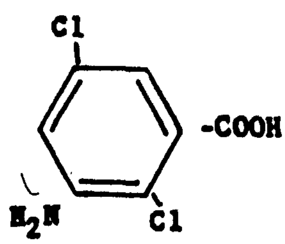
Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
32. N'-(3,4-dichlorophenyl) N,N-dimethyl urea	diuron	233.1 
33. N'-(3,4-dichlorophenyl) N-methoxy-N- methyl urea	linuron#*	249.1 
34. N'-(3,4-dichlorophenyl) N-butyl-N-methyl urea	neburon	275.2 
35. 3-(m-trifluoro-methylphenyl)-1,1-dimethyl urea		232.2 

	MP	VP mm Hg	Solubility Solvent	G/100ml	°C	Comments
32.	158-159	3.1×10^{-6} (50°C)	water	43ppm	25	oral LD_{50} rat 3.4 g/Kg UV absorption maxima at 250 mu
33.	93-94		water acetone, ethanol, benzene, toluene	75ppm s.	25	oral LD_{50} male rat 1.5 g/Kg UV absorption maxima at 250 mu
34.	101.5-103		water	4.8ppm	24	oral LD_{50} male rat 11 g/Kg
35.	163-164.5		water	90ppm	25	oral LD_{50} male rat 8.9 g/Kg female rat 7.9 g/Kg male mice 0.9 g/Kg female mice 2.4 g/Kg dog 10 g/Kg

Freed

	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
36.	1,3-bis-(2,2,2-trichloro-1-hydroxyethyl) urea	DCU	354.9 
37.	N'cyclooctyl-N,N-dimethyl urea	Cycluron#* OMU	198.3 
38.	3-(hexahydro--4,7-methanoindan-5-yl)-1,1-dimethyl urea		222.3 

	MP	VP mm Hg	Solubility Solvent	G/100ml	°C	Comments
36.	191 decomp					
37.	138		water	150ppm	20	intraparateneal
			acetone	9.8	20	LD_{50} mouse 0.3g/Kg
			methanol	109	20	LD_{50} rat 1.5g/Kg
			benzene	4.2	20	
38.	171.2		water	150ppm	25	oral LD_{50} Wistar rat 1476 mg/Kg
			polar organic solvents	s		Sprager Dawley rat 6830 mg/Kg
			nonpolar organic solvents	insol		dogs 3700 mg/Kg
						dermal LD_{50} to rabbits 23 g/Kg

	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
	BENZOIC AND PHENYLACETIC ACIDS		
39.	2-methoxy-3,6-dichlorobenzoic acid	Dicamba #*	221.0 
40.	2,3,6-Trichloro-benzoic acid	2,3,6-TBA	225.5 
41.	2,5-dichloro-3-aminobenzoic acid	Amidben# Chloramben*	206.0 

	MP	VP mm Hg	Solubility Solvent	G/100ml	°C	Comments
39.	114	3.78×10^{-3} (100° C)	water	7900ppm	25	oral LD_{50} rat 1.04 g/Kg
			ethanol	sol.		UV absorption maxima at 275 mu pk 1.94 ΔH Solution Kcal/mole
40.	118		water	7200ppm	25	oral LD_{50} .7-1.5g/Kg pk 2.6 ΔH Solution 1.6 Kcal/mole
41.	204	7×10^{-3} (100° C)	water	630ppm		oral LD_{50} 3.5 to 5.6 g/Kg
			CCl_4	insol.		UV absorption maxima at 297, 238 mu
			benzene	0.02		
			chloroform	0.09		
			ether	7.01		
			ethanol	17.28		
			methanol	22.26		

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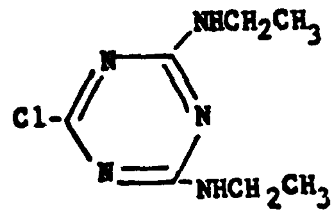
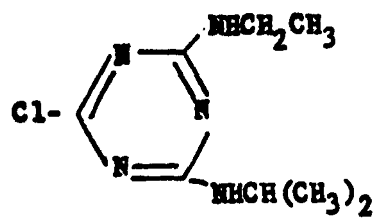
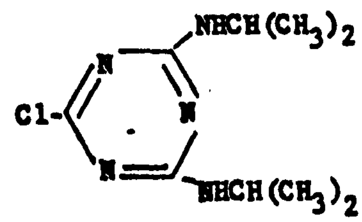
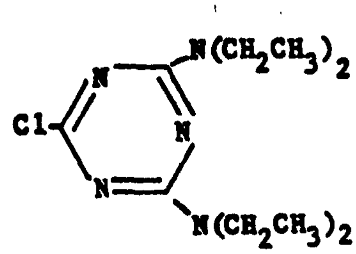
	Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
	TRIAZINES		
42.	2-Chloro-4,6-diethylamino-s-triazine	Simazine#*	207.7 
43.	2-chloro-4-ethylamino-6-isopropylamino-s-triazine	Atrazine#*	215.7 
44.	2-chloro-4,6-diisopropylamino-s-triazine	propazine#*	229.7 
45.	2-chloro-4,6-bisdiethylamino-s triazine	Chlorazine#*	257.8 

