Pesticides,
Pest Control
and
Safety on
Forest and
Range Lands

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...editors
PREFACE

The pages of this Continuing Education Book contain the papers presented on the Oregon State University campus, March 22-24, 1971 at which time several hundred individuals gathered to learn the requirements for the Oregon Public Employee “Special Applicator” license test.

The purpose of this Short Course on Pesticides, Pest Control and Safety on Forest and Range Lands, was to familiarize pesticide applicators with pest control problems and pesticide behavior to enable them to carry out effective and safe pest control programs. The course also served to prepare the participants to take the State of Oregon Public Employee “Special Applicator” license test. This test was administered to registrants for the short course on the final afternoon of the March sessions.

The short course was sponsored by Oregon State University, School of Agriculture and Cooperative Extension Service; the Division of Continuing Education, and with the cooperation of the United States Forest Service.

Continuing Education Publications has assembled the papers presented during this short course and acknowledges the assistance of Oregon State University’s Schools of Forestry and Agriculture, the Cooperative Extension Service, and the United States Forest Service, as well as the authors of the several papers presented during the sessions.

The first person voice and colloquial expressions used during the actual presentations have been retained in these proceedings to impart some of the flavor obtained by attending the short course to persons using this document as a reference source. If you wish to correspond with any of the participants you will find their names and 1971 addresses in Appendix A following the last paper in Section V.

We hope the papers presented here will continue to serve as a ready source of information in the continuing battle to provide in this ecological age for effective and safe pest control programs. We trust that you will find other uses, too, in your own personal continuing education program for the reference materials found in these pages.

J. M. Morris
Managing Editor
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FOREWORD

These proceedings are prepared from a short course on pest control and safety in the forest and on the range, which was presented to operating and supervisory personnel of various public agencies charged with the protection of these natural resources.

The protection of these resources involves not only the control of pest species such as unwanted plant competition, damaging insects and rodents, but also the management of the total environment for the common good of diverse interests in our society.

Since much of the management of populations of pest species involves the use of chemicals as one of the tools, a critical aspect of this management is the prevention of unwanted or harmful environmental effects which may potentially be associated with the use of pesticides. The past decade has seen an enormous increase in our understanding of the subtle chronic or long term effects of chemicals in the environment, and the changes in management practices reflecting this have been more rapid and recent than changes resulting from our increased understanding of pest biology.

The emphasis on protection of the environment is reflected in the construction of these proceedings. Out of five one-half day sessions in the short course, only one of the half-day sessions was devoted to pest management problems—the other four sessions were devoted to pesticide management problems. An entire session was concerned with the chemistry and biochemistry of these chemical tools, because every skilled workman must "know his tools" inside and out. One session was devoted to the effects these chemicals can have in the environment, and another considered the problems of application, drift, and other operational safety issues. The last session was concerned with the relationship of pest control operations to the general public.

Although the chemicals considered were not restricted to herbicides, these received the major emphasis because they are the principal class of chemicals in use in the forests and on the range. This short course was one of a continuing series designed to provide recent scientific information to all pest control operators. It is hoped that these proceedings will be a useful reference and convenient source of information to them.

Conference Editors
Joseph Capizzi
and
James M. Witt
SECTION I

FOREST AND RANGE PEST PROBLEMS

Chairman: Spencer Moore
Dealing with forest insect problems requires a three-stage approach. First is detection where damage must be recognized and the cause identified. Second is evaluation where damage extent needs to be determined. Values at stake must be established, method of action analyzed, and cost estimates made before suppression decisions are reached. Third is control where the best and most practical methods are used to reduce insect-caused losses. Frequently, small local insect problems have been detected and control measures used without any serious evaluation. There have been instances where suppression measures were used without insects or damage being detected. These practices are not only wasteful, but they can lead to more serious control problems later.

Insect Detection

Fire lookouts in the past also detected forest insect outbreaks. They could monitor existing outbreaks, map infestation trends and note changes in damage intensities. Insect-killed timber became prime fire hazards that required constant surveillance. Beyond the fire lookout's field of view, insect problem areas were located by forest workers during their routine work schedules. Because of low-valued timber and inadequate control measures, insect infestations were often allowed to run their course. As forest management intensified, stumpage values increased and insect control measures became more economical, insect losses were no longer tolerated. However, more effective detection methods were needed to locate new insect problems during the same season that they occurred.

Oregon aerial surveys began in 1944 when 320,000 acres were flown in the northwestern part of the State by the Bureau of Entomology and Plant Quarantine. Later, Bureau aerial surveys were made with the intense cooperation of other timber resource managers such as Crown Zellerbach, U. S. Forest Service, Oregon State Department of Forestry and Weyerhaeuser Timber Company. The Bureau's forest entomological functions were transferred to the Pacific Northwest Forest and Range Experiment Station in 1954, July 1961 Insect Surveys and Control moved
from the Experiment Station to forest administration. Regardless of which Federal agency was responsible for insect surveys and control, annual aerial detection flights have continued uninterrupted with the close cooperation of the State of Oregon and private timber companies.

The primary objective for these flights in Oregon is to detect outbreaks of six major insect tree killers. Two bark beetles include the Douglas-fir beetle, *Dendroctonus pseudotsugae*, that infests both east and west side Douglas fir and the mountain pine beetle, *Dendroctonus ponderosae*, that attacks commercial-size ponderosa pine, lodgepole, and western white pine. Particular detection effort is directed to four defoliators. These are the Douglas fir tussock moth, *Hemerocampa pseudotsugata*, that feeds primarily on Douglas fir and true firs but will eventually move into the pines. The western hemlock looper, *Lambdina fiscellaria lugubrosa*, that occurs along the coastal hemlock – spruce stands and will move into adjacent Douglas fir and cedar after their preferred food supply is exhausted. Western spruce budworm, *Choristoneura occidentalis*, which is found in Douglas fir and true fir stands and will infest Engelmann spruce, western larch and hemlock.

Balsam woolly aphid, *Chermes piceae*, an imported pest from Europe, is spreading in Oregon and destroying mature true fir stands west of the Cascades. In 1968 spot infestations were detected on the Deschutes National Forest just east of Willamette Pass. East side environmental conditions are expected to influence this aphid spread into the Blue Mountains.

Secondary insect aerial detection objectives are to locate and map other bark beetles that periodically damage Douglas fir, spruce, pines and true firs; and to delineate defoliation areas caused by pandora moth, needle miners, sawflies, casebearers and native budworms. Noninsect damage caused by bears, winter kill and ice are also located. Any unfamiliar defoliation or crown fading is mapped and ground checked later to determine the cause.

Progress has been made to distribute insect detection information to the appropriate timber managers as soon as flights are completed, data are transferred to specific maps and acres computed. Prior to 1965, only one aerial detection team covered the entire State. The Oregon State Department of Forestry provided both pilot and aircraft while the Forest Service furnished the trained survey observers. In 1965 Oregon acquired a forest entomologist who has become proficient in insect aerial detection procedures. This made it possible in 1968 to use two aircraft and observers. Half of the forested areas are flown by Oregon while the remaining areas are covered by the Forest Service, Branch of Insect and Disease Control. This closely coordinated program begins in early July and
continues through August, which is about the median time to distinguish current bark beetle tree fading and defoliator feeding.

Using two aerial detection crews has speeded locating insect problem areas, mapping their size and distributing this information to the proper land managers in time to shift timber harvest priorities or to begin planning control projects for the following season. Federal projects requiring special Congressional appropriations need additional information gained through ground surveys and biological evaluations of target insect populations. Finally, all annual survey data are compiled in a report, “Forest Pest Conditions in the Northwest” and distributed by the Forest Service each season.

Evaluations of Forest Insects

Douglas fir beetle has had the greatest economical impact on timber here in the Northwest. This insect prefers freshly cut trees and large logging slash or trees distressed by insect defoliators, windthrow, fire, land slides or road fill. When these preferred breeding sites become limited, beetles will attack nearby standing green trees. The transition from low population levels to epidemic proportions requires about 2 years. After reaching a peak, it will take 3 years before beetle damage reaches low levels again. In Oregon considerable tree volume has been lost during the course of past outbreaks.

Staying abreast of Douglas fir beetle infestations can be a problem because tree fading occurs after beetles mature and leave standing trees. Faded trees detected and mapped are indicators of past beetle activity. Clues to beetle infestations in recently attacked green standing trees are pitch streaks about midbole and red boring dust at the tree base, signs that can only be seen from the ground. Down trees can be sampled by removing bark sections and examining beetle population condition. Infested standing old-growth Douglas fir offers a population sampling problem because beetle attacks are concentrated above 30 feet.

Following the 1962 Columbus Day storm, tree blowdown areas were located on aerial maps and harvest priorities shifted to salvage distressed trees before bark beetles and tree diseases could become a major problem. By 1965 numbers of tree fading areas were detected along the Oregon Coast Range and information was needed about newly infested green tree volume. The Pacific Northwest Station devised an aerial photo, ground sampling survey using infrared color photos and a relatively small number of statistically selected ground plots. Ground plot data determined the ratio between recently faded trees that were distinguishable on the photos with adjacent newly attacked green trees. Currently, faded tree counts were then made on all photo plots and both faded and green infested
volume computed. Green infested timber was harvested first and most infested trees were removed before beetle populations could mature. Also, by comparing old and new infested volume, this survey showed that Douglas fir beetle activity was beginning to decline.

Mountain pine beetle infestations have and are still taking a large toll in western white pine stands located in the Cascade wilderness areas and in east side lodgepole and ponderosa pine stands. In the past, efforts were made to define what stand classes of the more valuable ponderosa pine were beetle susceptible. High risk stands were harvested before beetles could become established. Because east side lumber mills were mainly geared to handling large-diameter ponderosa pine, small lodgepole pine were not usually utilized and left to the mountain pine beetle. Within the past 2 years, lodgepole pine values have increased and demand for this resource is expanding.

Unlike Douglas fir beetle, mountain pine beetle prefers standing green trees. Infested pines will fade while infested. Beetle populations accumulate in the lower bole and are more accessible for ground sampling. By comparing the numbers of previous years faded tree crowns with current faded ones, a rough estimate of population trend can be made. A more accurate population trend estimate is made by using a sequential sampling procedure involving a flexible sample size. Cumulative counts are made of the beetle population from specific size bark samples. When the total number of beetles fits the physically predefined classes, predictions can be determined whether beetle population levels will increase, remain at the same level or decrease. This method saves considerable tree sampling and provides an opportunity to evaluate natural control factors that influence brood development. High beetle attack density related to tree diameter will ultimately intensify beetle larval competition for food and limit adult numbers reaching maturity. The impact on all beetle developmental stages like predators such as clerid beetles, *Enoclerus sphegeus*, a predaceous fly, *Medetera aldrichi*, and several woodpecker species and also a parasitic wasp, *Coeloides dentrotoni*, can be assessed. These natural control agents have influenced beetle population levels so that timber harvest priorities have been changed.

Major Douglas fir tussock moth outbreaks have occurred east of the Cascades beginning in Douglas fir and true fir stands. Like most defoliators, infestations are cyclic and develop within a 6-to-10-year period. But once infestations begin, they build up quickly and spread rapidly over large areas before natural factors can again regain control. Rapid population spread is not dependent on the female moth, because it cannot fly. Winds disburse the newly hatched larvae in late summer and they can also travel considerable distances searching for food. A last major outbreak occurred
on the Malheur National Forest in 1963 when 50 acres were detected defoliated. By the following year 41,000 acres were defoliated and predicted population trends for 1965 would increase to 200,000 acres. When an infestation begins, only new growth is destroyed, but as moth larval populations increase, all foliage is stripped from firs and then pines. Tree mortality shortly follows complete defoliation. Between tussock moth epidemics, ground surveillance is conducted in previous outbreak areas to locate moth cocoons with attached egg masses. Discovery of one cocoon with viable eggs indicates a major potential insect problem. Permanent insect defoliator plots have been established in Oregon and they are sampled annually. Plot samples collected in 1970 north of Enterprise on the Wallowa-Whitman National Forest contained Douglas-fir tussock moth larvae. More larvae were collected farther east on the Umatilla National Forest. No defoliation was detected from the air last season, but ground surveys will be made this fall to locate egg masses and determine population trends. New major outbreaks could be developing in this northeastern Oregon area.

Western hemlock looper infestations develop rapidly and usually will extend over a 3-year period before declining. By the time infestations subside, valuable hemlock, Douglas-fir and Sitka spruce stands are destroyed. Timber stands under 60 years old seem to be resistant to hemlock looper outbreaks. The last major outbreak in Oregon occurred in 1945 in Clatsop County and extended over 11,000 acres. Aerial detection of defoliated trees is about the only meaningful method for locating hemlock looper outbreaks. Once defoliation is apparent, rapid buildup can be expected.

Western spruce budworm activity can be found scattered in Douglas-fir and true fir stands on both sides of the Cascades between epidemic peaks. Larval feeding is only confined to new growth, and rarely are the older needles damaged. This feeding habit continued through epidemic conditions. As a result of this feeding pattern, trees can lose much of their current season's foliage without suffering mortality. Because the older needles sustain them through the following season, but at reduced vigor. Severe new foliage loss that continued consecutively for three to four seasons will eventually cause tree top mortality. Crown mortality will continue downward until the entire tree is dead. Budworm defoliation weakens trees and makes them more susceptible to bark beetle attack. Heavy Douglas-fir bark beetle infestations have been known to suppress budworm epidemics, but the dead standing trees created serious fire hazards.

Once reddish tinged foliage indicative of spruce budworm feeding is detected, egg mass surveys are begun during late summer after current
moth populations emerge and fly. Douglas fir foliage samples are collected from outbreak areas and inspected. All budworm egg masses are collected, and tally made. Egg mass numbers related to foliage area, and numbers of new egg masses are compared with ones deposited the previous season. Data accumulated provides a basis for predicting expected defoliation for next season and budworm population trend providing environmental factors continue the same.

Balsam woolly aphid is changing true fir stand composition and management in Oregon. All native firs are susceptible to aphid attack but their reaction to the aphid differs by species. The most sensitive, subalpine fir, *Abies lasiocarpa*, will die within 3 years after being attacked while grand fir, *Abies grandis*, can endure prolonged aphid feeding. Both noble fir, *Abies procera*, and Shasta red fir, *Abies magnifica*, var *shastensis*, in natural stands have survived serious damage.

Damage is caused by aphid feeding when its saliva is pumped into tree tissue. These cells react abnormally to this toxic saliva. Tree terminal branches and buds react by swelling and forming club-like gouty structures that inhibit new growth development. Aphid feeding along the main stem causes compression-like wood formation that prevents water and food movement. Attacked trees are soon weakened and become attractive to bark beetles.

Aerial detection locates only advanced aphid damage. Early aphid infestation signs are located only from the ground. Ground surveys are used to delineate new outbreak areas and to select fir stands for salvage harvesting.

**Insect Control**

Both direct and indirect control programs have been used to suppress these six major tree killing insects.

Direct control methods were commonly used to suppress bark beetle outbreaks. Standing and felled trees were saturated with insecticides that became toxic gases and penetrated the bark. Hand treating was slow and beetles often matured in untreated infested trees before the control projects were completed. Beetle-infested trees have been cut, piled and burned because trees could not be economically utilized. Treatment costs for both methods often exceed the actual tree value.

Indirect control measures are currently used to suppress beetle outbreaks. In high value west side Douglas fir stands, windthrow, distressed trees, and beetle infested timber are quickly utilized to prevent future insect-caused resource drain. Because attacked Douglas fir fades after beetles leave, there is danger of removing these faders and leaving green infested trees. An administrative study on the Gifford Pinchot
National Forest indicates that Douglas fir beetle responds to trap trees. Prime trees were felled before spring beetle flights, they attracted adult beetles, and they were utilized before new beetle broods matured. Future studies are needed to determine the ratio of trap tree volume needed to attract and absorb nearby beetle populations.

Studies made by the Pacific Northwest Forest and Range Experiment Station have shown that ponderosa pine stands can be made mountain pine beetle proof when stand basal area is reduced to 90 square feet per acre.

Bark beetles have dictated suppression location. In the near future, foresters will be able to manage and direct beetle populations to specific accessible trees using natural or synthetically produced attractants. Forest entomologist and chemist at the University of California, Pacific Southwest Forest and Range Experiment Station, Boyce Thompson Institute have been isolating various bark beetle attractants. Recent field tests have been moderately successful in manipulating beetles using various chemical compounds.

Direct chemical control methods have been used to control defoliators. Several years before DDT restrictions came into effect, a research project was established at the Pacific Southwest Forest and Range Experiment Station. One of their objectives was to screen various insecticides and find an effective DDT substitute that would control defoliating forest insects without serious impact on the target area. Zectran, a carbamate, was found toxic to spruce budworm larvae at low dosage rates and it chemically disintegrated within hours after application. Zectran has now been registered for forest use and will be used this year in a limited Montana spruce budworm control project.

Pyrethrin is a botanical insecticide that is extracted from a chrysanthemum, and it has long been a favorite insecticide use for quickly knocking down fly household insects. Screening tests at Berkeley revealed that this insecticide was very toxic to western hemlock looper but harmless to warm-blooded animals. Its main drawback is its instability. Pyrethrin will break down chemically very quickly when exposed to ultra-violet light. A stabilized form has been developed that will extend its insecticidal activity from minutes to a few hours. Stabilized pyrethrin was used in 1969 against a small hemlock looper outbreak on the Mt. Baker National Forest. Results looked promising for hemlock looper suppression but this insecticide had a heavy impact on aquatic insects which are food source for trout and young salmon. Precise application away from streams will be required in future control tests.

The last Oregon Douglas fir tussock moth epidemic that occurred on the Malheur and parts of the Ochoco National Forests was controlled with
DDT in 1965. This project was extensively monitored to determine what impact DDT would have on target areas and associated animal life. Surveillance reports stated that nontarget animals suffered little after affects. The next tussock moth outbreak will be treated experimentally with a native virus that has been isolated and produced by the Pacific Northwest Forest and Range Experiment Station. Hopefully this virus will be tested on a small outbreak in California this season. The Station has taken steps to have this virus insecticide registered for general field use. Registration must follow the same testing procedures as a newly formulated chemical insecticide. Final approval has been delayed because no previous specifications have been established for viral insecticides. Unlike chemical insecticides, virus strains used must be pure and uncontaminated by harmful pathogens, it must prove to be harmless to man on his food or while handling and it will have no effect on nontarget animals.

Attempts have been made in the Northwest to indirectly control balsam woolly aphid by importing parasites that effectively control the aphid in Europe and releasing them in infested timber stands here. Results have been disappointing. Some parasites have been recovered but they failed to multiply and influence aphid populations. Chemical control using Benzene Hexachloride have successfully reduced aphid damage. A single treatment has been found to be effective for as long as 3 years. Because method of application involves the use of hydraulic spray equipment, tall, old-growth trees cannot be effectively treated and sprayer mobility is confined to roaded areas. Treating infested trees has been confined to high-value recreation sites. Because BHC is a chlorinate hydrocarbon and restrictions now exist against use of this insecticide group, aphid susceptible fir mortality will be a problem at these recreation sites.