	MP	VP mm Hg	Solubility: Solvent	G/100ml	°C	Comments
42.	225-227 (subl)		water	2ppm	0	oral LD_{50} mouse, rat, rabbit, chicken, pigeon 5.0 g/Kg
			water	5ppm	20	pk 1.65
			water	84ppm	85	ΔH solution 9.0 K cal/mole
			n-pentane	3ppm	25	
			ether	300ppm	25	
			methanol	400ppm	20	
			chloroform	900ppm	20	
43.	173-175		water	22ppm	0	oral LD_{50} mouse 1.75 g/Kg
			water	70ppm	27	rat 2 to 4 g/Kg
			water	320ppm	85	rabbit 600-750 mg/Kg
			n-pentane	360ppm	27	hen 2.2 g/Kg
			ether	1.2ppm	27	pk 1.68
			methanol	1.8ppm	27	ΔH solution 6.1 K cal/mole
			chloroform	5.2	27	
44.	212-		water	8.6ppm	20	oral LD_{50} mouse, rat 5.0 g/Kg
45.			water	10ppm		

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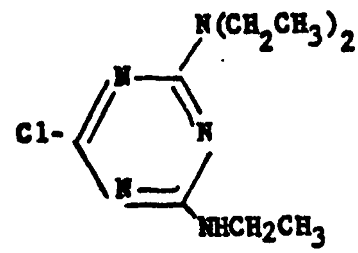
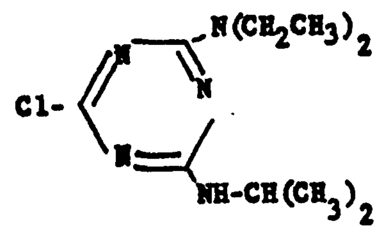
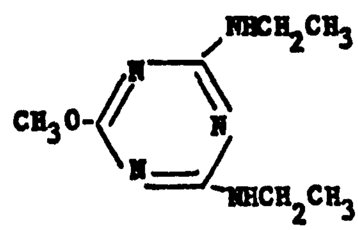
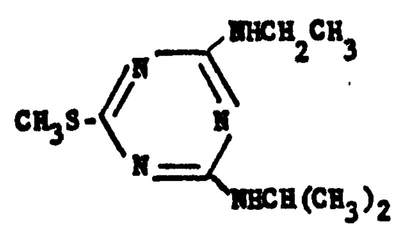
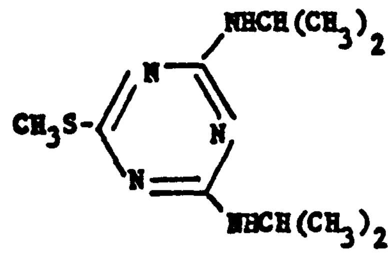
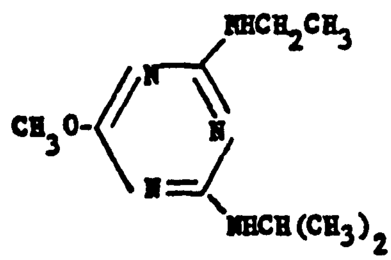
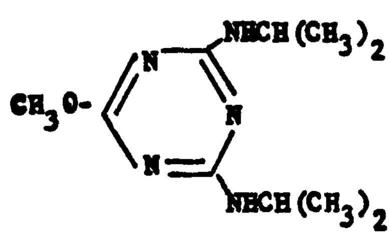
Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
46. 2-chloro-4-diethylamino-6-ethylamino-s-triazine	trietazine#*	229.7 
47. 2-chloro-4-diethylamino-6-isopropylamino-s-triazine	ipazine#*	243.7 
48. 2-methoxy-4,6-diethylamino-s-triazine	simetine# simeton*	197.2 
49. 2-methylthio-4-ethylamino-6-isopropylamino-s-triazine	Ametryne#*	227.3 

	MP	VP mm Hg	Solubility Solvent	G/100ml	°C	Comments
46.			water	20ppm		
47.						
48.	89.5-92		water	0.32		
49.	84-86		water	185ppm	20	oral LD_{50} rat 1.4 g/Kg mouse 0.95 g/Kg