**Range Insects**

Insects attack and damage many range plant species. They compete directly with wildlife and livestock for range forage. The Great Basin tent caterpillar, *Malacosoma fragilis*, has been a problem around Chemult, Oregon, where it was found defoliating bitterbrush. In 1967 this insect was building up to major outbreak proportions but population levels have been dropping during the past 2 years. The Pacific Northwest Station has isolated a native tent caterpillar and produce a supply to be used experimentally on future local outbreaks.

Grasshoppers have become a problem on the Siskiyou National Forest east of Brookings. Grasshopper populations emerge in spring and feed on grassy areas adjacent to Douglas fir stands used as seed production areas. By midsummer the native grasses mature leaving hungry grasshoppers
without a food source. They move into the adjoining seed production areas where they feed on the new growth and damage terminal branches. This season if grasshopper populations continue at high levels, a suppression project will be needed to reduce the population and prevent further tree damage.

The Forest Service can detect range insect problems occurring on their lands but responsibility for insect control remains with Agricultural Research Service.

Local Insect Control

Control of primary tree killers has been the responsibility of the Forest aided by the Regional Office. If the Forest is unable to suppress outbreaks by shifting timber harvest priorities, the problem is evaluated by the Regional Office and requests are submitted to Washington for special insect control funds. Large insect projects will continue to be handled this way but household insect problems around dwellings will be the District Ranger's responsibility. Guidelines are now being developed and will include the specification that insect control chemicals will be used only by a licensed public applicator. Household insect suppression projects will no longer move to the Regional Office and then to Washington for approval. These insect problems will be detected, evaluated, and controlled on the District when they develop.

Before using any insecticides for suppression, the target insect must be identified and its impact evaluated. Insecticide recommendations for controlling that specific insect can be found in Oregon Insect Control Handbook or manufacturer's data sheets and reproduction of insecticide labels that are available from pesticide distributors. The insecticide that will be used must have a U. S. D. A. registration number and must be registered for use in Oregon. All current insecticide recommendations in the Insect Control Handbook are registered or specific chemicals can be checked with Pesticides Registered with the Oregon Department of Agriculture that is distributed each April.

When the insecticide is selected and purchased, the first control step is to read the label. Any lawfully registered insecticide or pesticide label must contain the following information:

1. Name of product
2. Net container contents
3. Active ingredients
4. Directions for use
5. Caution statements affecting nontarget vegetation, animals or beneficial insects
6. Warning statements and if highly toxic to humans, it will have the word poison in red, contain red skull and crossbones and list the antidote
7. U. S. D. A. registration number
8. Manufacturer’s address

Unlawful insecticide use includes: (1) using chemical against insects not listed on the label, (2) using an application method not described, (3) varying the application rate used against the target insects, and (4) storing unused insecticides in other than original containers.

**Literature Cited**


The concept of resource management implies deliberate efforts by man to regulate productivity and composition of natural systems. Productivity can be measured in various ways; I will assume for this presentation that the management goal is for maximum production of forage or wood consistent with other uses of the land. I will also assume that our blunders of mismanagement leading to present problems are history.

Land managers are continually confronted with problems attributed to pests. Examination of the inventory of a dealer in agricultural chemicals will reveal that our tendency when confronted with a pest is to kill it. We use insecticides, herbicides, rodenticides, acaricides, miticides, and fungicides as our key management tools. Recommendations for their use are largely confined to application techniques and times for maximum effectiveness in killing the target organism. The scope of label registration does not include instructions for optimizing the opportunity for growing the crop. This is unfortunate in use on field crops, where county agents and numerous texts consider pest control as just one component of farm practice; it is disastrous for chemicals used on forests and ranges because the rest of the story is vastly complicated, and largely untold. It is especially serious when entire administrative hierarchies focus on pests and poisons, obscuring the importance of the rest of the biological system. The purpose of this presentation is to put pest control in general, and weed and brush control specifically, into their proper places in the much broader picture of constructive forest and range management.

Special Considerations in Forests and Ranges

Forests and ranges of the Pacific Northwest, our so-called wild lands, have three special features that are important in management: 1) the land must support not only the manager’s objectives, but those of a population that considers all wild land a part of the public domain, 2) wild lands are typically managed with resources innately a part of the site, with
no major additions of species, soil adjuvants or water, and 3) wild lands are very much more complex biological systems than agricultural lands, and as with icebergs, we try to manage on the basis of the small part that is readily observable.

Management of these wild lands has generally been extensive, with specific measures more or less defensive in nature. When problems appeared, we have taken measures to solve them. Only recently has there been much evidence of programs aimed at avoiding problems through deliberate management, and optimizing productivity through some orderly scheme.

Europeans have been managing wild lands deliberately for decades. We might logically ask ourselves why, when the benefit of European insight into total-system management is available, do we close our eyes to the merits of such strategy? There is more than speculation in the hypothesis that an abundance of resources has masked the need for intensive management. We therefore haven’t allocated the energy or inspiration necessary to develop our own special versions of management in anticipation of the need.

Management that is limited to solving problems tends to focus on the more obvious symptoms for treatment. This approach fails to prevent problems from recurring and doesn’t recognize the host of minor problems that interfere with management, but are not worth attacking individually. There are numerous management tools available that have been developed for problem solving. These are often equally well suited to problem prevention through total habitat management. With a little improvising, we can capitalize on many of the merits of the European approach, but with an unparalleled choice of management tools for implementation. I will share with you some thoughts on how our methodology fits in with whole-system management.

Vegetation Management Options

Management of biological resources includes a number of specific operations. I have grouped these into two categories, positive and negative, according to whether their immediate effects are to add to or subtract from present inventories of living organisms, or rates at which they function. They are grouped according to the nature of the operation; practices in either category may be used either constructively or destructively in the long run, depending on the general plan of which the specific practice is a part.
Positive options

Management inputs that add to natural biological capability are considered “positive.” Among these, additions to the resource base, such as water and fertilizer, stimulate over-all production. Placement of fertilizer for selective availability is an example of compound positive strategy. These are, however, physical operations that require substantial capital, and provide a stimulus to the system that accelerates everything in the system. When production increases, weeds, insects and diseases are thrust into a new environment in which their relation to management objectives must be examined in an entirely new framework. The system becomes energized, so to speak.

Changes in biological composition of systems (e.g. introducing a weed, planting trees) can and must be handled in a manner entirely different from that of physical inputs. Organisms introduced can dominate systems either on purpose or by error. Experience can help to predict, in some situations, which organisms will become dominant; we plant trees or seed rangelands to insure that the system is dominated by something we want. If we do not succeed in establishing desired vegetation, we accept whatever grows by default. The most basic fundamental of vegetation management is that the emphasis be placed on growing or utilizing some form of vegetation for deliberate enhancement of management objectives. We take this for granted, yet an enormous amount of energy and capital is expended on eradication of brush where there are no trees; sagebrush control without funds for grass seeding, etc. That is, land management is too common in which establishment and promotion of desired vegetation is not even part of the plan. The major objective is obscured in the process of handling a symptom.

Plant populations depend first of all on establishment; they also depend on optimum spacing for maximum expression of dominance. Too many can produce a stand of weak individuals; too few may result in inadequate site utilization. Establishment of desirable species at optimum stocking is an example of a compound positive biological input.

Negative options

Practices that remove or destroy biological entities of a system are described as “negative.” All pest control is negative, regardless of whether it is chemical or mechanical, or directed against animal or plant species.

Deliberate promotion of desirable vegetation was described above as fundamental to vegetation management. Pest control may be part of vegetation management, but our success is measured entirely in terms of how well we succeed in our positive options regardless of degree of kill or control in our pest programs.
Most of the operations of wild land management, other than planting, are of the negative type. These include insect control, weed and brush control, rodent control, etc. Repellants are weakly negative, also. The chemicals used in this list of practices are very effective, in general, if we use them strictly in accordance with recommendations, and if we judge effectiveness strictly in terms of target organisms. Success in using them in a constructive way depends on how well we have evaluated the problem we are trying to solve.

Pests affect our success in vegetation management in two major ways. They may damage or destroy the plants we wish to promote, or they may interfere with development of desirable vegetation by competitive means. The reason for the presence of a particular pest is often the key to whether control is well advised, rather than the fact of its presence.

Controlling a pest is usually treating a symptom of a more major environmental problem. Sometimes, it may be necessary to treat the symptom. Long-term success, however, depends on correcting the environmental problem of which the symptom is a part. There are many examples of this, of which I will describe a few.

Sagebrush control on bottomland ranges is a practice used to create an environmental niche that can be occupied by palatable forage grasses. The proper sequence of range seeding, brush control and livestock exclusion will lead to the development of a very desirable and stable community. The need for such a sequence arises usually because of overutilization of desirable grasses for an extended period, during which sagebrush has replaced the grass. It is clear that a greatly increased stand of grass will support more cattle than the impoverished stand before treatment. It is not nearly so clear, however, that the renovated range will remain stable under the degree of livestock usage that would appear possible in the short run. If we insist on heavy utilization, then we must plan on counteracting the constant pressure to suppress the desirable species in the presence of less desirable competitors.

Gopher poisoning programs are implemented in both forest and pasture management. Some techniques are effective in killing gophers. Yet poisoning must be continued for a prolonged period to protect from continued trouble. Enough is known about habitat requirements of gophers to make some pretty illuminating assumptions. These animals tend to feed on fleshy roots. The very presence of epidemic populations would suggest the presence of an atypically large food supply. When we kill individual animals, we are not solving the problem but are suppressing a symptom. We can assume, however, that the animals will seek other feeding grounds if we control the vegetation which has attracted them to the area of our concern.
Most nursery seedlings supplied to the forest industry are coated with repellants. There is evidence that animals will not feed as heavily on treated seedlings as on untreated trees, and thus there is a measure of protection immediately after planting. This practice is not directed at the source of damage, however, which is the combination of a palatable species and an animal population. Because most of the exposure of trees to animal damage occurs after the seedlings have burst buds, (when untreated growth is exposed), we cannot expect such treatment to have much long-term effect. In contrast to the use of repellants is the practice of planting some native species, such as true firs or hemlock, that are largely ignored by animals. This tactic has the same effect as eliminating the aspects of the animal population that are harmful.

Brush control in forest rehabilitation is based on the premise that satisfactory killing action on woody competitors will permit unrestricted development of forest seedlings. This cause-effect relation is seldom observed, and in this instance failure is only partially tied to the cause of the brush problem. Brush is most frequently present as a dominant cover because of our clumsiness in establishing conifers immediately after harvesting. Contributing to our reforestation blunders, however, are animal populations over which we may have little control. The above repellant approach has been the only major strategy for solving this problem.

Brush may be dominant today because animals prevented trees from maintaining a competitive position. The very presence of a dominant brush cover may well guarantee that a high population of browsing animals continues to be present. Under the circumstances, the cause of damage to seedlings may be either plant or animal, and solution of either problem separately will not achieve its purpose. Examination of our experience, and of some basic ecological principles, informs us that attempts to replace brush with trees that are attractive and accessible to browsing animals will be unsuccessful. Moreover, very little additional investigation is necessary to observe that our more tolerant species are not only tolerant of shade, but they are damaged less by falling branches and debris and are virtually ignored by animals. Some, like grand fir and hemlock, are capable of substituting for Douglas-fir in our expectations of growth, and have far greater probability of establishment. In summary, then, brushfield rehabilitation cannot ignore brush suppression. It must, however, include establishment of trees that will succeed under the influence of animals and re-encroaching brush.

Conclusions

Vegetation management on wild lands involves much more than planting and weed control. Combinations of strategy are almost universally
needed, because positive inputs tend to require supportive negative inputs. We must modify management to optimize land use in accord with capacity of the system, which also determines the potential for pests. If we have chronic problems with certain weeds or animals, changes in range utilization or selection of different timber species will frequently prevent recurrence of a given problem from causing trouble. It takes much less managerial effort, chemical cost and danger to non-target species if we acknowledge our potential for pest problems from the beginning, and avoid them by careful and deliberate management.

To this end, ecological analyses should be made by professionals. Chemical use should be a part of a general plan of biological system management. This should be drawn up by the local manager whose job it is to direct the future of the entire resource.
Once the decision has been made that a herbicide project is needed, it is necessary to evaluate the many technical and operational options available so you can choose the combination which will give you the desired control of brush, without degradation of the environment. Thorough evaluation, long-range planning, and planning in infinite detail, is essential for a herbicide project, to avoid both pollution and adverse public reaction.

Operational considerations begin with the choice of a herbicide. The choice of a herbicide is somewhat inflexible, but a choice must not be based exclusively on what will give the best control to the target species. With the current public concern for the environment, several questions of what, when, and where must be answered before a final choice of herbicides, carrier, and application method is made.

1. Is the herbicide registered for your proposed use? If it isn’t, you cannot use it.

2. Where is your project in relation to other landowners? And, to avoid “fouling your own nest,” where is your project in relation to sensitive areas on your own land? Space or distance from a sensitive area doesn’t give you license to contaminate, but in case of an accident, it does give you a greater margin for error.

3. What is your neighbor growing? If he is growing potatoes and you are going to apply Picloram, you will need to apply it with extreme care. If he is grazing turkeys or raising mink, you will probably have no trouble with a choice of herbicide, but unless you have a silent helicopter, you still have a problem—public opinion. If your neighbor is a public water supplier, you will need to use extra care to avoid accidents and possible contamination.

4. What degree of brush control do you want? Will you accept nothing less than a complete “kill” of all species? Or will a “top-kill” suffice. A complete kill of all species generally suggests heavy per-acre application of herbicides or mixtures of herbicides which are (or may be) more likely detrimental to forms of life. The more uncommon herbicides are also usually more expensive. As a rule, aim for the desired degree of control.
with the lowest per-acre application of the least toxic chemical available. Don’t trap yourself with the philosophy that “if a little is good, a lot must be better.”

5. When is your neighbor’s crop the most sensitive? Occasionally, there is an opportunity to delay or advance your project to avoid a crop’s most sensitive periods.

6. What carrier and thickening agents are compatible with the herbicide? And are the thickening agents compatible with the carriers? The field of surfactants and particulating agents is ever changing, and the addition of these agents is not always as predictable as you might be led to believe. Minute chemicals in the herbicide or carriers can cause the additives’ effect to range from nothing to a product resembling concrete.

The use of various combinations of herbicide and thickener quite often necessitates different application equipment. The modifications of existing equipment or the adaptation of new equipment to existing spray systems or helicopters is not always practical or possible. Before specifying a particular additive, talk to someone who has used it.

Answering these six questions will provide you a basis for choosing a herbicide that provides adequate brush control with minimum environmental impact.

The operation of large-scale aerial herbicide projects without detailed planning is fraught with opportunities for “goofs” or slip-ups that create much of the public opposition to aerial spraying. What are some of the “slips” that disturb people?

1. Spraying a known or suspected heavy-use big-game area. This is almost guaranteed to disturb “sportsmen.” In consideration of all uses, however, we certainly cannot spray indiscriminately in areas that are known to be used for big-game nurseries — especially since many of our dormant or foliar applications are during the normal period for big-game calving. It is very important that we identify calving areas prior to starting a spray project, and determine if the area is, in fact, being used. If it is, we must defer spraying until a different period.

2. Flying across private individuals’ land or, worse, directly over their homes, regardless of whether we are flying herbicides or ferrying empty ships. A large number of the individuals who live in the forest environment live there because they wish to avoid contact with other people and the noisy, fast-paced life associated with the reciprocating engine. Many of them also are extremely suspect of pesticides, and to fly across their lands with the noisy helicopter is literally “waving a red flag” in their faces.

At the present time, we have identified the sensitive land areas on our National Forest spray projects and arrange our flights so they do not pass over these areas. This point must be emphasized continually with
helicopter pilots. We have always had excellent cooperation from them, but it is very easy, in the rush of a project, for a pilot to forget this point.

3. Another item that upsets the forest-using public is for them to drive through an area that is being sprayed and to have their cars sprayed. This has occasionally happened. It hasn’t happened for a long time, however, because pilots are beginning to be much more aware of the controversial nature of spraying, and we have taken steps to prevent all traffic from passing through an area while spraying is in progress.

4. A housekeeping item that upsets people is to see the stains of herbicide spill along a road that is used as a heliport. In filling a helicopter it is common to have spills, possibly the size of a cup, occur. This is a small quantity, but it does create a large stain in a dusty road. Cleanliness of the tank truck is important. A dirty tank truck driving by a home, reeking of herbicide, and leaving a trail of deep stains on the road, is certain to arouse anger. This may seem a small point, but good housekeeping is also a small thing that we can accomplish very easily.

In areas of mixed land ownerships, cattle, either in trespass or under permit are often found in areas to be sprayed. If the cattle are in trespass, a first impulse is to spray them. However, we want to be good neighbors to everyone and having the livestock moved is easily done. To avoid spraying livestock which are legally on an area, a review of leases and permits needs to be made prior to contracting a spray project.

5. One of the prime factors that determine the success of a spray project (I am referring particularly to public land ownerships) is the awareness of the local people, and of people away from the local area who are concerned with the management of forest lands, of what we are doing, why we are doing it, and what our results have been in the past.

No spray program on public land can continue without public agreement on the need for the program. Obtaining this agreement is difficult, since the news media very often depict pesticide programs only in a negative sense.

Acceptance of herbicide programs by local residents can be difficult to achieve, but through personal explanation, visits to area before and after, and if necessary, explanation by experts in the field, most agreements can usually be reached.

The Siuslaw National Forest has, for a number of years, followed a practice of visiting every resident of land adjacent to, or within the same small drainages as a spray area. The Siuslaw’s program to make the public aware of what they are doing is larger than this one point, but I believe it is the key element in public acceptance of a continuing herbicide program.

A term which usually isn’t thought of as part of a herbicide project, but which plays an important role, is margin-of-error, or what I call
“insurance.” Just as in our private lives we require insurance, our herbicide programs also require it.

Private insurance costs money and so does our insurance. Detailed plans are our insurance, and they are expensive.

Water monitoring, or the testing of water samples taken from streams in sprayed areas, is a practice which I consider insurance, and it is also expensive. Water monitoring will not decontaminate a stream, but it will reveal if a particular practice is resulting in stream contamination. This practice can be corrected which will make future projects free of contamination.

Following a herbicide project you will occasionally be accused of contaminating a watershed to an extent to cause fish, wildlife or livestock mortality. Unfortunately, in cases such as this, you are usually judged guilty until proven innocent and the burden of proof placed on you. Without water sampling, convincing people of your innocence may be difficult.

My last insurance item is personnel. Without adequate numbers of people, an aerial spray project that meets the goals of controlling brush without adverse environmental impact is impossible. Too many people are also a hazard, but a sufficient number must be available to observe and double check every facet of a project.

We have all heard of cases where an area not scheduled to be sprayed has been sprayed. This could be very embarrassing if the area sprayed belonged to another ownership or contaminated a sensitive use. Helicopter pilots generally do an excellent job of locating spray areas, but the only positive way to know you have the correct area is to have a ground observer present in each spray area to direct the pilot. This observer also provides insurance in monitoring wind direction and speed, which is essential if drift is to be avoided.

Operational considerations in brush control projects are many and varied. Most are simple and can be handled by the check list, adequate numbers of trained people, attention to detail, and lots of pre-project planning.

In summary, before starting a project, anticipate by asking

1. What degree of control do you want?
2. Where is your project in relation to sensitive areas?
3. When is your project to be conducted?
4. Plan and anticipate to reduce the odds of an unexpected “happening.”
5. Prepare detailed plans and have sufficient numbers of well trained people to carry them out.
6. Conduct program in a manner to allow greatest margin of error.

The simplicity of these items often results in their omission, which is an easy way to find out how complex a herbicide project can become.
SECTION II

CHEMISTRY AND BIOCHEMISTRY OF PESTICIDES

Chairman: Virgil Freed
I. Introduction

Some of the basics of organic chemistry can be of considerable help in understanding the behavior of pesticides. Many pest control specialists have not had any organic chemistry, or studied it 20 years ago and are stopped cold by a chemical name or structure. This chemical classification system can act as an open dictionary. It is not necessary to know all 200,000 words in Webster's dictionary to use the dictionary to define a word. In the same way, it is not necessary to know all the chemical structures, but it is important to recognize them. The names and structures of these materials will take on some meaning that can be related to their behavior in the environment, increasing our ability to use these materials safely in forest pest control practices.

Even in consumer products a great many chemical names are used – F-310, hexachlorophene, MFP, Persperex, to name a few. The advantages of F-310 are highly touted, yet probably both the advertiser and the consumer have little idea of what F-310 is or what it's supposed to do. They may have an idea that F-310 is supposed to reduce that black cloud of auto exhaust smoke. But what is it? Why and how does it work? Does it really do any good? When a consumer hears these names, he does not receive an image in terms of physical, chemical or biological properties.

It may not be too important to the consumer to know exactly what Persperex is or what it does, but it is important that the practitioner of pest control understands the properties of the chemicals with which he works. The chemical name itself – 2,4,5-T, Dicofhol, MFP, or F-310 – is just a shell or concept. To use this word to describe a chemical without simultaneously invoking in the mind an image of the chemical structure, properties, and behavior is to use an empty shell of words – like an apple pie without any apples in it.

It is really quite simple to unravel chemical names, provided one starts at the end of the word instead of the beginning. There are distinct relationships among pesticides that are easily observed when they are all placed together on one page. There are many books and compilations
listing all the pesticides in alphabetical order. This makes it easy to look up names, but it doesn't show how one pesticide has evolved from another closely related compound.

Any classification system only proves to be useful in that it groups elements of like character together. A system of classification can be based on anything, for instance color, if color is important to use. However, a very rigorous adherence to a particular method often produces anomalous bedmates — things grouped together that do not seem to belong. This system is kept deliberately flexible. Although it is called a chemical classification, the fundamental classification will not be chemical but functional. This is done in order to prevent the grouping of such compounds as methyl bromide along with DDT under the term “halogenated hydrocarbon.” Although they are both halogenated hydrocarbons, they are not grouped together because they act quite differently, are used for different purposes, and behave quite differently in the environment. Some names in this system are a little different than what are used in other chemical classifications. For instance, in the insecticide grouping, the term “polycyclic” is used instead of the term “cyclodiene,” which allows the grouping of compounds like lindane along with those like chlordane.

II. Structural Representation in Organic Chemistry

One is often faced with a confusing array of names that are hard to pronounce and seem to have little meaning, therefore a review of chemical nomenclature and structure may be useful before we get into pesticide chemistry. Typically symbols are used rather than names. Five different symbols for the element carbon can be used and are shown in Figure 1.

Figure 1. Representation of Carbon in Organic Compounds

A. carbon

\[ \text{or} \]

B. \( \cdot \)

\[ \text{D.} \quad \cdot \quad \cdot \]

\[ \text{or} \]

C. \( \cdot \)

\[ \text{E.} \quad \]

\[ \text{or} \]
Each provides a little different information about the element. The first way is the word "carbon." The letter "C" is another representation. It is common practice to use the first letter or pair of letters in the name of an element (P for phosphorus, K for potassium from the German "Kalium") as the symbol for the element. This is a convenient way of symbolizing, but it doesn't provide much information. The symbol (-C-) provides the additional information that four things attach to a carbon. The lines represent the number of electrons that are available for bonding, although electrons do not always represent the exact number of bonds possible.

The fifth symbol (IE) is a three-dimensional representation of the way in which the bonds must fit. According to stereo chemistry, the substituents that attach to these electrons have to be in a certain relationship with each other which cannot be violated except through force, and even then not very much. This limits the groups that can be next to each other, and sometimes limits the orientation of a group on one carbon in relation to a group on another carbon atom, causing isomeriza-
tion. Thus, structures that look alike may in fact be quite different compounds depending on how the carbon bonds are fixed. Whether a bond is pointing up or down sometimes makes the difference between two compounds, as in the cases of dieldrin and endrin.

If four hydrogens are put on each of the four bonds of carbon, the result is CH₄ or methane (2A1). Methane refers to the satisfied compound and is found in nature as part of natural gas. With one hydrogen removed, the methane becomes a methyl group, which can attach to another molecule. The noun "methane" becomes the adjective "methyl" or "methanyl." In the name of any chemical compound, the term "methyl" refers to that portion of a molecule which is derived from methane.

Four methyl groups strung together form butane, which can also be written in several different ways (Figure 2A-2). Since the complete way to write it (2A-2a) is time-consuming, there are several shorthand ways to write it, such as the line or "stick" figures. With a hydrogen left off, butane becomes a "butyl" group (2A-2b). In the stick figure, there is a carbon atom at each "bend" and at the "ends" of the stick, i.e. either a CH₂ or a CH₃ group. The stick structure by itself doesn't identify these carbon atoms, but this is a convention that is commonly used. Rearranging the atoms, a structure (2A-2c) with the same number of carbons but representing a slightly different compound can be formed. This one is a geometric isomer rather than a stereo isomer. There are a lot of these isomers in insecticides, drugs, and other chemicals. The stick structure (2A-2c) represents the isobutyl radical.

Hexane (in Figure 2B) has six carbons in a chain instead of the four
A. STRAIGHT-LINE OR ALKYL CARBON COMPOUNDS

1. 
   a. noun; represents satisfied compound 
   \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \quad \text{C} \quad \text{H} \\
   \text{H} \\
   \end{array}
   \]
   \( \text{CH}_4 \quad \text{or} \quad \text{Methane} \)
   
   b. adjective; can attach to another molecule 
   \( \text{CH}_3 \quad \text{or} \quad \text{methanyl or methyl} \)

2. 
   a. noun represents satisfied compound 
   \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \quad \text{H} \quad \text{H} \\
   \text{H} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \\
   \text{H} \\
   \end{array}
   \]
   \( \text{butane} \)
   
   b. adjective; can attach to another molecule 
   \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \quad \text{or} \quad \text{butyl} \)
   
   c. adjective; with atoms rearranged 
   \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \quad \text{or} \quad \text{isobutyl} \)

B. RING CARBON COMPOUNDS

1. 
   \[
   \begin{array}{c}
   \text{H} \\
   \text{C} \\
   \text{HCH} \\
   \text{HCH} \\
   \text{HCH} \\
   \text{HCH} \\
   \text{C} \\
   \text{H} \\
   \end{array}
   \]
   \( \text{cyclohexane or} \ \text{C}_6\text{H}_{12} \)

2. ring 

3. carbon atom flip down 

4. carbon atoms flip up
that butane has. If the last carbon is joined to the first one, they form a ring or circle and the compound is called “cyclo hexane.” The term “cyclo” means a ring or circle. There are three or four different ways of writing this compound. Writing it out with all the hydrogens (2B-1) is long and difficult. The stick structure (2B-2), with each bend representing a \( \text{CH}_2 \), is usually used, which is convenient but doesn’t provide a pictorial representation of the three-dimensional structure. The chair form (2B-3) and the boat form (2B-4) can be used to show whether the pair of carbon atoms flip up or down. A slight energy difference exists between these two forms, and there is an equilibrium between the two forms that has some importance in some structures.

In addition to bonding to hydrogen and other groups, carbon can bond to itself forming a double bond (2C). Three double bonds in alternate positions in the cyclo hexane ring make a resonant structure. The bonds can be in one position or the other, and they resonate or achieve an equilibrium between these positions, forming the familiar benzene compounds. To avoid the argument among chemists as to whether benzene has double bonds or not, it is often drawn with a circle in the middle (2C-3). I prefer to write it with a double bond (2C-2) because it reacts as if they were clearly double bonds. When benzene is bonded to something else it is called a “phenyl” group, not to be confused with phenol, which is completely different. The Greek letter “\( \phi \)” that stands for “P,” the first letter in phenyl, is sometimes used to abbreviate the structure in the same way that “me” is used for methyl.

These structures can be put together in several ways. If the carboxylic group (2D-1b) is put on the benzene ring (2D-1a) it becomes benzoic acid (2D-1c), which is sometimes drawn (2D-1d) with a dash going through the middle, meaning substituents can be put on any place, as long as they are bonded directly to one of the carbons. Substitution refers to taking off one hydrogen and putting on another kind of group. The \( -\text{OH} \) group is called the hydroxyl group in aliphatic chemistry. Benzene and related rings are termed aromatic, because the first such compounds discovered were all sweet smelling and odiferous. The hydroxyl benzene is called phenol (2D-2a). Substituting the nitro group makes nitro benzene (2D-2b); substituting the chloro group makes chloro benzene (2D-2c). Oxygen in front of the methyl group, called the methoxy group, shortened from “methyl-oxy”, is another of the many substitutions possible (2D-2d).

Other elements can be brought into these rings to form the hetero aromatics (2E). Hetero means “unlike,” thus in the hetero aromatics all the members of the ring are not carbons. Some may be nitrogen, oxygen or sulfur. When these are substituted for carbon in the ring, however, it is
C. AROMATIC OR ARYL COMPOUNDS

noun
1. benzene or $C_6H$

adjective
$\phi$ or phenyl

2. Phenols
   a. $-OH = \text{phenol or hydroxyl}$
   b. $-NO_2 = \text{nitro}$
   c. $-Cl = \text{chloro}$
   d. $-OCH_3 = \text{methoxy}$
   e. $-C-OH = \text{carboxyl}$

D. SUBSTITUTION

1. Aromatics
   a. $\text{Benzene} + \text{carboxylic acid} = \text{benzoic acid}$
   b. $(\text{phenyl})$ group

2. Phenols
E. *NON CARBON (HETERO AROMATIC) RINGS*

1. \[
\begin{array}{c}
\text{noun} \\
\text{benzene}
\end{array}
\quad \begin{array}{c}
\text{adjective} \\
\text{phenyl}
\end{array}
\]

2. \[
\begin{array}{c}
\text{noun} \\
\text{pyridine}
\end{array}
\quad \begin{array}{c}
\text{adjective} \\
\text{pyridyl}
\end{array}
\]

3. \[
\begin{array}{c}
\text{noun} \\
\text{triazene}
\end{array}
\quad \begin{array}{c}
\text{adjective} \\
\text{triazy1}
\end{array}
\]
not a matter of just running a reaction, breaking open the ring, substituting, and closing it again. The ring must be rebuilt almost from scratch. When nitrogen is inserted into the benzene or phenyl ring (2E-1), it becomes pyridine (2E-2). The noun refers to the compound; pyridyl, the adjective, is used when pyridine is tacked onto another group. Three nitrogens can be inserted in a number of arrangements, forming the compound triazine (2E-3).

A pesticide structure (3A) may or may not have recognizable meaning. A long chemical name, such as “p,p'-dichlorodiphenyltrichloroethane” is difficult to pronounce and read. The grammar of chemical names is a lot like German, probably because the best of the early organic chemists were all German. The simple way of reading a name is to start at the back of the word and work backwards to find a familiar name. This will be the noun and everything else will be adjectives.

In the case of DDT, the noun is ethane (3B). The structure for ethane, two carbon atoms and all the hydrogens (3B) may help untangle the name. Going back a little farther, “chloro” indicates there are some chlorines, and “tri” indicates how many chlorines – “tri-chloro-ethane” means three chlorine atoms. (A chemist doesn’t usually use hyphens all the way through a name because hyphens have certain specific meanings in the nomenclature. They are used here because they make it easier to read and pronounce the syllables.) Three chlorines can be added to the ethane, without showing the hydrogens, to form trichloroethane (3C). The term “di-phenyl-” indicates that two phenyl groups are added to the structure (3D). The “p.p” indicates that chlorines belong in the para position (3E). Thus it is now possible to pronounce the long name for DDT as “p,p'-dichloro-di-phenyl-tri chloro-ethane,” understand the compound and draw the structure.

Although it is not used in the forest anymore, DDT is a familiar chemical and makes a good example. There are several isomers of DDT (Figure 4) such as p,p'-DDT and o.p'-DDT. The three positions “o,” “m,” “p” are from the Greek – “ortho” means near, “meta” means middle, and “para” means far. The first use of “o,” “m,” or “p” refers to the first ring, and “o’,” “m’,” or “p’” refers to the second ring. These isomers of DDT simply have their chlorines in a couple of different places but they have quite different properties. The p,p'-DDT is acutely toxic while the others are not; but some such as o,p'-DDT have interesting pharmacological properties. Since “ortho,” “meta” and “para” refer to more than one position depending upon the direction taken around the ring, they can be confusing when there are many substituents on the ring. Another way to designate ring position is to number the positions. The point of principal
Figure 3. Derivation of the Chemical Name for DDT

A. \[
\begin{array}{c}
\text{Cl} \\
\text{H} \\
\text{C} \\
\text{C-Cl}_3
\end{array}
\quad p,p'-\text{dichlorodiphenyltrichloroethane}
\]

B. \[
\begin{array}{c}
\text{H} \\
\text{H-C-H} \\
\text{H-C-H} \\
\text{H}
\end{array}
\quad \text{ethane}
\]

C. \[
\begin{array}{c}
\text{C} \\
\text{C-Cl} \\
\text{Cl} \\
\text{Cl}
\end{array}
\quad \text{tri-chloro-ethane}
\]

D. \[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{C-Cl}_3
\end{array}
\quad \text{diphenyl-tri-chloro-ethane}
\]

E. \[
\begin{array}{c}
\text{Cl} \\
\text{H} \\
\text{C} \\
\text{C-Cl}_3
\end{array}
\quad p,p'-\text{di-chlorodi-phenyl-tri-chloro-ethane}
\]
Figure 4. Representation of Isomers of DDT

A.

B.

C.

\[ \text{p,p}' \quad \text{DDT} \\
\text{para, para}' \quad \text{DDT} \]

\[ \text{o,p}' \quad \text{DDT} \\
\text{ortho, para}' \quad \text{DDT} \]

\[ \text{o,m}' \quad \text{DDT} \\
\text{ortho, meta}' \quad \text{DDT} \]
attachment is number 1 and from there on the positions are numbered 2, 3, 4, 5, and 6. This less confusing method is most frequently used. Although direction around the ring doesn’t matter, the convention is to designate the most important substituent with the smallest number.

The numbering system will help unravel 2,4-D (Figure 5), a chemical that is often used in the forest. The noun at the end of the name, “2,4-dichlorophenoxyacetic acid” (5A), is “acetic acid” (5B). The next part of the name is “phenoxy,” shortened from phenol oxygen, which means there is an oxygen between acetic acid and the next part, so it is phenoxyacetic acid (5C). The term “dichloro” indicates that there are two chlorines on the phenoxy group, and the numbers 2,4 give their location (5C-2). Again the name can be understood by working backwards. Sometimes 2,4-D is written out with the chlorines in a different position (5D-2). This bond is freely rotating and the chlorines are apparently moved from the 2,4- to the 4,6- positions, but the molecule can be moved over and around in the imagination to come up with the same compound. Although there is a conventional way of writing it, differences do occur. Confusion over a structure is often the result of a bond rotation.

A series of analogues have a family relationship to one another. They are not isomers, but different compounds. The series of analogues, 2,4-D, 2,4,5-T and 2,4,5-TP, are all closely related with just one atom different in each case (Figure 6). Everything about 2,4,5-T or 2,4,5-trichlorophenoxy-acetic acid, is the same as the 2,4-dichloro compound except for the first part, 2,4-di and 2,4,5-tri. Obviously if the chlorines go on the 2,4,5 positions, there are three chlorine atoms and the name must change from di to tri; thus, 2,4 becomes 2,4,5. 2,4,5-T is an analogue of 2,4-D but with one more chlorine. All the rest of the properties and differences between 2,4,5-T and 2,4-D are reflections of that one additional chlorine. 2,4,5-T is a little less volatile and less readily metabolized, thus it kills brush a little better because it stays long enough to kill the hardy brush. 2,4,5-TP or Silvex (6C) is another analogue. The chemical name is 2,4,5-tri-chlorophenoxy-proprionic acid. The “P,” of “TP,” in this case refers to propionic acid. To be perfectly analogous, 2,4,5-T should have been called 2,4,5-TA, the “A” referring to the acetic acid. The one additional carbon in the acid gives Silvex a few more residual properties and a slightly different herbicidal activity.

Some compounds, particularly in the groups of acids, are referred to as derivatives (Figure 7). In a derivative, a bond has been broken and reformed easily, usually in the formulation process, making either an ester or a salt out of that acid group. Starting with the carboxylic acid group, it can be seen that an alcohol can be bonded in place of the hydrogen to
Figure 5. Development of the Chemical Name For 2,4-D

A. Cl
   O-CH₂-C-OH
   Cl
   2,4-dichlorophenoxyacetic acid

B. H-CH₂-C-OH
   acetic acid

C. 1) O-CH₂-C-OH
   phenoxy-acetic acid

   2) O-CH₂-C-OH
   phenoxy-acetic acid
   (with positions numbered)

D. 1) Cl
   O-CH₂-C-OH
   Cl
   2,4-dichlorophenoxy-acetic acid

   2) O-CH₂-C-OH
   2,4-dichlorophenoxyacetic acid
   (with phenyl group rotated,
   either presentation is correct)
Figure 6. Analogues of 2,4-D

A.  
\[
\begin{align*}
\text{Cl} & \quad \text{Cl} \\
\text{Cl} & \quad \text{Cl} \\
\text{Cl} & \quad \text{Cl} \\
\text{O-CH}_2\text{C-OH} & \quad \text{O} \\
2,4\text{-D or} & \quad 2,4\text{-di-chloro-phenoxy-acetic-acid}
\end{align*}
\]

B.  
\[
\begin{align*}
\text{Cl} & \quad \text{Cl} \\
\text{Cl} & \quad \text{Cl} \\
\text{Cl} & \quad \text{Cl} \\
\text{O-CH}_2\text{C-OH} & \quad \text{O} \\
2,4,5\text{-T or} & \quad 2,4,5\text{-tri-chloro-phenoxy-acetic-acid}
\end{align*}
\]

C.  
\[
\begin{align*}
\text{Cl} & \quad \text{Cl} \\
\text{Cl} & \quad \text{Cl} \\
\text{Cl} & \quad \text{Cl} \\
\text{O-CH}_2\text{CH}_2\text{-C-OH} & \quad \text{O} \\
2,4,5\text{-TP (Silvex) or} & \quad 2,4,5\text{-tri-chloro-phenoxy-proprionic-acid}
\end{align*}
\]
Figure 7. Derivatives of 2,4-D

A. 

\[
\begin{array}{c}
\text{Cl} \\
\text{O-CH₂-C-OH} \\
\text{Cl} \\
\text{Cl}
\end{array}
\]

2,4-D acid

B. 

\[
\begin{array}{c}
\text{Cl} \\
\text{O-CH₂-C-O-CH₂-CH₂-CH₂-CH₃} \\
\text{Cl} \\
\text{Cl}
\end{array}
\]

2,4-D ester

butyl ester of 2,4-D

C. 

\[
\begin{array}{c}
\text{Cl} \\
\text{O-CH₂-C-OHN(CH₂-CH₂OH)₃} \\
\text{Cl} \\
\text{Cl}
\end{array}
\]

2,4-D salt

tri-ethanol-amine salt
form an ester. An OH group can react fairly rapidly with an acid and be split off fairly readily, while still remaining 2,4-D acid. It is possible to add different lengths of esters, a short 3 or 4 carbon ester, or a long 8 carbon ester. An ester is a pretty volatile compound. A volatile derivative of 2,4-D (3 or 4 carbon ester) will vaporize and be carried around in the air and can cause plant damage just by vaporization without any drift of the spray. A compound with 8, 10 or 12 carbons on the ester doesn’t volatilize so readily, because the molecular weight is high.