Chemical Name	Common Name #WSA *BSI	M.W. Structural Formula
50. 2-methylthio-4,6-diisopropylamino-s-triazine	prometryne#*	241.4
51. 2-methoxy-4-ethylamino-6-isopropylamino-s-triazine	Atratone# Atraton*	211.3
52. 2-methoxy-4,6-diisopropylamino-s-triazine	prometone# prometon*	225.9







	MP	VP mm Hg	Solubility Solvent	G/100ml	°C	Comments
50.	118-120		water	48ppm	20	oral LD_{50} mouse, rat 3.75 g/Kg pheasant 1.0 g/Kg
			most organic solvents	s.		
51.			water	0.18	22	
52.	91-		water	750ppm	20	oral LD_{50} rat 2.2 g/Kg mouse 1.05 g/Kg distillable under reduced pressure pk 4.3
			benzene	33	20	
			chloroform, methanol, acetone	100		

THE OPERATIONAL AND MAINTENANCE REQUIREMENTS
OF
RESPIRATORY PROTECTIVE APPARATUS
FOR
PESTICIDE USERS

S. Edward Law

INTRODUCTION

Concern today in maintaining our environmental quality has caused a reevaluation of many of the effective methods and materials used for protecting agricultural crops from insect, disease and weed pests. Chemical pesticides have well protected our food and fiber production from about 10,000 kinds of insects and 1,500 plant diseases[1]. In some instances, environmental abuse has resulted from the use of certain pesticides. While research on alternative control methods (radiation, biological, cultural, etc.) is well underway, these methods at present appear to be only promising complements to chemical pest control. Thus, environmental preservation has made it imperative that drastic improvements be incorporated into the use of chemical pesticides.

Two improvements which can considerably lessen the deleterious environmental effects caused by chemical pest control are: (1) reducing pesticide output rates per unit area, and (2) reducing the persistence of the toxic chemicals used. Agricultural engineering research has demonstrated encouraging improvements by utilizing electrostatic deposition of pesticide particles to achieve satisfactory coverage of field-crops with pesticide output from nozzles reduced typically to half-rates[2,3].

The formulation and use of less persistent pesticides (such as the organic phosphates) has certainly reduced the severity of the environmental hazard associated with the "hard" chlorinated hydrocarbons. However, the mammalian toxicity of these less persistent materials is often extremely high. So while the environmental hazard is reduced, the personal safety hazard is greatly increased for workers who mix and apply some of these less persistent pesticides. The proper use and maintenance of personal protective apparatus by these workers becomes an absolute requirement of any pest control program.

Papers presented earlier this week have discussed the acute toxicity hazard encountered in the use of many pesticides. Possible routes of entry of the toxic materials into the body may be: (1) dermal, (2) through skin wounds, (3) oral, and (4) respiratory. The extreme importance of the dermal route of entry has been noted, and protective clothing to minimize dermal exposure has been discussed.

The purpose of this paper is to now consider certain aspects of personal protective apparatus available to reduce pesticide entry via. the respiratory route. Particular emphasis will be placed on the routine operational and maintenance requirements that these devices require in order to satisfactorily provide the protection for which they were designed.

TYPES OF RESPIRATORY HAZARDS AND PROTECTIVE DEVICES

The several governmental agencies and professional scientific groups directly concerned with occupational respiratory hazards are the U.S. Bureau of Mines, the Entomology Research Division of USDA, the American Industrial Hygiene Association and the American National Standards Institute, Inc. Specific and detailed information on respiratory protection is contained in publications available from these groups[4,5,6,7] as well as from commercial sources[8].

At the present time the U.S. Bureau of Mines is the official governmental agency responsible for testing and approving respiratory protective equipment. Complete protective devices are tested and passed under one of a number of Approval Schedules setting forth the minimum requirements that the various types of respiratory protective equipment shall satisfy for safe use.

In general, there are three broad classes of respiratory protective devices tested by the Bureau of Mines: (1) air purifying, (2) air supplied, and (3) self-contained apparatus. The Bureau of Mines selection chart (Figure 1.) illustrates the utilization of these three classes of devices for protection against a number of general respiratory hazards. Using this chart as a guide, a brief discussion follows to indicate the various types of protective devices available to minimize pesticide entry into the body via. the respiratory route. The maintenance requirements common to all of the devices will then finally be considered.

OXYGEN DEFICIENCY HAZARD

An oxygen deficiency hazard exists when the ambient oxygen content drops below 16% volume concentration from its normal value of 20.9%. Such a hazard is fairly uncommon in agricultural pesticide application except, perhaps, in the fumigation of closed spaces such as grain elevators and the holds of ships. Adequate protection against an oxygen deficiency is provided by either: (1) self-contained breathing apparatus carried by the wearer, or (2) a hose mask with blower which delivers breathing air from a distant uncontaminated region. Furthermore, these two type devices provide adequate respiratory protection against toxic contaminants since the wearer is completely free of respiratory exchange with the atmosphere surrounding him.