A salt is another type of derivative. The salts are very loosely bonded, compared to esters. Tri-ethanol-amine, one of the common bases formulated as a salt with the 2,4-D acid (Figure 7C), has an electron surplus around the nitrogen and can accept the hydrogen ion of the 2,4-D acid and thus provide the + and - attraction, or electrostatic bond of a salt.

Quite frequently in a series of compounds used as insecticides or herbicides, the members of the series will show a very slight change in the basic structure. Although it is confusing to see them en masse, a knowledge of their structural evolution will make them easier to remember. One such series is shown in Figure 8, and on this basis, insecticides, herbicides and fungicides can be classified into a chemical order. Starting with the familiar aliphatic acid or carboxylic acid (8A-1), the methyl carbon group can be removed from acetic acid and nitrogen inserted. Carbamic acid (8A-2), which has many new properties but is still very close to acetic or carboxylic acid is formed. The hydroxyl group is removed and another nitrogen added; urea (8A-3) is the result. With three nitrogens substituted, a guanidine (8A-4) is formed. Going back to carbamic acid, a sulfur can be substituted for one of the oxygens. Sulfur and oxygen are very much alike; they often enter the same reaction, and sulfur can be substituted for oxygen in just about any chemical structure. Substituting one sulfur gives a thio-carbamate (8B-2). Substituting two gives a di-thio-carbamate (8B-3). The nomenclature is not mysterious. “Thio” is the Greek chemical word for sulfur, so “di-thio-carbamate” means two sulfur-carbamate. Di-thio-carbamates are familiar as herbicides and fungicides. Another aliphatic hetero compound is di-alkyl-di-thio-carbamate (8B-4). “Alkyl” simply refers to two sets of carbon groups stuck onto a sulfur. This is only a series of related compounds, not analogues, yet one evolves into the other. Try to keep these patterns in mind and look for relationships in a series of compounds. Look at the structure of an unfamiliar herbicide and see if it fits into a familiar pattern. This can provide information about its behavior and effectiveness.
Figure 8. Aliphatic Hetero Compounds

A. \( \text{CH}_3\cdot\text{C}-\text{OH} \)

1) \( \text{aliphatic acid} \)
   \( \text{carboxylic acid} \)

2) \( >\text{N-C-OH} \)
   \( \text{carbamic acid} \)
   \( \text{carbamate} \)

3) \( >\text{N-C-N} \)
   \( \text{urea} \)

4) \( >\text{N-C-N} \)
   \( \text{guanidine} \)

B. \( >\text{N-C-OH} \)

1) \( \text{carbamic acid} \)

2) \( >\text{N-C-O}^- \)
   \( \text{thio-carbamate} \)

3) \( >\text{N-C-S}^- \)
   \( \text{di-thio-carbamate} \)

4) \( \text{CH}_3 \cdot \text{C-S}^- \)
   \( \text{di-alkyl-di-thio-carbamate} \)
III. Classification of Pesticides

This is not a complete classification system of all the herbicides, insecticides, and fungicides, but only attempts to show the more important groups in some of the subdivisions within the major structural groupings. A complete listing of the structure, chemical names, and properties of nearly all pesticides is available in the publication entitled: Guide to the Chemicals Used in Crop Protection, edited by E.Y. Spencer and available from the Canadian Department of Agriculture.

The unique feature of our classification of pesticides is that they are grouped together within the functional categories, herbicide, fungicide or insecticide, according to structural similarities. This arrangement by structure rather than the usual method of alphabetical grouping, enables the reader to see at a glance the similarities and differences between the various pesticides. In many cases it can quickly be seen that pesticides of quite different names are actually quite closely related. There is an evolution from one pesticide to another by the addition of an increasing number of carbon, chlorine, or nitrogen atoms in a logical and steady progression. It is not important that the user of pesticides know all the structures and all the physical and biological properties of every pesticide he attempts to use, but he should demonstrate some degree of appreciation of the nature of these structures and their general properties. This classification system will enable the user who has familiarity with a few pesticides to see that these have a close structural relationship to other pesticides. To some degree, he can transfer the properties of the familiar pesticide to those with which he is not familiar, provided that the structural similarity is fairly close. He may remember the general principle that as the molecular weight increases, that is, a few more carbon atoms or chlorine atoms are tacked on to a molecule to constitute a new pesticide compound, the new compound will generally be less volatile, will be metabolized slower by living organisms, will be less soluble in water, and will persist longer in the environment. With the insertion of oxygen atoms into a structural type which did not contain oxygen atoms the water solubility will be slightly increased as will be the rate of breakdown by living organisms. Compounds with similar structures will generally have similar acute toxicities; however, it is not possible to make general statements covering acute toxicities across an entire group of pesticides with simplicity. Chronic toxicity of the pesticides may be quite different for pesticides of extremely similar structures.

Knowledge of these factors enables the user to be more critical in his pesticide applications and to make situation-by-situation judgments which
will allow him to avoid problems. For instance, if he is dealing with highly toxic compounds, the person applying the material must have both adequate warning and adequate protective devices, and should not use them where bystanders are present. Highly volatile compounds, particularly the herbicides, should not be used adjacent to crops or other vegetation that must be protected from damage. Water soluble compounds should not be used in situations where water runoff may carry them into streams. Even water insoluble compounds should not be used where there is a chance of erosion of soil or plant material into the waterway. These are only general statements concerning the properties of pesticides. Detailed properties of some of the herbicides and insecticides are presented in other portions of these proceedings.

This classification system should enable the reader to transfer information which is available about a single pesticide to the behavior of other pesticides which are similar in structure. The principle types of structures of herbicides, insecticides, and fungicides are shown in Figure 9. The herbicides (9A) are divided into three major categories; 1) the oxygen aliphatic and aromatic compounds, 2) the nitrogen aliphatic compounds and 3) the nitrogen hetero cyclic compounds. The category of “oxygen aliphatic and aromatics” (9A-1) refers first to the fact that oxygen is an important part of the functional part of the molecule. This is principally noted through the presence of the carboxylic acid or the phenolic groups. The term “aliphatic” refers to straight-chain carbon compounds, and the term “aromatic” refers to ring compounds containing a series of double bonds. In this case it refers specifically to the benzene ring, or as it is sometimes called, the phenyl group. It can quickly be seen from 9A that there is a progressive evolution from the aliphatic carboxylic acids, simple compounds somewhat related to vinegar which have evolved into herbicides by the addition of chlorine atoms, into the phenolic compounds and then into compounds which combine the phenols and the aliphatic carboxylic acids, the phenoxy acids. The organic acid group, or carboxylic acid, can be attached directly to the ringed compound (9A-1d), forming the benzoic acids. Thus a simple chloroaliphatic acid has evolved into a benzoic or aromatic acid. The inclusion of the toluidines (9A-1e) in this group of oxygen compounds is a structural anomaly; that is, they do not chemically belong with this group, but since they have the same type of action and effectiveness as the preceding compounds and there is no large group in which they can be included, for convenience and clarity we have violated some of the strict rules of chemical classification and included them with this group.

The second group of herbicides (9A-2) is part of the large group of
Figure 9. Major Groupings in the Chemical Classification of Pesticides

A. HERBICIDES
1. Oxygen Aliphatics and Aromatics
   a. chloro-aliphatic acids
   ![Chemical Structure]
   b. phenols
   ![Chemical Structure]
   c. phenoxy acids
   ![Chemical Structure]
   d. benzoic acids
   ![Chemical Structure]
   e. toluidines

2. Nitrogen Aliphatics
   a. amides
   ![Chemical Structure]
   b. carbamates
   ![Chemical Structure]
   c. thiocarbamates
   ![Chemical Structure]
   d. di-thio-carbamates
   ![Chemical Structure]
   e. ureas

3. Nitrogen Hetero Cyclics
   a. mono-N pyridine
   ![Chemical Structure]
   b. di-N (1) pyradazyl
   ![Chemical Structure]
   (2) uracil
   ![Chemical Structure]
   c. tri-N (1) triazol
   ![Chemical Structure]
   (2) triazine
   ![Chemical Structure]
nitrogen-containing herbicides. The second group is limited to the nitrogen aliphatic compounds, those that are built along a straight chain. The structures shown in this section all contain some open bonds, that is, bonds from the nitrogen, carbon, oxygen or sulfur atoms which do not have their substituent groups attached. This is because a variety of types of groups may attach to all of these open bonds. Details of such compounds are shown in Figure 10.

A rather neat sequence of change from structure to structure exists within these nitrogen aliphatic compounds. The first member is a simple amide, a carbon with one oxygen and one nitrogen attached (9A-2a). When this is surrounded on both sides by other carbon atoms it is called a ketone. When two oxygen atoms and a nitrogen atom are attached to the same carbon the familiar organic acid or carboxylic acid is formed. In this case, it is different from the organic acids previously considered, in that a nitrogen atom is attached, thus it becomes a carbamic acid or a carbamate (9A-2b). If sulfur atoms are substituted for the oxygen atom in this carbamic acid, an important series of herbicides are produced; the thiocarbamates (9A-2c) when one sulfur atom is substituted, and di-thio-carbamates (9A-2d) when two sulfur atoms are substituted. When a nitrogen atom is added to the amide group, so that the ketone group has nitrogen atoms attached to both sides, another important class of herbicide compounds, the ureas, are produced (9A-2e). If the empty bonds in this structure are filled with hydrogen, the compound urea, a fertilizer, is formed. However, when various organic carbon groups are attached to the empty bond spaces, a series of herbicidal compounds is formed.

The third and last major grouping of herbicides included in Figure 9 are the nitrogen heterocyclic compounds (9A-3). These are organic or carbon compounds which also contain nitrogen. The term "heterocyclic" refers to the fact that the compounds are all based around a ring structure. Unlike benzene in which the ring consists entirely of carbon atoms, these rings include both carbon and nitrogen atoms. Nitrogen atoms are a part of the ring, they are not just attached to it in a side chain. Within this class the ring compounds are conveniently grouped according to the number of nitrogen atoms in the ring. Those with one nitrogen are called mono-nitrogen rings, those with two nitrogen atoms incorporated in the ring are called di-nitrogen rings, and those with three nitrogen atoms are called tri-nitrogen rings. Pyridine is the only example of a mono-nitrogen ring in the herbicidal chemical field although there are other types of mono-nitrogen rings in chemistry. Both pyradazyl and uracil are di-nitrogen ring compounds. The essential ring structure of the uracils is similar to that of pyradazyl, but differs somewhat in the spacing of the nitrogen atoms and
in the fact that ketone groups are bonded off of two of the carbon atoms in specific arrangements. Under the tri-nitrogen ring compounds, there are examples of both five-membered and six-membered rings, both of which contain three nitrogen atoms. These are known respectively as the triazol and triazene ring compounds. The uracils and triazenes probably constitute the most familiar herbicides within these groupings.

The important classes of insecticides are shown in Figure 9B. These also are divided into three major groups; 1) chlorinated hydrocarbons, 2) the organo-phosphorous-esters and 3) the carbamates.

The chlorinated hydrocarbon insecticides are the class of insecticide about which so much concern has been shown with regard to their persistence in the environment, their accumulation in a wide variety of biota, and the fact that they have produced some deleterious effects, particularly the production of thin eggshells in some species of birds. There are however, some important differences between the various classes within this group of chlorinated hydrocarbons. Perhaps this classification arrangement will illustrate these differences. The first category within the chlorinated hydrocarbon insecticides are what we have termed the di-phenyl-alkanes (9B-1a). The term “di-phenyl-alkane” refers to the fact that there are two phenyl, or benzene, groups attached to a straight-chained carbon compound. The important members of this class are DDT, TDE, and methoxychlor. Another portion of this group of di-phenyl-alkanes is illustrated in Figure 9B-1a2. Here there is a hydroxyl group attached to the central carbon atom instead of a hydrogen. Examples of members of this group are compounds like Chlorobenzilate, Acaralate, Dicofol and Dimite. The presence of the hydroxyl group makes quite a difference in how this chemical behaves. Members of this group kill mites, but do not kill insects. Whereas members of the DDT group (9B-1a) kill insects but do not kill mites. The reason for this difference in mode of action is not understood at all. The compounds with the hydroxyl group attached do not persist within living organisms or in the environment to the point that they become hazardous as do most of the first group of di-phenyl-alkanes.

The di-phenyl-thioates (9B-1b) are closely related to those di-phenyl-alkanes carrying the hydroxyl group (9B-1a2). The term “di-phenyl-thioate” means that the chemical has two phenyl groups or benzene rings as do the di-phenyl-alkanes. In this case, instead of being attached to the carbon straight-chain compound, they are attached to a sulfur compound. The term “thio” means sulfur; these compounds are called “di-phenyl-thioates.” The fact that both sulfur and oxygen are present means that they are slightly more water soluble, they are broken down more easily,
B. INSECTICIDES

1. Chlorinated Hydrocarbons
   a. di-phenyl-alkanes
      \begin{figure}[h]
      \centering
      \includegraphics[width=\textwidth]{di-phenyl-alkanes.png}
      \caption{Di-phenyl-alkanes}
      \end{figure}
   b. di-phenyl-thioates
   c. poly-chloro-alkyclics

2. Organo-Phosphorous-Esters
   a. phosphate
      \[
      \begin{array}{c}
      \text{H}\quad\text{O} \\
      \text{P}\quad\text{O}\quad\text{R}
      \end{array}
      \]
   b. thiono-phosphate
      \[
      \begin{array}{c}
      \text{S} \\
      \text{P}\quad\text{S}\quad\text{R}
      \end{array}
      \]
   c. thiol phosphate
      \[
      \begin{array}{c}
      \text{O} \\
      \text{P}\quad\text{S}\quad\text{R}
      \end{array}
      \]
   d. di thio phosphate
      \[
      \begin{array}{c}
      \text{S} \\
      \text{P}\quad\text{S}\quad\text{R}
      \end{array}
      \]

3. Carbamates
   a. SEVIN
   \[
   \begin{array}{c}
   \text{CH}_3 \\
   \text{O} \\
   \text{N}\quad\text{C}\quad\text{O}\quad\text{H}
   \end{array}
   \]
   b. IPC (herbicide)
   \[
   \begin{array}{c}
   \text{O} \\
   \text{C}\quad\text{M}
   \end{array}
   \]

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and behave quite similarly to the di-phenyl-alkanes carrying the hydroxyl group. In fact, these chemicals are all miticides. They kill mites but do not kill insects. Examples within this group are Sulfenone, Tedion, Chlorobenside, and others. The third group of chlorinated hydrocarbon insecticides (9B-1c) are called poly-chloro-alicyclics. This term simply means that there are many chlorines (poly-chloro) on a ring (cyclic) that does not have very many double bonds (alicyclic). The term “cyclodiene” is often used to describe most of the members of this group. In this classification that term is avoided because it excludes the one-, two-, and six-membered rings. The sequence of the ring structure is clearly shown in the diagrams. It proceeds from a single ring with six carbon atoms to a two-membered ring with five carbons each. (Some of the carbon atoms are common members of more than one of the rings.) Finally, the six-membered ring has both 4 and 5 atom rings. This, in fact, is a closed or box-like structure. The members of this group in the order that they appear in the ring systems are 1) Lindane, 2) Toxaphene and Strobane, 3) Chlordane and Heptachlor, 4) Aldrin and Dieldrin, and 6) Kepone and Mirex. Generally, the members of this class are fairly persistent, accumulate in wildlife, and have the potential of causing them some damage. The amount of accumulation and the propensity for causing damage may be less for Toxaphene and Chlordane. They appear to have less severe environmental impacts than do the other members of this category.

The second major group of insecticides are the organo-phosphorous-esters. This term refers to the fact that they are all some variation of phosphoric acid. The simple inorganic phosphoric acid has been illustrated in Figure 9B-2. Phosphoric acid is, of course, not an insecticide. It is illustrated in order to show the basic structure on which all the organo-phosphorous-esters are constructed. The rest of the term “organophosphorous-ester” refers to the fact that phosphoric acid, like any acid, can form an ester, that is, can combine with an alcohol. When the ester is formed with any of certain groups of organic alcohols, an insecticidal compound will result. Many of the compounds in this general category have a high acute toxicity to man and other mammals; thus special care needs to be taken in their handling. Generally they break down fairly rapidly in the environment, do not accumulate in wildlife and do not pose a great environmental hazard, although they represent a greater hazard to the users. There are some important differences within the various categories of the structures. The term “phosphate” is used for those compounds that are illustrated in Figure 9B-2a. Examples of this category are compounds like Phosdrin, Dibrom, Bidrin, DDVP. Many of these compounds are quite toxic.
Figure 9. (cont.)

C. **FUNGICIDES**

1. **Hetero-Aliphatics**
   
   a. chloro-aliphatics
   
   b. iso-thio-cyanates
   
   c. di-thio-carbamates
   
   d. nitriles

2. **Hetero-Aromatics**
   
   a. chloro-aromatics
   
   b. phenolics
   
   c. nitro-aromatics
   
   d. phthalimides
   
   e. triazines
   
   f. benzimidazoles

3. **Organo-Metallics**
   
   a. mercury compounds
   
   b. aryl-mercury compounds
   
   c. tin compounds
When sulfur is substituted for the oxygens within the esters some decrease in toxicity results, although it is not general throughout all groups. If one sulfur is substituted, it can be in either the threo or thiol position. Examples are either of the two isomers of Systox. Both of these compounds, even with the sulfur substitution are quite toxic. When both oxygens are substituted by sulfur, the compound is called a di-thio-phosphate. A somewhat higher degree of safety can be achieved within this group. Notice the symbols of a lower case “r” and an upper case “R” used in these generalized structures. This is a shorthand way of writing a series of indeterminant carbon compounds derived from the word “radical” which in chemistry refers to a carbon compound with one unsaturated bond that may be attached to some other compound. The capital “R” indicates a carbon group with a high molecular weight (six to twelve carbons) and the small “r” a low molecular weight (two or three carbons) compound. This ratio and arrangement is necessary to achieve insecticidal activity.

The third category of insecticides presented are the carbamates. It will be recalled that carbamates also are a category of herbicides. Although both the insecticide and herbicide compounds within their respective groups are carbamates, there are important differences in their structures. The insectical carbamate compounds have a large organic group attached to the oxygen or ester linkage of the carbamic acid and small organic groups attached to the nitrogen or amide portion of the carbamic acid, while the herbicides exactly reverse this arrangement of large and small groups. These are illustrated in Figure 9B-3 with the insecticide Sevin and herbicide IPC shown in proximity to make this distinction clear.

The fungicides (Figure 9C) are not so neatly arranged in series as are the herbicides and insecticides, and many of the chemical categories contain only a single compound. In general it might be said that the fungicides represent a disparate group of compounds with little in common; however, some classification is possible and some similarities can be noted. The three general groups of fungicides are 1) hetero-aliphatics, 2) the hetero-aromatics, 3) the organo-metallics. The term “hetero-aliphatic” simply means a straight chain carbon compound with some atoms other than carbon, such as nitrogen, sulfur, or chlorine, tacked on somewhere. The most simple fungicides are the chloro-aliphatics; simple straight-chained carbon compounds with some chlorines attached (9C-1a). A series with some similarity evolves between the iso-thio-cyanates and di-thio-carbamates. A close examination of the iso-thio-cyanate molecule reveals that when one sulfur is added to the carbon to which the nitrogen and sulfur atoms are already attached, it becomes a di-thio-carbamate. This is
similar to the organic acids but instead of two oxygens on a carbon atom, there are two sulfurs on a carbon atom. A group of di-thio-carbamates also exist in the herbicides but the distinction in mode of action is in the arrangement of the carbon radicals on the open bonds and the size or molecular weight of these carbon groups. A similar situation existed in the carbamate class of the insecticides. Obviously it is important that fungicides and insecticides do not have any herbicidal activity, otherwise it would not be beneficial to use them on the host plants.

The members of the fourth group within this class of hetero-aliphatics are called nitriles (9C-1d). This compound perhaps has some similarity to the iso-thio-cyanates in that a hetero atom is attached to a carbon in both cases. In this case however, a nitrogen is triply bonded to a carbon instead of a sulfur doubly bonded to a carbon. There are some similarities in mode of action between some of these compounds in that some are transformed and metabolized into common types of compounds by the plant thus enabling them to carry out their fungicidal function.

A second group of fungicides are called hetero-aromatics (9C-2). This simply means that some aromatic compounds, that is some cyclic compounds with three or more double bonds in equilibrium with each other, form an aromatic ring or nucleus to which are attached a variety of atoms other than carbon. These are generally illustrated in Figure 9C-2. It will be noted that some of the members of this class of compounds are also present in the herbicides, such as the chloro-aromatics, the phenolics, and triazines. However, as before, the distinction in the mode of action is achieved by the nature and the size of the radical groups attached to the central structures.

The third group of fungicide compounds are classified as organo-metallics. This term simply means that a metal atom such as mercury, tin, cadmium or one of the inherently toxic metal elements, is combined with some form of an organic compound. Generally the function of the various modifications in the organic portion of these metal organic compounds is to provide a compound with the appropriate physical properties for penetration and transport within the plant system in order to reach the active site in the fungus organism. Frequently some metabolic alteration takes place during the period of exposure, and often the actual toxic action is carried out by some quite different form of metal element than that in which it was supplied. The most common organo-metallic fungicides are those containing mercury and tin. The largest group of compounds are those containing mercury and have been used for seed treatment and preblossom treatment in fruit trees. There can be a considerable environmental contamination problem resulting from the use
of organo-metallic compounds. No matter what alterations the environ-
ment or the living organisms perform on these compounds the metal
element still remains intact, although the organic form may be quite
modified. Nevertheless, the metal still remains in some form and can be
transfered through the environment or picked up by wildlife at the site of
use if it is still available as an active compound. There are, however, many
ways of using these compounds that do not pose any particular
environmental problems.

IV. Herbicide Classification

Because the pesticides which are of principle importance in manage-
ment of forest systems are the herbicides rather than the insecticides or
fungicides, some greater detail has been provided concerning the types and
structures of the compounds within each of the categories of herbicides
which are shown in Figure 9A. Similar detail for the insecticides and
fungicides has been omitted because of the infrequency of their use on a
forest district basis. Figure 10 shows the oxygen aromatic herbicides, the
phenols, the phenoxy acids, and the benzoic acids. Phenol itself is shown
as an example of the basic structure, but it is not used as an herbicide. It is
too volatile and too generally toxic to perform adequately as an herbicide.
By the addition of five chlorine atoms, the molecular weight is increased
so that a residual effect can be obtained, and the compound pentachloro-
phenol or PCP is formed. Most of the other phenolic herbicides are some
variation of a nitrophenol, that is a phenol with an \( \text{NO}_2 \) or a nitro group
attached plus assorted other organic carbon sidechain substituents. Phenols
are generally toxic compounds and are used only in restricted situations.
They can cause severe problems if they enter waterways, but do not
generally cause environmental problems because they can be metabolized
fairly readily by most of the higher organisms.
The phenoxy acids combine a chlorophenol, that is, a phenol
compound with chlorine atoms attached in various configurations, to an
aliphatic acid or organic carboxylic acid. Although the phenols are capable
of forming esters with the acid, the attachment is not made in this manner,
but rather it is made from one of the terminal carbons of the acid to the
phenol group. Thus the phenolic oxygen has carbon attachments on both
of the oxygen bonds forming an ether linkage which is not so readily
hydrolized or broken as is an ester linkage. The common phenoxy acids
are 2,4-D, 2,4,5-T and Silvex. Figure 10 shows the sequence involved in
the evolution from one structure to another. Principally the changes
involve the addition of more carbon atoms in the aliphatic acid chain and
an increase in the number of chlorines on the benzene or phenol ring.
These increases in molecular weight increase the stability of the com-
Figure 10. Oxygen Aromatic Herbicides

A. PHENOLS

1. PCP

2. DNOC

3. DNBP

4. NITROFEN

B. PHENOXY ACIDS

1. 4-CPA

2. 2,4-D

3. MCPA

4. MCPB

5. 2,4,5-T

6. SILVEK
C. BENZOIC ACIDS

1. AMIBEN

2. DICAMBA

3. 2,3,6-TBA

4. TIBA

5. FENAC
Figure 11. Nitrogen Aliphatic Herbicides

A. AMIDES
1. Alkyl Amides
   a. CDAA
      \[ \text{CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-N-C-CH}_2\]
      \[ \text{CH}_2\text{-CH}_2\text{-CH}_2\text{-Cl} \]

   2. Aryl Amides
      a. PROPANIL
         \[ \text{Cl} \]
         \[ \text{CH}_3\text{-CH}_3\]
         \[ \text{CH}_3\text{-CH}_3\text{-N-C-CH}_2\text{-Cl} \]
      b. RAMROD
         \[ \text{H} \]
      c. ALACHLOR
         \[ \text{CH}_3\text{-O-CH}_2\text{-N-C-CH}_2\text{-Cl} \]
         \[ \text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_3 \]
      d. CYPROMID
         \[ \text{Cl} \]
         \[ \text{Cl} \]
pounds so that they will have longer residual properties thus remaining in
the plant for a longer period of time. They are also more effective than the
lower molecular weight compounds against the brushy or more resistant
plants. All of the compounds will be broken down fairly readily within a
short period of time, six to eight weeks, and do not pose environmental
hazards. The last group of the oxygen aromatic compounds are the
benzoic acids. At first these appear to be similar to the phenoxy acids, but
they are different in that the organic acid or carboxylic acid group is
attached directly to the ring or benzene group rather than going through a
side chain and through a phenolic or ether linkage. Amiben, Dicamba and
TIBA are the more well known herbicides in this class. The sequence of
structure in this class, principally involves changes in the substituents on
the benzene ring, the number and arrangement of chlorine or iodine
atoms.

Some of the classes of nitrogen aliphatics which were shown in Figure
9A-2 are shown in more detail in Figure 11. The groups containing the
largest number of commonly used herbicides are displayed. In these
examples the general structures that give the groups their names are shown
without the added side groups. That is, the amide group, the carbamate
group, the thiocarbamate group, and the urea group are shown as examples
and then specific herbicides containing these groups are shown. It is not
important to remember every structure of every herbicide but it is of value
to keep in mind what the basic structure looks like and to find this
structure within the groups of examples.

The third group of herbicides which are illustrated in detail are the
tri-nitrogen cyclic compounds shown in Figure 12. Examples of both the
triazols and triazines are shown.

The details of the structures are less important than an understanding
of the general class of the compound. The word “triazine” should have a
real meaning to the pesticide user and should invoke a picture of the
six-membered ring compound containing three nitrogens. The difference
between a triazine and a urea or thiocarbamate should be kept in mind
because these herbicides are frequently referred to according to this type
of class name. The user should understand which herbicides fit into which
classes and the principle that all thiocarbamates will tend to act more like
each other than like ureas, while each of the ureas will have similarities in
behavior both with regard to their activity on the plant species which he is
attempting to control and with regard to acute or environmental hazards.

V. Reading the Label

An important reason for becoming familiar with the chemical names
and understanding the chemical structures of the various pesticides is to be
B. CARBAMATES

1. IPC

2. CIPC

3. BARBAN

4. TANDEX

5. TERBUTOL
C. THIOCARBAMATES

1. EPTC

\[
\text{CH}_3\text{-CH}_2\text{-CH}_2\text{N-C-S-CH}_2\text{-CH}_3
\]

2. PEBULATE

\[
\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{O-N-C-S-CH}_2\text{-CH}_2\text{-CH}_3
\]

3. CYCLOATE

\[
\text{CH}_3\text{-CH}_2\text{N-C-S-CH}_2\text{-CH}_3
\]

4. DIALLATE

\[
\text{CH}_3\text{CH}_3\text{Cl Cl N-C-S-CH}_2\text{C=H}
\]
D. UREAS

1. FENURON

2. MONURON

3. DIURON

4. LINURON

5. NEBURON

6. CHLOROXURON
Figure 12. Tri-Nitrogen Herbicides

A. *TRIAZOL* 

\[ \begin{array}{c}
H \\
\text{N} \\
\text{N} \\
\text{N} \\
\end{array} \]

AMITROLE

\[ \begin{array}{c}
H \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{NH}_2 \\
\end{array} \]

B. *TRIAZINE*

\[ \begin{array}{c}
\text{N} \\
\text{N} \\
\text{N} \\
\end{array} \]

(1) ATRAZINE

\[ \begin{array}{c}
\text{Cl} \\
\text{CH}_3 \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{H} \\
\text{CH}_2 \\
\text{CH}_3 \\
\text{CH}_3 \\
\end{array} \]

(2) SIMAZINE

\[ \begin{array}{c}
\text{Cl} \\
\text{H} \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{H} \\
\text{CH}_2 \\
\text{CH}_2 \\
\text{CH}_3 \\
\text{CH}_3 \\
\end{array} \]
able to read the label. All labels for pesticides contain information on how they should be used properly, pests that they are effective against, rates of use, warnings on their safe use and possible hazard. The label should be read and clearly understood. All labels also contain an active ingredient statement. This is where the chemical names appear. Sometimes common or trade names such as EPTAM or Chem Hoe or DDT are used on the label. Sometimes the full chemical name is used. Often the user of pesticides will not be sufficiently familiar with the chemical name to identify the compound from the active ingredient statement. The same compound may be present under a variety of trade names. In order to fully understand which of the pesticides is being used, the user should have some ability to recognize and unravel the active ingredient statement and the long chemical names which are contained therein.

An example of a portion of the active ingredient statement from a typical label is shown in Figure 13A. The trade name is Chem Hoe 75W by PPG Industries. The term Chem Hoe, of course, does not identify the compound. The term “75W” means that it is 75 percent by weight of the active ingredient in a wettable powder. PPG stands for Pittsburg Plate Glass, the manufacturer of the compound. The active ingredient is identified as isopropyl N-phenyl carbamate. What kind of compound is isopropyl N-phenyl carbamate? Can it be identified using our classification of chemicals and an understanding of chemical nomenclature? The first step is to go to the last word in the term, “carbamate.” This is the noun, the central structure about which the rest of the chemical name is built. The carbamate structure is split out and shown in Figure 13. The next part of the word is “N-phenyl,” Notice that it is a upper-case “N,” which means that a phenyl group is tacked on to the nitrogen atom in the carbamate structure. Since it is not specified what it is that fills the other bond, it is a hydrogen atom. Still working backwards through the chemical name, the next part is “isopropyl.” This indicates that an isopropyl group is also attached, but it is not attached to the nitrogen group, otherwise it would be specified with an upper case “N.” The only other available point of attachment is on the oxygen atom of the carboxylic acid group to form an ester. The propyl group contains three carbon atoms, just a straight chained carbon compound with three carbon atoms. But which carbon atom? The use of the word “iso” in the term “isopropyl” indicates that it is one of the carbon atoms which is different from the others. Since there are only three carbon atoms, and the ones at each end are identical, the one in the middle, which is different in its bonding from the other two and therefore an iso atom, must be the point of attachment. Thus isopropyl N-phenyl carbamate is illustrated in Figure 13. In this way the kind of
Figure 13. Reading The Label

A. HERBICIDE TRADE NAME LABEL

CHEM HOE 75w  

PPG Industries

formulation:  
75% active ingredient- 
wettable powder

Active ingredient:  
isopropyl N-phenyl carbamate

Identifying the structure:

\[
\begin{align*}
\text{carbamate} & \\
N\text{-phenyl carbamate} & \\
isopropyl N\text{-phenyl carbamate}
\end{align*}
\]
B. **HERBICIDE LABEL**

**Eptam EC 6**

**formulation:** 6 lb/gal emulsifiable concentrate

**Active ingredient:** ethyl \(N,N\)-di-propyl-thiolcarbamate

**Identifying the structure:**

- **thiol-carbamate:**
  \[ \text{CH}_3\cdot\text{CH}_2\cdot\text{CH}_2 \]

- **N,N-di-propyl-thiol-carbamate**
  \[ \text{CH}_3\cdot\text{CH}_2\cdot\text{CH}_2 \]

- **ethyl \(N,N\)-di-propyl-thiol-carbamate**
  \[ \text{CH}_3\cdot\text{CH}_2\cdot\text{CH}_3 \]
compound in that bag called Chem Hoe can be identified. The most essential part to always be aware of in working with labels like this is the noun. Which carbamate herbicide it is is less important than the fact that it is a carbamate herbicide. This provides the most information about the properties of the chemical, and that part of the chemical name in the active ingredient statement is very easy to read.

Figure 13B illustrates a portion of the active ingredient statement from an Eptam label, which can similarly be unraveled. It is a thiol-carbamate and the various organic substituents can be hung around on the central thiol-carbamate group like ornaments on a Christmas tree, finally reaching the compound, ethyl N, N-di-propylthiolcarbamate or EPTC.

To summarize, if one reads the active ingredient portion of the label on packages of herbicides, insecticides, and fungicides and gives some thought to what kind of compound each of the active ingredients is and relates this type of compound to others in the same class, he can roughly predict the pest control properties and environmental behavior. This classification system should help make the chemicals more understandable and thus increase the safety and effectiveness of the pesticide application.
REFORESTION RODENT CONTROL

Introduction

This paper contains brief life history descriptions of those rodents and rabbits which the author believes are most damaging to reforestation programs in Oregon. Whenever possible, several control techniques have been included for an animal. These techniques may be used singly or in combination, depending upon the nature of the problem, the degree of control wanted, and the period of time during which control is needed. Information pertinent to controlling damage by specific animals is discussed under the following headings:

Economic Significance – Type and extent of damage.
Life History Facts Pertinent to Damage Control – This section gives information which may assist resource managers in timing and conducting successful control programs. The information provided is general in scope and may vary when food supplies and population densities change.
Control – Damage control techniques have been selected on the basis of adaptability to Forest conditions, and agreement with Fish and Wildlife Service recommendations. Assistance must be requested from State Game Departments when damage caused by protected animals cannot be solved with non-reductional practices.

Porcupine

Economic Significance

In the past porcupine damage has been considered a major problem throughout much of the pine forest. However, intensive control efforts in recent years have reduced porcupine numbers to a level which is more compatible with timber management objectives.

Porcupine feeding is still serious in some areas, and has the potential for becoming critical anytime a population is allowed to increase. Current emphasis is therefore on maintenance of populations at levels which will not jeopardize reforestation programs.

Porcupine feeding on trees up to 10 years of age is usually basal and often kills the trees. Gophers cause similar damage for which porcupines are commonly blamed. Girdling of the upper portions of older trees results
in deformities which reduce commercial values. The majority of feeding occurs from late summer through winter.

Porcupine damage has been observed more frequently in recent years west of the summit of the Cascades. It appears that a slow but persistent westward population migration is taking place. Occasional animals have been reported as far west as the coast range. Population control in the western part of the Region will be more difficult because of rough terrain and increased vegetative cover.

Life History Facts Pertinent to Damage Control

Preferred Habitat. Pine forests where there are rock outcrops or old trees and logs suitable for dens are favored areas. Clearcut units on the west slope of the Cascades also appear to provide satisfactory environment.

Food and Feeding. Bark, buds, grasses, and forbs are taken seasonally. Bark feeding usually does not start until more succulent vegetation starts drying in the later summer.

Activity. Porcupines actively forage from dusk through early morning. Daily travel is usually very limited and animals often remain in one area for many days. Seasonal movement usually covers several miles, and is probably related to changing food preferences.

Reproduction. A single animal is born each year during May or June. Birth takes place in a den following a gestation period of about seven months. The minimum breeding age is one year.

Control

It is best to combine a variety of methods.

Baiting. Strychnine treated salt blocks may be used in dens or porcupine cubbies.

Salt blocks to be used in dens should be fastened to the end of a pole and placed well into the den. This will make it possible to check on feeding as well as to protect other animals. Be sure that the block is within reach of porcupine using the den. The den site should be numbered and recorded for future checking.

Salt block placed in cubbies have worked successfully along travel routes. The cubbies keep livestock and big game from salt blocks and protect the blocks from weather.

Fifteen inch diameter aluminum or steel culvert pipe in four foot lengths provides a satisfactory and very safe cubby. The salt block should be fastened equal distance from each end. When the culvert is in position on the ground, the bottom of the salt block should be eight vertical inches from the bottom of the culvert.
There are a number of procedures that should be followed when placing a porcupine cubby. These are:

1. Fasten salt blocks securely to cubbies with No. 9 wire or bolts.
2. Use only one salt block per cubby.
3. Place salt blocks in cubbies with the holes up.
4. Do not place cubbies in areas frequently used by the public.
5. Do not place cubbies in areas where they are readily visible to roads commonly used by the public.
6. Fasten the cubby securely with five foot steel fence posts and No. 9 wire as shown in the following diagram.