TOXIC CONTAMINANT HAZARD

Respiratory hazards may occur when breathing from atmospheres contaminated with: (1) toxic particulate matter in the form of dusts and sprays, (2) toxic gases and vapors, or (3) a combination of these toxic agents. Devices appropriate for protection against each of these respiratory hazards are available.

Toxic Particulates - Mechanical filter respirators provide respiratory protection against dusts, mist and fumes. Toxic particles are physically trapped in a fibrous material as the inhaled air passes through the filter. Particulate filtration theory indicates that the individual dust or spray particles are deposited onto individual fibers within the filter medium by the combined action of three filtering phenomena: (1) a straining effect in which particles too large to pass between fibers are collected, (2) an impingement onto fibers by particles having sufficient momentum to penetrate through the slipstreams flowing around the fibers, and (3) interception. The efficiencies of these filter phenomena are functions of particle size, and the maximum difficulty in filtration occurs for particles of approximately 0.3 micron diameter. Certain mechanical filter respirators are available commercially with filter efficiencies guaranteed to be not less than 99.98% as established using 0.3 micron diameter DOP (di-octyl phthalate) test smoke.

The American Conference of Governmental Hygienists annually publishes a listing of the Threshold Limit Values (TLV) for airborne contaminants including certain pesticides . These TLV's define concentration levels of toxic airborne particulates (and gases) above which respiratory hazards are probable for continual eight-hour workday exposures. Technical specifications describing many mechanical filter respirators indicate their approval for protection against the inhalation of dusts and mists having a TLV as low as 0.1 milligram/cubic meter.

It must be emphasized that the mechanical filter respirator alone does not offer adequate protection against the volatile particulate matter typical of many pesticides.

Toxic Gases - Respiratory protection against certain toxic gases and vapors is provided by two types of air purifying devices: (1) chemical cartridge respirators, and (2) gas masks. These two types of devices differ in size, service life, and the contamination level in which they may be utilized. In both the inhaled air is usually drawn through a bed of activated charcoal in which the toxic gas is adsorbed onto the surface of the finely divided charcoal particles.

Chemical cartridge respirators provide protection against certain toxic gases and vapors in concentrations as high as 0.1% by volume. These are half-face masks which cover the mouth and the nose, but do not protect the eyes.

Gas masks protect against certain toxic gases and vapors in concentrations up to 2% by volume. These are full-face masks which also protect the eyes.

Models are available with the chemical canister chin-mounted directly onto the mask, and chest or back-mounted using a length of flexible hose. The back-mounted canisters are advisable when very high vapor concentrations exist directly in front of the wearer as, for example, when pouring fumigant directly onto the surface of stored grain. The smaller size of the chin-mounted type limits it use to gas concentrations no greater than 0.5%.

Combined Toxic Gas and Particulate - Most agricultural pesticides are applied as either particulate dusts or sprays. In many instances the pesticide formulation is quite volatile. Thus, the most common respiratory hazard encountered by pesticide users is a combined gaseous and particulate exposure. Adequate protection is provided by utilizing an appropriate gas or vapor adsorber in conjunction with a high efficiency particulate filter.

Chemical cartridges and canisters are available with particulate filters assembled as an integral part. These combination units are very compact. Their one disadvantage is that the particulate filter usually becomes clogged before the more expensive chemical cartridge part is exhausted. The whole unit must then be discarded. Some commercial respirators with independently replaceable particulate filters are available as an alternative.

As recently as 1966 the Entomology Research Division of USDA routinely tested the protective efficacy of commercial air purifying filter-cartridges and canisters against particulate and gaseous exposures of certain pesticides. A listing is given of those cartridges and canisters found to provide adequate respiratory protection specifically against dust, mist, and low vapor concentrations of some fifty pesticides[5]. These units tested are recommended for use in airborne pesticide concentrations of no greater than 5 milligrams/cubic meter and 50 milligrams/cubic meter when installed in half-mask respirators and in full-face gas masks, respectively. The purifying units were not tested against high vapor concentrations of commercial fumigants.

RESPIRATORY EQUIPMENT MAINTENANCE

No matter how well suited a respiratory protective device is for a particular job, it cannot provide the protection for which it was designed unless it receives proper maintenance. A number of maintenance requirements are common to most of the above mentioned devices, and these are discussed in detail below. Specific details on maintenance of the more complicated self-contained apparatus should be obtained from the manufacturer.