![Diagram showing the placement of steel fence posts and wire around a cubby]

Start both steel posts into the ground at the indicated angle. Fasten two strands of No. 9 wire to the steel post immediately below the post space, leaving enough slack wire to allow posts to be driven 24 to 36 inches into the ground. Posts should be driven until the wire strands firmly encircle and snag the cubby to the ground.

7. Stencil or paint the word “POISON” on the outside of each cubby.

Twelve inch high chicken wire has been used to direct porcupine into bait stations. These fences radiate from two opposite corners of the bait cubby and extend several hundred feet into each direction.

Proper location is most important to cubby success. It may be necessary to make several moves to find a favorite travel route: creek bottoms, meadow edges, and drainages are often good bait station
locations. Skid trails or firelines may also be used as porcupine prefer to take the easiest route of travel.

Use a fetid scent to attract the porcupine. A good scent may be made from one gallon of decaying meat and one pint each of peanut butter and honey. The scent should be liberally applied to a piece of burlap fastened to the inner surface of the cubby. Dead porcupines near the cubby will also attract other porcupines.

Cubbies should be serviced at least twice a year preferably in the spring and fall. Early spring baiting usually provides the best control so the greatest effort should be made during that period.

A formal maintenance plan should be prepared. As a minimum, this plan should contain the station number, location, service record and effectiveness.

Trapping. Porcupines are easily caught with a No. 2 jump trap set in the following manner. Dig a slanting hole six inches deep by two or three inches wide and clear out a bed immediately in front of the hole for the trap. This should be slightly larger than the trap and deep enough to permit the trap to be placed one-half inch underground. Drive the trap stake into the ground under the proposed trap site and attach the trap chain to it. Place the trap in the depression with the spring in line with the slanting hole. Be sure there is no debris under the trap pan to prevent it from functioning. Place a “trap pad” (a piece of light canvas cut to fit inside the spread jaws) and sift fine dirt over the entire trap until it is completely covered.

Many of the normal precautions used in making the set for furbearers, coyotes, and bobcats have been purposely omitted to avoid unwanted catches. Most of the forenamed animals will avoid a trap unless it is set with utmost care. If there is a high chance of the trap taking desirable animals, another control technique should be used or the trap should be left bedded but exposed.

Trap sets should be baited with fetid scent or porcupine urine. The scent should be swabbed onto a heavy object close to the trap. The same formulation that is effective with cubbies will work in trapping.

Hunting. Porcupines may be effectively hunted under the following conditions:

1. Daytime hunting in the early spring when vegetation starts to develop. Look for porcupine where they feed in meadows, along stream sides, and open grass and weed covered ridges in the early morning and late evening.
2. Night road hunting during the breeding season in late summer and early fall.
3. Daytime hunting on tracking snow during late fall, winter, and early spring. Porcupines are quite active after a snow storm. Tracks and fresh droppings are easily seen.

Pocket Gophers

Economic Significance
In many areas of eastern and southwestern Oregon, pocket gophers are considered to be a major animal factor limiting reforestation. Both tops and roots of conifers are eaten. Feeding on individual trees is usually so extensive that it results in a high mortality rate.

Life History Facts Pertinent to Damage Control
Preferred Habitat. Grasslands, meadows, clearcuts, burns, and open conifer forests having adequate soil depth for burrowing are the most desirable sites. Gophers are found region-wide wherever suitable habitat occurs. Food and Feeding. Bulbous roots of forbs and grasses are favorite foods. Aerial parts of grasses and forbs are taken to a lesser extent. The roots and upper parts of small woody species such as young pine trees and other conifer species are also readily eaten.
Activity. Gophers spend most of their time below the ground surface. They do come above ground at night, during cloudy days and when young are leaving the brood tunnel system to establish new homes. When snow persists, burrow systems may be extended into the snow. Each adult has its own burrow system. Main tunnels are two to three inches in diameter, are usually several hundred feet in length, and vary from a few inches to several feet below the surface. Feeding tunnels are normally two to eight inches below the surface and are most extensive in areas where vegetation is sparse.
Reproduction. One litter a year is normal for species in Oregon. Breeding begins in early spring and four to eight young are born after a gestation period of about 30 days. The female rears the young which become solitary as soon as they are weaned.

Control
There are currently two gopher control methods. These are habitat manipulation and direct removal.
Habitat manipulation is a method in which the environment is altered to make it unsuitable for gophers. This is usually done by spraying an area
with selective herbicides to destroy valuable gopher foods. Much work still remains before this method can be recommended as a control measure on National Forest lands.

Direct removal techniques include hand baiting, machine baiting, and trapping. Choice of method will be based on site characteristics, season, and available manpower. These are discussed under each method.

Gopher control is a difficult job which usually requires one or more annual follow-up treatments. The number of additional years of baiting and time intervals between baiting will vary from area to area. Initial control success, type of habitat and potential for invasion from untreated areas will be factors controlling variability.

Control effectiveness can be readily checked by marking and opening a number of burrow systems on the treated area. If the systems are still occupied they will usually be closed within 48 hours. Mortality checks should not be made until bait has been exposed for two weeks.

Hand Baiting. Any site regularly occupied by pocket gophers may be hand baited but there are a number of conditions that regulate control effectiveness. These conditions follow:

Active mound building must be taking place to allow best selection of spots to bait. Fresh mounds can be identified by their unweathered appearance and loose structure. Very recent mounds will often be darker than surrounding soil because of greater moisture content.

Soil moisture should be sufficient to prevent burrow crumbling when probing or excavating tunnels for baiting. Moisture becomes less critical in soils that are well structured, fine textured or heavily sodded.

Experienced baiters are necessary to insure correct bait placement.

The number of available baiters must be large enough to permit complete area coverage. This often becomes a problem on areas of several hundred acres or more.

The following diagrams illustrate the location of lateral and main runways in relation to earth mounds, mound plugs and main runway plugs. Knowledge of these burrow characteristics if necessary for efficient and accurate bait placement.

Main runways may be located and baited by probing or excavating with a strong garden trowel.

1. Probing. This is the most commonly-used method. It is the fastest hand baiting technique, but requires considerable knowledge of gopher habits to be done effectively.
Ideally a probe should be of metal. It should have a small end 1/4 to 3/8 in. diameter for exploration and a larger end, 3/4 in. diameter for opening the bait drop hole. Both ends should be sharpened for easier soil penetration. A short handle welded at a right angle to the large end is also helpful when probing in hard soil or heavy sod.

Expertness in using the probe is gained largely through experience and self training. The first step is to select a spot on which to check for the presence of a burrow. The probe should then be gradually forced into the ground at that location. If the choice is correct a sudden release of pressure will be felt when the point enters the burrow.

Initial attempts at probing should be verified by digging out the lateral and part of the main runway. In this way errors can be quickly discovered and corrected.
The following sequence should be used when baiting with a probe:

1. Select an area with recent mound building activity.
2. Locate the main runway by probing out a lateral runway to its junction with the main runway. Laterals will usually join a main run in two feet or less. One or two test probes down each arm of the main runway to form a rough “T” will verify the location.

   Main runways may also be located by the presence of small convex earth plugs. The plugs are made when gophers close their burrows upon return from surface excursions. A probe should be made directly into the earth plug as the main runway is often immediately below.

3. Enlarge a probe hole in the main runway to accept the bait – being careful to avoid a deep hole in the bottom of the burrow.

4. Drop a teaspoonful of strychnine-rhoplex treated oats \(^1\) or a strychnine-treated carrot stick\(^2\) into the burrow.

5. Carefully cover all probe holes with clods, rocks or other suitable material to prevent light from entering the burrow system.

6. Bait two spots in what appears to be the active working area of a single gopher.

7. Mark treated areas by scuffing the tops of several earth mounds. This will prevent confusion if several people are working in the same area.

---

2. Excavating. Opening main runways with a garden trowel is a very positive method for locating the best bait spot. The only disadvantage is that it is relatively slow.

   Excavating is an excellent way to learn gopher burrow building habits and patterns and in this respect serves as a useful tool for training inexperienced baiters to use a probe. One of two days of burrow excavation before advancing to a probe will help insure good control results.

---

Baiting should be done in the following way:

1. Select an area with recent mound building activity.
2. Open a lateral or main runway earth plug to its junction with the main runway. Avoid disturbing the main burrow if possible.

---

\(^1\) The bait used by the Forest Service is a 0.5% strychnine treated steam crushed oat bait prepared by the Pocatello Supply Depot, U. S. Fish and Wildlife Service. The strychnine is bonded to the oat kernels with rhoplex. Comparable commercially prepared baits are also acceptable.

\(^2\) Carrot baits are prepared by splitting an average carrot into about 8 longitudinal strips and cutting the strips 3 to 4 inches long. Sixteen pounds of carrots are cut, allowed to dry for a few hours, and then dusted with 1 ounce of strychnine alkaloid powder. Even distribution may be obtained by gently tumbling in a large plastic bag.
(3) Place a teaspoonful of strychnine-treated oats or a strychnine-treated carrot stick into the main burrow several inches from the opening.
(4) Carefully close the opening with a clod or rock to exclude all light. Do not allow an excessive amount of soil to fall into the burrow.
(5) Bait two spots in what appears to be the active working area of a single gopher.

Machine Baiting. The Forest-land Burrow Builder provides an effective means for controlling pocket gophers within limits determined by slope, surface and subsurface obstructions, soil texture, and soil moisture.

The machine is pulled through the soil creating an artificial burrow while at the same time depositing small amounts of strychnine treated oat bait. Gophers locate the new burrows and eat the deposited bait within a few days. Maximum control is usually achieved within seven to ten days following treatment. Operating instructions, limitations and purchasing information for the Forest-land Burrow Builder may be obtained from the Regional Forester, U. S. Forest Service, 319 S. W. Pine St., Portland, Oregon.

Trapping. Gopher trapping is effective but it is so time consuming that it should be used only on very small areas or on areas where the use of toxic baits is undesirable.

Trapping procedures follow:
(1) Select an area with recent mound building activity.
(2) Open the lateral runway with a trowel.
(3) Set a gopher trap and insert it, with prongs forward, well back into the burrow. If the lateral runway is very short, the main runway will often be exposed during excavation. It then becomes necessary to set a trap in each arm of the main burrow.
(4) Secure traps with a light chain and pin.
(5) Leave entrance hole partly open to attract the gopher.
(6) Mark each trap spot with flagging so it may be relocated easily.
(7) When trapping is done in the spring, traps should be reset after a catch is made, as a burrow system may have several occupants at that time.

Correct trapping procedures are illustrated in the following diagram:

3 The Victor and Macabee gopher traps are the most common. They may be purchased at local hardware or farm supply stores.
White-Footed Mice

Economic Significance
White-footed mice are considered the most devastating of the seed eating rodents. Field studies have shown that they eat and cache large quantities of conifer seed and that relatively few mice can make a serious reduction in natural or artificial seed fall.

Life History Facts Pertinent to Damage Control
Preferred Habitat. Nearly all habitat types in the Region are occupied. Apparently the need for heavy cover is not as great as in the case of meadow mice and shrews. Large numbers of white-footed mice are often found on severely burned areas. The only obvious surface cover in such areas is charred logs and limbs.
Food and Feedings. Seeds, fruits, and insects provide the major source of food.
Activity. White-footed mice are active throughout the year. They are primarily nocturnal. The average home range is about four acres.
Reproduction. Litter sizes vary from three to seven and an average of four litters born a year. The gestation period is from 22 to 25 days. Young mice will breed when six to eight weeks old. The population peak is usually in November.

Control

Endrin should be used to protect seed for fall sowing in areas where mice are anticipated to be a problem.

Endrin is Federally registered as a conifer seed protectant at the rate of one half percent active endrin and two percent active thiram. The active ingredients are bound to the seed coats with rhoplex or latex adhesive. Monastral green dye or aluminum pigment is included in the treatment to identify the seed and provide bird repellency.

The hazard in handling endrin powder is high, so it is recommended that treatment be contracted to competent commercial seed treatment plants.

Endrin-treated seed should not be sowed in sensitive areas such as live stream courses, ponds, lakes, intermittent streams used by anadromous fish, campgrounds, viewpoints, or other areas in which people congregate. Dispensing methods which prevent contamination of the above areas should be used. For example, rough terrain may make it impossible to protect a stream when distributing seed from the air. In this case a buffer strip should be left along stream banks for hand baiting.

Baiting. Baits may be applied aerially or by hand. Baiting should precede natural seed-fall or artificial seeding by three to five days. Re baiting in the early spring before seed germinates may also be necessary. Where snow cover accumulates, spring baiting is most effective immediately after snow melt.

The U. S. Fish and Wildlife Service recommends 1080 treated wheat for baiting white-footed mice. This bait is supplied by the Service’s Pocatello Supply Depot, but must be used under their supervision, or in some cases, under supervisory training arrangements. The latter applies to training given to other Federal agency personnel by the Fish and Wildlife Service.

The need for baiting should be determined before field application. This is most effectively documented by running a snap trap census using 25 or more traps. Trap lines are routed through areas of representative mouse habitat and individual traps are set in areas of good cover where mice are most likely to be found. An effective bait is a mixture of 50% peanut butter and 50% oatmeal.
Trap lines should be run from 1 to 3 nights, depending upon the number of white-footed mice or other seed eaters such as chipmunks and golden-mantled ground squirrels caught.

If a 5% catch of primary seed eaters occurs any time during the 3 day period the need for seed protection is considered justified and trapping may be discontinued.

Aircraft. Aerial application should usually be made when the areas to be treated are large, manpower is limited, or white-footed mice are the only species posing a threat to the seed.

Wheat treated with 10 ounces of 1080 per one hundred pounds of wheat is the bait registered for aerial use. This formulation is highly toxic, with one kernel being lethal to a mouse. Apply bait evenly over the area to be treated at the rate of one-half pound per acre.

Bait density of one-half pound per acre should be about one kernel every 7 to 9 square feet. Both density and distribution patterns can be checked by placing grease or lard coated squares of cardboard or plastic throughout the project area. Be sure the squares contain enough adhesive material to secure the seeds as they hit. Sample squares should be horizontal to the angle of seed fall.

The number of square feet per seed can be figured by dividing the square feet of sample area by the number of seed caught.

Hand. Handbaiting is recommended where areas are small, several seed-eating rodent species are present, the chance of reinvasion is high, or where baits must be carefully placed to avoid hazards to people and non-target animals.

Baits to be placed by hand are prepared in a less concentrated form—two ounces of 1080 per 100 pounds of grain. Teaspoonful amounts of bait should be placed under logs, in burrow entrances, and in other protected places.

Control will be more effective when a few good bait spots are selected than when many poor ones are used. As a general rule, ten well-selected spots per acre are sufficient in most cover situations. This number should be modified either upwards or downwards to fit ground cover conditions.

The 2-100 1080 formulation loses its toxicity rather quickly when exposed to rain or heavy dew. It is therefore necessary to protect the bait to obtain maximum effectiveness. This may be done by placing the bait on a dry piece of bark and covering it with another larger piece — allow sufficient room for small rodent access to the bait. The bark bait station should be placed under a log or in other suitable cover. Protecting the bait
in this manner has the additional advantage of reducing danger to non-target animals, birds, and humans.

Chipmunks

Economic Significance

Coniferous tree seeds are one of the favorite foods of chipmunks. These seeds are eagerly sought after and stored for winter consumption. Studies have shown that chipmunks can consume more than 200 ponderosa pine seeds in one day's feeding. When these animals are present in large numbers they have a repressive effect on both natural and artificial seeding. Most seed stored by chipmunks is in deep caches and chances are slight that it will grow, even if left uneaten.

Life History Facts Pertinent to Damage Control

Preferred Habitat. Chipmunks occupy nearly all timber and shrub sites in the Region.

Food and Feeding. Principal foods are flowering plant and tree seed, grasses, berries, roots and some insects. Large quantities of seeds are stored in deep underground burrows to provide food during the winter.

Activity. Chipmunks are terrestrial, but climb readily when pressed by an enemy or when searching for food. Activities are confined to daylight hours. Nests are usually underground, near the base of a stump or beside a rock or log. Animals are most active during the spring, summer and fall. They spend much of the winter sleeping, but wake occasionally to eat from stored food and make short excursions from their dens.

Reproduction. Breeding occurs once a year, usually in March or April. The gestation period is 28-30 days and litters average four to six.

Control

Control is necessary when populations become numerous in reforestation project areas. The two most effective control periods are spring and early fall. Spring control will protect emerging seedlings. Early fall control three to five days prior to natural seed-fall or artificial seeding, will protect the seed during the period in which it is normally collected and stored by chipmunks.

Baiting. Use 0.5% strychnine-treated oats. Scatter teaspoonful amounts under logs, among concentrations of limbs, under upturned stumps or in other protected spots. Bait spots should cover two or three square feet. Do not bait during the winter as chipmunks are not active enough to be effectively controlled.
Protect tree seed with endrin.

Golden-Mantled Ground Squirrels

Economic Significance
Golden-mantled ground squirrels search out and consume large quantities of both coniferous seed and emerging seedlings. They are the most destructive of the ground squirrels to forest regeneration programs.

Life History Facts Pertinent to Damage Control
Preferred Habitat. Forested lands, containing rocky areas for nesting, provide ideal habitat. Distribution occurs throughout the eastern part of the Region, on the western slopes of the Cascades, and in the Siskiyou Mountains of Southern Oregon.

Food and Feeding. Green vegetation, roots, bulbs, seeds, grain, nuts, fruits, berries, mushrooms, and meat are easily eaten. Diets vary with seasonal availability of different plants and plant parts. Meat is apparently eaten whenever available.

Activity. Golden-mantles are active during daylight hours. They rarely climb trees. Nesting is in underground burrows which are usually in rocky areas. Hibernation starts about the middle of September and usually lasts until May. Variations in the hibernating period are caused by location, elevation, weather, age, sex, and physical condition.

Reproduction. Breeding occurs once a year shortly after emergence from hibernation. Four to six young are born in late June or early July.

Control
Baiting. Use 0.5% strychnine-treated oats. Place treated oats along squirrel runways or around burrow entrances. Bait should be distributed in teaspoonful amounts and should be scattered over several square feet to prevent livestock or big game from consuming lethal quantities.

Golden-mantled ground squirrels do not readily take grain baits in the spring. They must be controlled in the summer or early fall prior to hibernation.

Meadow Mice

Economic Significance
Meadow mice are known to be detrimental to many agricultural crops during the period when their populations are high. They also eat conifer tree seedlings and girdle young trees, and in this respect pose a threat any time forest plantations occur within their habitat.
Life History Facts Pertinent to Damage Control

Preferred Habitat. Meadow mice occur in a variety of sites in which sufficient vegetation is produced to provide food and cover. Areas of dense grass provide the most desirable habitat.