TIGHTNESS

Tightness of face-fit and mechanical connections should routinely be checked to prevent leakage. Less than 0.1% contaminant leakage from toxic atmospheres may be obtained using a properly fitted full-face mask[6]. This degree of tightness is generally not possible with half-face chemical cartridge respirators since they must fit a portion of the face having more individual variation. Factors which prevent a satisfactory face-fit are beard growth, heavy sideburns, temple pieces of eye glasses and absence of dentures. Two simple field tests for checking face-fit follow.

Positive Pressure Test - The exhalation valve cover is removed and the valve closed by covering. Air is exhaled gently into the facepiece and held. If the slight positive pressure built up in the mask can be maintained without any evidence of outward leakage, then the face-fit and the seating of the intake valve are considered satisfactory.

Negative Pressure Test - The intake opening of the cartridge or canister is covered with the palm of the hand. The wearer inhales gently and holds his breath to cause the mask to slightly collapse. If the mask remains slightly collapsed for ten seconds and no inward leakage is detected, then the face-fit and the seating of the exhalation valve are considered satisfactory.

Realistic Test For Face-Fit - Two additional face-fit tests are sometimes used[7]. In both of these tests a fairly harmless airborne material is dispersed into a small plastic enclosure or vacant room in order to create a realistic test condition. To detect gas leaks, isoamyl acetate vapor is dispersed, and the wearer checks for odor. To detect particulate leaks, an irritating smoke is dispersed using stannic chloride - impregnated pumice. Particulate leakage is indicated by throat irritation.

PARTICULATE FILTER REPLACEMENT

The useful life of the particulate filter depends upon: (1) filter area, (2) level of exertion of the wearer, (3) airborne particulate concentration, and (4) the particulate size distribution. The independently changeable type particulate filters should be changed twice daily or oftener if breathing becomes difficult.

CHEMICAL CARTRIDGE REPLACEMENT

The service life of chemical cartridges and canisters depends upon: (1) gas or vapor concentration, (2) level of exertion of the wearer, (3) volume of the unit, and (4) humidity. The wide variations in these exposure conditions makes it impossible to rigidly specify service life. Thus, generally it is recommended that chemical cartridges be changed after eight hours of actual use or oftener if any pesticide odor is detected by the wearer. It should be mentioned that since the first detection of odor by the wearer indicates the end of the service life of chemical cartridges, these should never be used for protection against odorless gases or gases which paralyze the olfactory nerves so quickly that detection by odor is unreliable.

WASHING AND DISINFECTION

Respiratory protective devices should be thoroughly cleaned inside and out following each use with pesticides. In the interest of personal hygiene, it is also desirable to disinfect any device which is worn by more than one worker. Cleaner-disinfectants which contain bactericidal agents are available from respirator manufacturers; these are recommended for convenience. After removing any filter or cartridge or canister, the whole facepiece and breathing tube is immersed into a solution of the cleaner-disinfectant, then rinsed in clean water, and air-dried. When a commercial cleaner-disinfectant is not available, the facepiece and breathing tube may be washed with household liquid detergent and then disinfected in either a hypochlorite solution or an aqueous iodine solution.[7] All disinfectant solutions must be thoroughly rinsed since they may cause dermatitis, corrode metal parts and age rubber.

DECONTAMINATION

Any respirator which has become contaminated with organic phosphate pesticides must be treated before reuse. It should be washed thoroughly with strong alkaline soap. This hydrolyzes parathion and produces a yellow color. Thoroughness of the decontamination is conveniently indicated by the disappearance of the yellow. The alkaline soap is corrosive, and it must be completely rinsed from the respirator with ethyl or isopropyl alcohol (50%).

STORAGE

Respirators and gas masks should be stored in their original packing cartons or in closed plastic bags. The rubber parts should rest in an uncramped position so that no permanent distortion will occur in storage. Protection should be provided against heat, sunlight, dust, excessive moisture and damaging chemicals. Rubber parts which have become stiff during storage can be made pliable and flexible by stretching and massaging the rubber.

REPAIR

Respiratory protective devices should be repaired using only the manufacturer's recommended parts and instructions.

SUMMARY

The high mammalian toxicity of many presently used pesticides poses a serious personal safety hazard to users. In particular, the dermal and the respiratory routes of entry into the body require protection. The respiratory hazard may exist as an oxygen deficiency or a toxic contaminant hazard due to the presence of airborne particulate matter and poisonous gases and vapors. Appropriate respiratory protective devices are available, and they should be selected and used only against the specific hazard for which they were designed.

Maintenance recommendations for respirators and gas masks are simple, quick and easy. If this maintenance is routinely implemented, then these devices should reliably provide adequate respiratory protection against the chemical pesticides for which they are recommended[5].

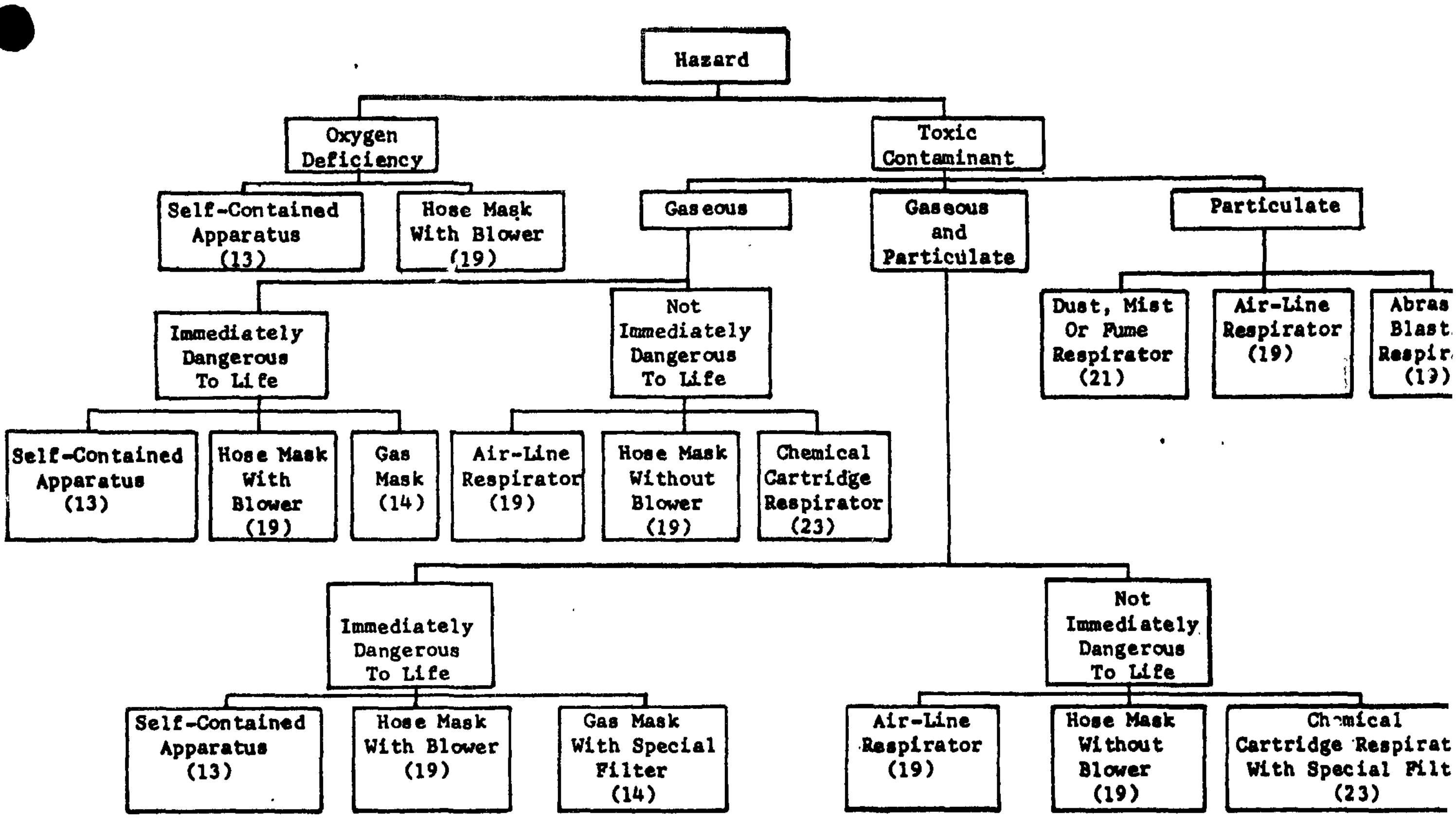


Figure 1. Selection of appropriate protective devices for various respiratory haza
(Numbers refer to USBM Approval Schedules)