Food and Feeding. Vegetation, including grass, herbaceous foliage, twigs, roots, seeds, and bark are acceptable foods.

Activity. Meadow mice are active both day and night throughout the year. Their presence is readily detected by distinct winding runways beneath the vegetation. Each mouse generally maintains its own set of runways, but its territory may be occupied by several mice. Individual home ranges vary from a few square feet to areas as large as a tennis court.

Reproduction. Four to ten young are born after a short gestation period of three weeks. Females can breed when only three weeks old and many have litters continually from early spring to late fall. Populations often fluctuate drastically from year to year, generally peaking every three to four years.

Control

Baiting. Meadow mice can usually be controlled with a 1% zinc phosphide treated wheat. Distribute the bait in one-half teaspoonful quantities directly in runways and burrows. Quantity of bait needed per acre will vary depending upon mouse density, and cover distribution and density.

Two pounds per acre will normally be enough to control high populations in dense cover. Correct bait placement is very important as the mice seldom venture from the protection of their runways. Baiting is most effective in late fall, but should be initiated as soon as meadow mice are detected on a plantation. Baitings may be needed for several years in problem areas.

Habitat Destruction. Destroying food and cover is an effective method for controlling damage from meadow mice, but it may have serious effects on other wildlife. This approach to damage control is generally limited to old fields and other areas where equipment can be driven. Habitat destruction can be accomplished by cutting, cultivation, burning, or spraying with herbicides.

Snowshoe Hares

Economic Significance

In many areas of the Northwest, rabbit damage to conifer reforestation projects is considered to be more critical than that caused by big game.
Rabbit feeding often results in the immediate loss of the seedling rather than a temporary suppression as is often the case with browsing damage.

Life History Facts Pertinent to Damage Control
Preferred Habitat. Snowshoes usually occupy most commercial forest areas provided there is an abundance of good protective cover.
Food and Feeding. Green grass, roots, seeds, berries, foliage, twigs, and bark of many species of shrub and trees are all readily taken.
Activity. Daily movements are usually limited to a small area. The period of greatest activity is from dusk to dawn. Burrows of other animals are used for protection. Snowshoes do not migrate but will move downhill to different vegetative types under deep snow conditions. Speed and agility are relied on to escape enemies.
Reproduction. Snowshoe hares normally have three to four young per litter and may have up to four litters a year. Young are born from April through August. The gestation period is 36 to 40 days. New born hares are well developed and are soon able to move about.

Control
Baiting. Use strychnine-treated apple baits. Place bait during fall and early winter when succulent plants are not available. Bait can be most effectively placed in trails and feeding areas when there is a soft cover of snow. Place two to four pieces of apple at each spot. Baits should be placed in protected areas to prevent feeding by big game. Best results will be obtained if untreated apples are exposed for one to two weeks before the treated apples are placed.

The bait is prepared by treating 16 pounds of apples with one ounce of strychnine alkaloid powder. Use apples of average size, 4 to 6 ounces each. Delicious apples are preferred because of aroma and keeping quality. Cut each apple into 16 longitudinal sections and spread the cut pieces out to dry for a short time. Next, place 1/3 of the apple pieces in a large tight bag of strong plastic and add 1/3 ounce of strychnine alkaloid powder. Tumble the bag gently until all pieces are coated with powder. Repeat this procedure until the materials have been used up.

Silvicultural Modifications. Disposing of slash, brush and accumulations of logging debris will reduce the attractiveness of the habitat for rabbits. When a serious rabbit problem is anticipated, use of large seedlings two or more feet in height will reduce feeding damage.
Individual Plant Protection. Plant trees that have been treated with Thiram animal repellent. Make repeated applications of Thiram in the field after
each growing season until trees grow large enough to be out of danger. The repellent can be applied effectively with a backpack sprayer. The recommended dilution is one gallon of 20% Thiram to one gallon of water.

**Brush Rabbit**

*Economic Significance*

Brush rabbits are common in western Oregon and at times their tree feeding has a serious impact on reforestation efforts. Damage is usually localized.

*Life History Facts Pertinent to Damage Control*

**Preferred Habitat.** Dense brush interspersed with openings provides ideal habitat. Distribution is limited to the areas west of the Cascade summit in Oregon.

**Food and Feeding.** Buds, twigs, bark, grasses, clovers and a wide variety of succulent plants are eaten.

**Activity.** The main period of activity is at night. Movements are confined to very small areas and a rabbit may spend its entire life within a few feet of its birth place. The young are hairless and blind and spend a much longer time in the nest than do hares.

**Reproduction.** Breeding may take place three to four times a year with four to seven young born per litter.

*Control*

Use the same measures as for snowshoe hare.

**Mountain Beaver**

*Economic Significance*

Mountain beaver rarely conflict with man's interests in mature forests. However, they present very serious local problems to conifer plantations. Lateral and terminal branches may be removed from trees up to ten feet in height.

*Life History Facts Pertinent to Damage Control*

**Preferred Habitat.** Distribution is limited to a small area of heavy rainfall along the Pacific slope from British Columbia to central California. They are generally found in heavy timber, but quickly adapt to west side cutover areas. Populations are most abundant near springs, streams, and areas with damp, deep soil.
Food and Feeding. Mountain beaver have voracious appetites. They are strictly vegetarian, and feed on almost any available plants growing near their burrows. In order to forage in suitable vegetation, they will dig a tunnel directly into an area and then develop short trails into the feeding areas. Plant material is often cut, gathered, and layed out to dry. After cutting, vegetation is taken into the burrow to use as nesting material and food.

Activity. Most surface activity takes place at night, but movements within the extensive burrow system may occur night or day. While mountain beaver do not actually hibernate, their activities in many areas are restricted in the winter. Some burrowing takes place in the snow and animals are occasionally seen running on the surface. Late spring is the season of greatest activity.

Mountain beaver are generally unsociable. The activities of the individual seem to concern only itself and are in no way related to the common good. Captive animals resent contact with each other and fight continually.

The burrow system consists of extensive irregular tunnels four to eight inches in diameter. These tunnels form a network of passages from a few inches to several feet beneath the ground surface. There are many entrances and unrepaired roof openings.

The nest is a deep and fairly elaborate structure containing numerous layers of well packed leaves.

Although not sociable, mountain beaver often densely populate areas. One sample area 100 by 500 feet was estimated to have a population of 11 animals. There were 100 burrow entrances in this area.

Reproduction. Breeding takes place once a year in late February or early March. Two or three young are born at the end of a 28-30 day gestation period. Females do not bear young until they are in their second year.

Control

Control of mountain beaver in large areas has often fallen far short of success. Control measures are effective only when the animals are actively feeding and moving about. At the present time, population reduction is the best method available for reducing mountain beaver damage.

Baiting. Baiting is the most economical means of controlling mountain beaver. Place two or three pieces of toxic bait well back into entrances of active burrows. Use apple bait during spring, summer, and fall and swordfern fronds during the winter. Do not place baits in holes that are
being used for pushing out dirt and rubbish as the bait will most likely be buried.

Apple baits are prepared as directed for rabbits except that each apple is cut into 12 pieces.

Swordfern fronds are cut into 10 inch lengths. One ounce of strychnine alkaloid powder is then dusted over ten pounds of fronds to prepare the bait.

Trapping. Trapping is the surest method of removing mountain beaver from small areas. A No. 1 steel trap should be used. Traps should be set on the ground just inside the burrow entrance. Before setting a trap in a burrow be certain that it is being used for a doorway and not for pushing out excavated earth, spoiled food stores, or other trash. Secure traps with stakes and chains. Place traps lengthwise to the burrow. There is no need to conceal or cover traps. Visit sets at least twice a day to avoid unnecessary suffering of captured animals, and to insure maximum effectiveness.

Conibear traps set upright and crosswise in the underground runways are also effective. These traps generally catch the animals around the neck and kill them quickly.

Conclusion

In closing I wish to emphasize that in conducting rodent control we are dealing with a job that is both sensitive and hazardous. Mistakes are costly in terms of non-target species loss and loss of tools needed to keep forest lands productive. An analysis of past problems invariably traces the cause back to a failure of the applicator to follow label instructions, to use prescribed application techniques, or to use common sense. These are the most important aspects of any rodent control program.
Before going into a discussion of the specific properties of herbicides, I think we need to ask the question, “Why is there concern over the physical and chemical properties of these compounds?” In order to answer this question we must briefly look at the historical development and use of these chemicals.

In the decade following the introduction of organic pesticides the primary interest was in the biological properties of the compounds. People were interested in what weeds, insects, or other pests the chemicals would control. There was also interest in acute toxicities to mammals, but there was not very much concern over long-term, low-level exposure. As more and more chemicals were introduced into the environment — from pesticides, industry and domestic sources — it became increasingly apparent that we could not continue to indiscriminately use chemicals.

Therefore we saw laws governing the use of pesticides. Prescribed uses and residue levels were established. Also, persons applying materials were licensed to insure that the chemicals were properly used. What I am trying to emphasize in discussing the historical development is that the public has come to expect, and rightfully so, that the pesticide chemicals are used safely. Therefore, it is incumbent on you, as users of pesticides, to use these materials in the safest possible manner.

Now to get back to the original question as to why we are interested in the physical and chemical properties of these compounds. The reason we are interested in these properties is that we must know the behavior of the chemicals in the environment in order to use them in the safest manner. In order to appreciate their behavior and anticipate problems, we must know their properties since their behavior is a function of these properties.

The first property which I should like to discuss is volatility or the tendency of a chemical to go into the vapor state. We are all familiar with this property, having seen water evaporate. Water has a relatively high vapor pressure so it rapidly evaporates. All compounds, even metals, have a vapor pressure or tendency to evaporate. However, as in the case of metals, the vapor pressure is so low that it is insignificant from a practical
standpoint. There is so little vapor being formed that it cannot be measured by even the most sensitive means of detection.

The important question we need to answer now is what volatility problems may be encountered with the herbicides used on forest and range lands. By problems I mean the situation where the chemical volatilizes and the vapors drift into an area having sensitive plants. Some of the compounds whose vapor pressures are so low that there is insignificant hazard are simazine or Princep, atrazine or Aatrex, diuron or Karmex, Amitrole or Aminotrazole, and the arsenicals MSMA and cacodylic acid.

Two additional compounds which could be included to this list are dicamba or Banvel and picloram or Tordon. The reason I have listed these separately is that under extremely high soil temperatures a small amount of these chemicals could volatilize. If the treatment area were adjacent to a highly sensitive crop, growth regulator symptoms could be encountered. Although such a situation is unlikely, I think it is well to keep such possibilities in mind when making treatments near susceptible crops.

The most important compounds with respect to the amount of usage are the phenoxy compounds 2,4-D, 2,4,5-T and silvex. The volatility of these compounds is a function of the type of formulation. Three types of formulation are available. These are the free acid, amine salt, and the ester. The vapor pressures of the acid and amines are extremely low. Thus these formulations present no hazard with respect to volatility.

The ester formulations do have significant vapor pressures so that there is a potential problem with these derivatives. This does not mean there will often be a problem. Under normal circumstances, the very small amount of vapor which arises from volatility is not significant. However, if very hot weather were to follow an application of the ester, and the area were adjacent to a very sensitive crop, it is possible to get growth regulator symptoms on the crop. It is highly unlikely that even under such conditions the crop would be permanently damaged. However, all a grower has to see is some minor bending and curling of bean stems and you have a real problem. So we must keep in mind this volatility potential of the phenoxy esters when they are used in sensitive areas.

At this point I would like to differentiate between volatility and drift. With volatility the chemical reaches the target area and the chemical forms vapors which can move with air currents. The amount of chemical which will volatilize is a function of the vapor pressure of the chemical and the temperature of the surface from which it is evaporating. In the case of drift the small spray droplets do not reach the target area. The small droplets settle so slowly that air movements carry them out of the treated area before they reach the ground. This property of drifting is independent of the type of chemical being applied. Any chemical spray will drift, the
amount of which depends on the size of the spray particle and the velocity of the wind.

One final point I should like to mention about volatility is the fate of the small amount of vapors that arise through volatility. Some of the more radical and vociferous “pseudo-ecologists” would have us believe that these small amounts of chemical are permanently poisoning our environment. Our answer to this is that the chemicals are of low toxicity, they are present in very small amounts and they do not persist in the environment. Studies have shown that the vapors are photo-degraded or broken down by light and that which is washed to the soil with rain is fairly rapidly broken down by soil microorganisms. In fact, the primary reason we can continue to use these herbicides without a continual build-up in the environment is that they are broken down by soil microorganisms.

Another property which is important in the behavior of pesticides is the adsorption of chemical by soil or forest floor litter. The adsorption process is quite important because it determines the amount of chemical which is available to plant roots, the degree of leaching in the soil and the ease with which the chemical will run-off into surface waters. I think the best way to describe this process is by comparing it to a water softener. As you pass water through a softener, dissolved metals such as calcium and iron are adsorbed by the resin in the softener. The same type of process occurs with pesticides in soil. You apply pesticides and rain comes and dissolves the chemical. As this solution of chemical permeates the soil, much of the chemical may be adsorbed or bound to constituents in the soil or litter.

An important feature of this adsorption is that it is an equilibrium or reversible process. For illustration lets assume that 90% of a chemical is adsorbed from solution by the soil surface. As water penetrates the soil the 10% which isn’t adsorbed moves to the next layer of soil and 90% of this 10% which moves is again adsorbed. You can see that the chemical doesn’t have to go very far before most of it is adsorbed. However, since it is an equilibrium process, as chemical is removed by the soil solution more chemical comes off or is desorbed from the soil. In the above illustration, as the 10% which isn’t adsorbed moves away from the surface, 10% of that which is adsorbed is again released into the soil solution. So this is a really dynamic situation. There is chemical being adsorbed and desorbed, with depth of soil penetration being dependent on how extensively the chemical is adsorbed. The soil is serving as a reservoir of chemical. As chemical is leached or degraded more adsorbed chemical is released.

The two factors which largely regulate the amount of adsorption are water solubility of the compound and the nature of the adsorbing soil. Water solubility is important since it is a measure of the affinity of the
compound for water. If a compound has a low water solubility it will normally have more of a tendency to adsorb on soil.

There are exceptions to this generalization, whereby a certain property of the chemical may allow it to be extensively adsorbed even though it has a high water solubility. Such an exception is amitrole. This compound has a high water solubility. However, it has chemical group called an amino group which binds quite strongly to certain constituents in the soil. Thus the chemical remains close to the soil surface until it is degraded.

Two constituents in the soil which are largely for the adsorption process are clay and organic matter. With most of the herbicides used on forest and range lands, organic matter plays a larger role in the adsorption process. Most of the herbicides are strongly bound to this fraction of the soil. Therefore, most chemicals don’t permeate more than first few inches of soil.

I think we can show the importance of adsorption by considering the water solubility and movement in soil. The solubility of most herbicides varies from a few ppm to several thousand ppm. If we assume a low solubility of 20 ppm then 1 acre inch of rain would dissolve 4 pounds of chemical. So an acre inch of rain is enough to dissolve most application of chemical. If there were no adsorption the chemical would leach to several feet and contaminate ground water. This doesn’t happen because adsorption is operative.

With this general discussion in mind let us get back to specific compounds. Most of the compounds — the phenoxy acids, arsenicals, ureas, triazines and amitrole are fairly immobile in soil. These chemicals, even in high rainfall areas, do not penetrate to great depths. Two compounds which are somewhat more readily leached are picloram and dicamba. These compounds are not sufficiently mobile to cause problems with ground waters, but they can cause injury problems when selectivity is based on placement of chemical in the soil. A good example is use of dicamba in lawns under deeper-rooted plants such as trees. The phenoxy acids have not given any problems, but dicamba can move deep enough to where some of the feeder roots of the tree can pick up the chemical. Another example is with the uracil herbicides. These chemicals can move in soil so that deeper rooted plants can be injured.

The final property of the herbicides which I should like to discuss is the persistence or stability of the chemicals in the environment. It is obvious that if we release a chemical in the environment it will persist until some reaction degrades it.

One means of degradation is photochemical, whereby the rays of the sun degrade the chemical. This is mainly operative on chemicals in the vapor state. Chemicals in the soil are largely shielded from light. Another
means of degradation is decomposition of chemicals in the plant. Even susceptible plants have the capability of degrading herbicides. Beans, which are quite sensitive to 2,4-D are able to decompose appreciable amounts of this chemical. This is why beans can recover from the injury encountered when a small amount of drift results in growth regulator symptoms.

Since most of the applied chemical ultimately reaches the soil, the primary mechanism for reduction of pesticide residues is through decomposition of chemical in soil. All of the pesticide chemicals have been found to be degraded in soil. This is true even for DDT which is quite persistent. The problem with DDT is that the rate of degradation is quite slow so that there is ample opportunity for the chemical to become distributed in the environment through volatility and surface run-off. With herbicides the persistence varies from a few days to a year or two, depending on rate of application. Most of the chemicals are decomposed during the year following application. 2,4-D normally has the shortest residual life, being less than 30 days under most circumstances. Picloram, the ureas and triazines may persist for more than a year, especially when used for soil sterilization along rights of way. However they will not cause an environmental residue problem since they are not sufficiently mobile — through volatilization or leaching — to leave the treated area.

One final point I should like to mention is the behavior of herbicides in animals. One of the reasons for concern over DDT was that it is stored in fatty tissue. Thus a continued low level exposure results in an accumulation in the fat. This accumulation is magnified along the food chain. This behavior is not encountered with the herbicides. These compounds are not stored, but are rapidly excreted. Thus there is no magnification of residues along the food chain.

In summary, I think we can conclude that herbicides are safe when used according to recommended procedures. This conclusion is based on the following facts:

1. The chemicals have a low vapor pressure so that there is little hazard of vapors contributing to air pollution.
2. The chemicals do not leach so that they will not contaminate ground waters. Studies have also shown that adsorption binds the chemicals so there is little hazard of run-off contributing to surface water pollution.
3. The chemicals are not persistent in the environment but are degraded by plants and soil.
4. These compounds are not stored in animals so that even if there were occasional small residues, such residues would not be magnified in the food chain.
The behavior of a chemical in the environment begins with its initial distribution and continues through its subsequent movement, persistence, and fate in each component of the environment. Behavior will determine the quantity, persistence, and chemical form of a pesticide in different parts of the environment. This paper considers the behavior of some chemicals in the forest environment. It illustrates the importance of papers by Witt and Montgomery and lays a background for several other papers in this proceedings.

CONCEPT OF CHEMICAL ACTION

Chemical action is the direct effect of a chemical on an organism. Chemical action on any organism requires that the chemical be present at the site of action in an active form in sufficient quantity and for a sufficient period of time to produce an effect.

The concept of chemical action applies to target and nontarget organisms alike. It determines the biological effectiveness of a spray operation, the selective toxicity among organisms, and the danger to nontarget organisms from the use of chemicals in the forest. The intrinsic toxicity or biological activity of a chemical and the potential for exposure of an organism to the chemical are the two factors which determine the probability of chemical action occurring.