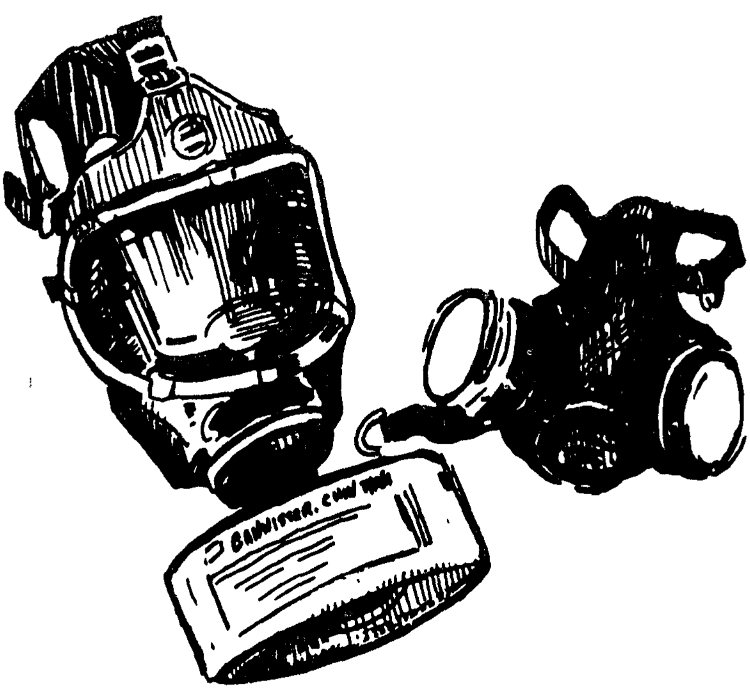


Figure 2. Respiratory protective devices commonly used against pesticides.
(1) Full-face gas mask with chin-mounted canister.

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PESTICIDE EQUIPMENT MAINTENANCE

H. B. Goolsby

The farm sprayer is a versatile machine that must be capable of many different uses in applying pesticides to farm crops.

This paper deals only with the operation and maintenance of the farm sprayer for protecting the environment against any after effects from pesticide usage.

Due to the possibility of using a sprayer for many different jobs in which the sprayer must be changed often, its maintenance is directly related to over application and incorrect application of pesticides.

One of the most important things on a sprayer that must be kept in excellent working order is the tank agitator. This agitator must continue to operate in the sprayer tank even while moving from field to field so that the pesticide will not tend to settle out.

Sprayer hoses should be flexible and reinforced to prevent collapsing under vacuum. They must also be able to withstand a much higher pressure than under average operating conditions. All hoses must be able to resist sunlight, oil and chemicals.

Adjustments on the pressure regulator of a sprayer are used in calibrating. Maintenance of the adjustments is imperative in maintaining correct calibration so that excess amounts of material will not be applied to the crop and, in turn, contaminate the environment.

All recommendations of pesticides for crops made by the Cooperative Extension Service are designed to apply only enough pesticide to do the job without harmful effects to wildlife, livestock and humans. Any excess of spray material is in direct conflict with environmental protection.

Sprayers for farm crops, especially ground driven sprayers, generally operate in a range of 0 - 100 psi. Any deviation upward of this pressure is generally used for the specialized jobs.

Tanks on sprayers should be made of corrosive resistant materials or should be lined with an anti-corrosive substance to minimize flaking sediments that cause screen stoppage, excessive wear and ineffective spraying.

Maintaining the nozzle and sprayer tips are of uppermost importance in protecting our environment. The majority of nozzle tips being sold today are fast wearing. In some cases, after 10 hours of use and with certain pesticides, some nozzles will apply as much as 12 to 15 percent more material. Chrome plated and stainless steel nozzle tips will tend to wear less. Farmers that utilize fast wearing nozzles should calibrate their machine more often to offset fast wear of nozzle tips. If abrasive materials are used, calibration should be done twice daily. The selec- [illegible] application is going to be effective by putting the material only where it should go. Strainers in nozzles are provided to keep down nozzle wear but often these strainers become clogged and must be removed, cleaned and reinserted into the nozzle. It is necessary for farmers and sprayer operators to check the discharge from each nozzle many times during the days operation.

The use of hand sprayers in and around the home should be handled in a like manner as sprayers used on the farm. Wire or knives should never be used to clean nozzle tips. Their use will destroy the spray pattern and also increase the material applied. At the end of each spray season and after the sprayer has been cleaned, the nozzles should be removed, cleaned thoroughly, covered with thin oil and stored.

The farmer and/or sprayer operator must be well informed as to the sprayer setup for various jobs to be done. Maintenance of the sprayer in this regard is very important for doing a good job and in protecting the environment.

Sprayers for certain jobs use complete coverage applications. Some sprayers must be set up to direct application to certain parts of plants and to the soil. In many cases, pesticides must not come in contact with plants or crops which the farmer wishes to protect. The complete maintenance of the sprayer setup during operation is a must if farmers wish to do the best job protecting his crop and apply the material only where it should go. In many cases during the actual spraying operation, nozzles need adjusting since dangers could result not only to the crop itself but to the environment as well.

In view of the fact that sprayer users must calibrate often, in 1957 equipment manufacturers, chemical companies, agricultural research and the Cooperative Extension Service established a Georgia standard for calibration. This was done so that the farmers would not be confused by the many hundreds of ways in which to calibrate. The main objective of this standard was to apply certain materials to certain pests in order to make crops more productive. The farmer's ability to calibrate would greatly limit the danger that might be incurred when using an incorrectly calibrated machine. Farmers of Georgia are supplied vest pocket cards giving the Georgia standard of calibration for various jobs.

Each crop and pesticide requires different rates and application techniques. Sprayer users must be cognizant of these recommendations and adjust his sprayer so that these rates of application can be maintained.

All types of sprayers must be cleaned often and stored properly during the off season if they are to be effective in doing a good job and not contaminate our environment.

Operators should use extreme care while maintaining and operating a sprayer by wearing the correct clothing, face mask respirators and having available washing material in case the pesticide gets on the bare skin.

The farm sprayer is a necessary tool for the farmer to carry out an effective pest control program. Care in handling and maintenance can guard against unnecessary damage to the environment.

EQUIPMENT MAINTENANCE RINSING AND WASHING FOR ENVIRONMENTAL INTEGRITY

Charles E. Rice

The Summary of Interim Guidelines for Disposal of Surplus or Waste Pesticides and Pesticide Containers[1] gives the best guidance available for the rinsing and washing of agricultural spray equipment. These guidelines will be discussed and developed for application to the problem.

Excess mixed pesticide disposal can be minimized by close calculation of required amount so as to have a smaller gallonage for disposal. The use of low-volume application will also decrease the gallonage problem.

The guidelines give the following recommendation of the disposition of dilute pesticides.

"(1) When it is necessary to dispose of dilute pesticide mixtures or rinsings, whenever possible they should be carefully applied to the area that has been treated, adjacent borders or safe, protected waste area. Extreme care must be exercised so that the extra pesticide applied will not result in phytotoxicity, over-tolerance residues or other undesirable results."

To follow these guidelines, it is considered desirable to cut mixed dilute pesticides by adding ten (10) parts of water to one (1) part of the pesticide. After the mixture is cut, then apply to the treated area. This small ten percent added treatment would not be expected to exceed the tolerance or produce other undesirable results. Rinse water would be expended directly on another part of the treated area or safe borders.

The guideline for the occasions that do not fall under the first item raises a few problems.

"(2) When this method will not suffice, the dilute pesticide solution, emulsion or rinsing should be run into a shallow holding pit dug in a area where there will be no runoff or downward percolation and where the water table is at least 10 feet below the surface. Under no circumstances should dilute pesticides or rinse water be allowed to enter streams, lakes, sewers, drainage ditches or other areas where water contamination can result. The holding pit area should be properly identified so that no other use is made of this area, and so that subsequent contamination of other areas will not occur."

The handling and disposition of the dilute pesticide under this guideline should not occur frequently, but there will be many occasions for rinsing out equipment, and washing equipment that will fall under this guideline. The holding pit must be located so there is no surface drainage from the area. A small dike around the area will assure no loss of soil or water from runoff. The water will be removed by evaporation.

To minimize downward percolation, the pit should be dug in a soil that can be puddled and compacted. This will normally be a clay soil, or clay will have to be brought in to line the pit. Clay is recommended in the expectation of some of the pesticides combining with the soil. We recommend that the pit be filled with gravel so that the equipment can be driven onto the gravel for washing and rinsing. A small dike around the area will assure no loss of soil or runoff water.

The condition of 10 feet above the water table will be very difficult to meet in our Coastal Plain areas. In these cases select the best available site, and do an excellent job of puddling the pit to minimize percolation.

The pit should be located down grade from any well or other water supply. The distance recommended for burial is 500 feet from a water source. It may be impossible to locate the pit or to obtain wash water 500 feet from a water source, but it is a good figure to keep in mind. An antisiphon device should be used on the water supply hose bib.

The practice of washing a sprayer close to a well can be dangerous. Lewallen[2] reported on a polluted well dug near where a sprayer was washing area for the backfill. It was monitored for 4 years during which time there was a gradual decline.

The wash area should be fenced and a permanent sign posted. The fence will prevent the area from being used for other purposes such as grazing. The sign will warn any new management of the past use of the area and hopefully prevent it being used, for example, as a garden plot.

All used spray equipment should be kept in safe storage to prevent children from placing their hands or bodies on the equipment because of the potential danger of the chemical residues.

All washing and rinsing of the equipment should be done using the individual protective equipment recommended when applying the particular pesticides.

"References"

1 Working Group on Pesticides. Summary of interim guidelines for disposal of surplus or waste pesticides and pesticide containers. NTIS. Operations Division, Springfield, Virginia 22 151, Dec. 1970.

2 Lewallen, W. J. Pesticide Contamination a shallow bored well in Southeastern Coastal Plains. Paper presented at the National Ground Water Quality Symposium, Denver, Colorado, August 25-27, 1971.