Toxicity

There are two kinds of toxicity: acute and chronic. Acute toxicity is the fairly rapid response of organisms to a few, relatively large doses of chemical administered over a short period of time. Chronic toxicity is the slow or delayed response of organisms to the exposure of relatively small doses of chemical administered over a relatively long period of time. There are, of course, all gradations between these two extremes. The kind of response (acute or chronic) we observe in an organism depends on the magnitude of the dose and the duration of the exposure which results from the behavior of the chemical.
Potential for Exposure

The behavior of a chemical determines the potential for exposure. Behavior in the external environment determines exposure of the whole organism. Behavior of chemicals within the organism determines exposure of the biochemical site of action. What is it that controls chemical behavior?

There appears to be an aura of mysticism about pesticides. Yet there is nothing magical about pesticides at all. They are simply a special class of chemicals with properties that can be used to man's advantage or disadvantage. Montgomery (in this proceedings) has pointed out that pesticides, like all other chemicals, have physical and chemical properties (water solubility, vapor pressure) which can be accurately measured. All chemicals, including pesticides, obey the laws of physics, chemistry, and biology. The environment also has properties: temperature, moisture, surfaces, radiation, and wind.

The laws of physics, chemistry, and biology direct the interaction between properties of chemicals and properties of the environment to produce chemical behavior (Fig. 1). The resulting quantities of chemical in various parts of the environment at various times determine the duration and magnitude of exposure of various organisms to the chemical. The impact of chemicals on target and nontarget organisms (discussed by Terriere in this proceedings) and the selective action of chemicals (discussed by Appleby in this proceedings) depend on this exposure.

CHEMICAL BEHAVIOR

Initial Distribution of Spray Materials

Aerially applied chemicals will be distributed to four major portions of the environment: air, vegetation, forest floor, and water (Fig. 2). The amount of chemical entering each portion of the environment will be determined by the chemical used and the environmental conditions which prevail at the time of application (Norris 1967).

Some spray material will be dispersed by the wind as fine droplets called "drift." The degree of lateral movement of spray drift depends on droplet size, height of release, and wind velocity (Fig. 3) (Reimer et al. 1966). Additional amounts of chemical may remain in the air due to volatilization of spray materials while falling through the air or from intercepting surfaces. Most of the herbicide not lost through drift or volatilization is intercepted by the vegetation or the forest floor. Some small amounts of pesticide may fall directly on surface waters.
Figure 1. — The interaction of chemicals with the environment.
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Movement, Persistence, and Fate of Pesticides in the Forest Environment

The movement of pesticides includes movement within a given part of the environment such as leaching in the soil profile or movement from one part of the environment to another such as the rain washing of pesticide residues from leaf surfaces to the forest floor. Persistence is the tendency for pesticides to remain in an unaltered form. The fate of pesticides concerns the chemical pathway of pesticide degradation. The following section in this paper considers the movement, persistence, and fate of chemicals in various parts of the forest environment.

AIR

Preliminary research indicates losses of herbicides and insecticides to the air may be appreciable. During one test in western Oregon, for instance, from 20 to 75 percent of certain herbicides did not reach the
Figure 3. – Lateral movement of spray particles of various diameters falling at terminal velocity in a 5 m.p.h. crosswind. Shaded areas indicate uncertainty due to varying droplet evaporation (Reimer et al. 1966).

Similar values for some insecticides have been reported. This topic is covered in more detail by Maksymiuk in this proceedings.

Chemicals dispersed in the air are mostly moved to other locations where they may settle to the earth, be washed out with rain, or be taken up by plants and other organisms. Degradation in the air is also possible.

**VEGETATION**

The amount of pesticides intercepted by vegetation depends on the rate of application and the density of vegetation. Several mechanisms operate on pesticides intercepted by foliage (Fig. 4). There is only limited absorption and very little translocation of many pesticides. Through the action of rain, much of the pesticide not absorbed will be washed from the

---

Unpublished data. M. Newton, L. A. Norris, and J. Zavitkovski, School of Forestry, Oregon State University, Corvallis.
Figure 4. — The fate of pesticides intercepted by foliage.

The fate of pesticides intercepted by foliage.

surface of the leaf. Pesticide remaining on the leaf surface and any pesticide not translocated to other plant parts will also enter the environment of the forest floor due to leaf fall.

Pesticides retained by the plant may be excreted back into the environment through the roots or they may end up in some plant storage tissue to be released at a later time. Through metabolic activities, plants may degrade some pesticides to nonbiologically active substances.

Studies with herbicides show the highest concentrations occurring in foliage shortly after application (Table 1) (Morton et al. 1967, Getzen-

<table>
<thead>
<tr>
<th>Time after treatment (Weeks)</th>
<th>2,4-D&lt;sup&gt;2&lt;/sup&gt; ppm</th>
<th>2,4,5-T&lt;sup&gt;2&lt;/sup&gt; ppm</th>
<th>Picloram&lt;sup&gt;3&lt;/sup&gt; ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>100</td>
<td>135</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
<td>60</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>15</td>
<td>24</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>52</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Rate of application — 1 lb/acre.  <sup>2</sup>Data from Fig. 4 of Morton et al. 1967.

<sup>3</sup>Data from Table 5 of Getzendaner et al. 1969.
A combination of factors causes the concentration to decrease rapidly with time. Growth dilution, weathering, and metabolism of the herbicide by the plants are particularly important.

**FOREST FLOOR**

The forest floor is a major receptor of aerially applied spray materials. Pesticides in the forest floor may be volatilized and reenter the air, absorbed on soil mineral or organic matter, leached through the soil profile by water, or degraded by chemical or biological means. Volatilization of chemicals from the soil surface may be responsible for the loss of fairly large amounts of some pesticides such as DDT and perhaps some phenoxy esters.

Absorption and leaching are processes which work in opposition to one another. Absorbed molecules are not available for leaching, but absorption is not permanent. The amount of pesticide which is absorbed is in equilibrium with the amount of pesticide in the soil solution (Fig. 5). As

\[
\text{CHEMICAL} + \text{ ADSORBENT} \xrightarrow{k_1} \frac{k_2}{k_2} \text{CHEMICAL : ADSORBENT}
\]

Figure 5. – Chemical adsorption on soil is an equilibrium reaction.

the concentration of pesticide in the soil solution decreases, more pesticide will be released from absorption sites. Thus, absorption provides only temporary storage and the soil is, in effect, a reservoir of chemicals which will eventually be released. Leaching is a slow process capable of moving pesticides only short distances (Harris 1967, 1968). Herbicides are generally more mobile in soil than insecticides, but mobility is relative and even the movement of herbicides is measured in terms only of inches or a few feet (Fig. 6).

**SURFACE WATERS**

Degradation of environmental quality in the forest is often first recognized by changes in stream quality. Stream contamination is also a most important expression of environmental contamination in the forest because water is both the habitat for many biological communities and a critical commodity to downstream water users.

Pesticides may enter streams by several processes. The direct application or drift to surface waters will occur for only a short period of time but may cause high concentrations of pollutant. Pesticides may also enter streams in rainfall which washes particulate and vapor forms from the air.
Figure 6. – Relative mobilities of pesticides in sub-irrigated columns of soil (Harris 1967, 1968).
or from leaves. Pesticides may move to streams by leaching through the soil profile or in mass overland flow during periods of intense precipitation.

STREAM CONTAMINATION BY HERBICIDES

Stream contamination by herbicides is a subject which intensely interests the public. You may need to answer questions about it. Herbicides are the most commonly used group of pesticides in this forest region. You can greatly influence the amount of herbicide which enters streams near your spray areas.

Direct Application or Drift of Herbicides to Oregon Streams

I have looked for herbicides in streams after regularly scheduled spray projects on forests and rangelands in Oregon. The following examples illustrate several important points about minimizing stream residues (Norris 1967). You can best study these examples by observing the location of treatment unit boundaries, streams, and sampling points. Note in particular when the peak concentrations of herbicide occurred and how long residues persisted.

About 65 acres of the 3,500-acre Cascade Creek Watershed (western Oregon) were sprayed with low volatile esters of 2,4,5-T (2 pounds per acre) in March by helicopter (Fig. 7).
A small stream was sampled at point 1 from a 5-acre watershed which was completely sprayed. Streams sampled at points 2 and 3 did not enter but ran adjacent to the treated area. Herbicide residues were measured by gas chromatography in samples collected at these points (Table 2).

<table>
<thead>
<tr>
<th>Sample point 1</th>
<th>Sample point 2</th>
<th>Sample point 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hours after spraying</strong></td>
<td><strong>2,4,5-T (ppb)</strong></td>
<td><strong>Hours after spraying</strong></td>
</tr>
<tr>
<td>0.05</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>0.6</td>
<td>16</td>
<td>1.3</td>
</tr>
<tr>
<td>1.3</td>
<td>7</td>
<td>2.2</td>
</tr>
<tr>
<td>2.0</td>
<td>4</td>
<td>3.9</td>
</tr>
<tr>
<td>4.0</td>
<td>4</td>
<td>5.4^3</td>
</tr>
<tr>
<td>5.2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>9.8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>24.7</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>48.2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>74.8^2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

1 Rate of application – 2 lb./acre.

2 Herbicide residues were detected at point 1 up to 16 weeks after spraying.

3 No further residues were detected although sampling continued for 10 months.

The drainage basin at point 1 was characterized by a large slump and marshy area which indicated a high water table. The highest concentrations occurred shortly after application started, but low concentrations were found up to 16 weeks later. At points 2 and 3, only low levels of herbicide were found, and these persisted for less than 1 day. Data from points 2 and 3 reflect the small area of the watershed treated as well as the location of the treatment unit boundaries with respect to the sampled stream.
The Eddyville Watershed in western Oregon was treated with low volatile esters of 2,4-D at the same time as the Cascade Creek Watershed (Fig. 7). Several streams were included in the 71 treated acres.

Higher concentrations of herbicide were found in the Eddyville streams than in Cascade Creek (Table 3). This is attributed to a slightly higher rate of herbicide application, a larger proportion of the watershed being treated, and, most importantly, the fact that all of the sampled streams flowed from or through the treated area. The highest concentrations of herbicide were found shortly after application. Residue levels declined rapidly with time.

<table>
<thead>
<tr>
<th>Sample point 4</th>
<th>Sample point 5</th>
<th>Sample point 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours after spraying</td>
<td>2,4-D</td>
<td>Hours after spraying</td>
</tr>
<tr>
<td>(ppb)</td>
<td>(ppb)</td>
<td>(ppb)</td>
</tr>
<tr>
<td>0.8</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>33</td>
<td>62</td>
<td>30</td>
</tr>
<tr>
<td>1.8</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>13</td>
<td>71</td>
<td>44</td>
</tr>
<tr>
<td>2.8</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>13</td>
<td>58</td>
<td>25</td>
</tr>
<tr>
<td>53.5²</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td>9</td>
<td>44</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>53.6²</td>
<td>53.6²</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>11</td>
</tr>
</tbody>
</table>

¹Rate of application – 2.2-3.0 lb./acre.
²No further residues were detected although sampling continued for 10 months.

Other studies have been carried out on the Maiheur National Forest in eastern Oregon (Norris 1967). The treatment areas examined in eastern Oregon were generally larger than those in western Oregon, although the distance between units was greater. The spray units in eastern Oregon were treated by helicopter with 2,4-D low volatile esters in early June.

The West Myrtle treatment area is a fairly typical eastern Oregon spray project (Fig. 8). It contained nearly 600 treated acres in one block. Live streams were included in the treatment area. Herbicide residues were measured near the downstream end of the unit and at another point about 1 mile downstream. The concentrations of herbicide were higher than
those encountered in Cascade Creek in western Oregon but similar to those in the Eddyville treatment area which also included live streams (Table 4).

The point that needs to be emphasized is that the magnitude of this short-term contamination is not a function of the herbicide or the geographical location in which it is used. It is closely related to the manner
Table 4. — Concentration of 2,4-D in Myrtle Creek

<table>
<thead>
<tr>
<th>Sample point 1</th>
<th>2,4-D</th>
<th>Sample point 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hours after spraying</strong></td>
<td><strong>2,4-D</strong></td>
<td><strong>Hours after spraying</strong></td>
</tr>
<tr>
<td>1.7</td>
<td>132</td>
<td>2.0</td>
</tr>
<tr>
<td>3.7</td>
<td>61</td>
<td>3.9</td>
</tr>
<tr>
<td>4.7</td>
<td>85</td>
<td>5.0</td>
</tr>
<tr>
<td>6.0</td>
<td>10</td>
<td>6.2</td>
</tr>
<tr>
<td>7.0</td>
<td>26</td>
<td>7.2</td>
</tr>
<tr>
<td>8.0</td>
<td>75</td>
<td>8.2</td>
</tr>
<tr>
<td>9.0</td>
<td>59</td>
<td>9.2</td>
</tr>
<tr>
<td>13.9</td>
<td>51</td>
<td>14.1</td>
</tr>
<tr>
<td>26.9</td>
<td>3</td>
<td>17.0</td>
</tr>
<tr>
<td>37.9</td>
<td>9</td>
<td>38.0</td>
</tr>
<tr>
<td>78.0</td>
<td>8</td>
<td>77.8</td>
</tr>
<tr>
<td>80.8</td>
<td>1</td>
<td>81.0</td>
</tr>
<tr>
<td>1 week</td>
<td>T</td>
<td>104.8</td>
</tr>
</tbody>
</table>

1 Rate of application - 2 lb./acre

2 Sample point 2 is 1 mile downstream from sample point 1.

in which the treatment area is laid out with respect to live streams. Data from the Camp Creek spray unit in eastern Oregon illustrate these points. The Camp Creek unit resembled situations frequently encountered in western Oregon because the spray boundaries were close to but did not include live streams (Fig. 8). The concentrations of herbicide in Camp Creek after spraying were low and persisted for only a short time (Table 5).

Table 5. — Concentration of 2,4-D in Camp Creek

<table>
<thead>
<tr>
<th>Hours after spraying</th>
<th>2,4-D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ppb)</td>
</tr>
<tr>
<td>0.1</td>
<td>T</td>
</tr>
<tr>
<td>2.0</td>
<td>25</td>
</tr>
<tr>
<td>5.4</td>
<td>1</td>
</tr>
<tr>
<td>8.7</td>
<td>1</td>
</tr>
<tr>
<td>84.5</td>
<td>3</td>
</tr>
<tr>
<td>1 week</td>
<td>0</td>
</tr>
</tbody>
</table>

1 Rate of application - 2 lb./acre.
The Keeney-Clark spray unit in eastern Oregon illustrates a particular type of problem. This unit is a fairly flat, marshy area which contains several small live streams (Fig. 9). Standing water was noted in several areas at the time of treatment which suggested a high water table.

High concentrations of herbicide were found shortly after application (Table 6). The long persistence of fairly high concentrations of herbicide is characteristic of what would be expected from treating areas of this type. The length of time measurable concentrations flowed from this area is unknown. This particular situation is probably one of the most dangerous in terms of potential stream contamination. A slight rise in the water table could result in the release of large quantities of herbicide to the streams which drain this area.

I want to stress one point based on the data presented. Short-term high-level contamination results from direct application of herbicide to the water surface. This can be reduced markedly by excluding streams from treatment areas. In other words, if you do not want it in the water, then don’t put it there.

**Movement of Chemicals From Treated Areas to Streams**

The forest floor is a large reservoir of potential stream pollutants. Any amount of herbicide that has not been degraded, volatilized, or adsorbed is available for leaching or surface runoff.
Table 6. — Concentration of 2,4-D in streams in Keeney-Clark Meadows

<table>
<thead>
<tr>
<th>Hours after spraying</th>
<th>2,4-D (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>840</td>
</tr>
<tr>
<td>2.5</td>
<td>48</td>
</tr>
<tr>
<td>3.1</td>
<td>128</td>
</tr>
<tr>
<td>3.6</td>
<td>106</td>
</tr>
<tr>
<td>4.1</td>
<td>106</td>
</tr>
<tr>
<td>6.1</td>
<td>121</td>
</tr>
<tr>
<td>8.1</td>
<td>176</td>
</tr>
<tr>
<td>9.6</td>
<td>138</td>
</tr>
<tr>
<td>14.3</td>
<td>113</td>
</tr>
<tr>
<td>37.8</td>
<td>91</td>
</tr>
<tr>
<td>56.4</td>
<td>76</td>
</tr>
<tr>
<td>100.1</td>
<td>115</td>
</tr>
<tr>
<td>103.6</td>
<td>95</td>
</tr>
<tr>
<td>289.9</td>
<td>5</td>
</tr>
<tr>
<td>297.0</td>
<td>7</td>
</tr>
</tbody>
</table>

1 Rate of application — 2 lb./acre.

The mechanism by which chemicals are moved from spray deposit to a stream may be visualized as two competing reactions: leaching and surface runoff (Fig. 10).

Figure 10. — Chemical movement to streams.
Rainfall that is not lost through evaporation either enters the soil profile or runs over the surface. In either case, it carries surface deposited chemicals either in solution or as suspended matter. The greater the proportion of water entering the soil profile, the lower the proportion of water available for surface flow. In general, where the water goes the chemical also goes, but not as fast. There are numerous factors which influence the distribution of water between surface flow and infiltration. Some of these factors are:

1. Nature of surface
   a. Amount of surface organic matter.
   b. Slope.
   c. Depth of soil profile.
   d. Infiltration characteristics of soil.
   e. Immediate previous precipitation history.

2. Nature of precipitation
   a. Intensity.
   b. Duration.
   c. Form.

Factors which favor infiltration will decrease the amount of surface runoff occurring and with it the overland flow of chemical. These factors influence the amount of herbicide entering the stream due to surface flow:

1. Distance from stream course to closest point of herbicide application.
2. Infiltration properties of soil or forest floor.
3. Rate of surface flow.
4. Absorptive characteristics of surface materials.

Conditions which retard the rate of discharge of surface flow to the stream will result in a decrease in the immediate level of contamination. It will also reduce the long-term total stream load of herbicide because a longer residence time in the soil will provide greater opportunity for degradation of herbicide.

Surface flow or mass overland flow has the potential to carry a lot of chemical over a long distance in a short time. However, hydrologists say overland flow of this type seldom occurs on western forest lands because the infiltration capacity of the forest floor and soil is much larger than most rates of precipitation. Therefore, most pesticide residues enter the soil where absorption will prevent their rapid or extensive movement.

Leaching is a slow process capable of moving only small amounts of herbicide short distances. It offers little potential for serious stream pollution because the herbicide is available for degradation for a long period of time before sufficient movement would occur to permit release to a stream.
CONCLUSIONS

The biological action of a chemical depends on the likelihood organisms will be exposed to the chemical and on the intrinsic toxicity of the chemical. We have no control of the latter, but we can markedly influence the exposure of organisms by taking advantage of the behavior characteristics of the chemical. The behavior of a chemical results from an interaction between properties of the chemical and properties of the environment. This interaction is directed by the laws of nature. The effective and safe use of chemicals can be increased by maximizing exposure of target organisms and minimizing exposure of nontarget organisms.

The section on the chemistry of pesticides by Montgomery (in this proceedings) should be studied in connection with the behavior of chemicals covered in my presentation. The principles in these papers can be applied to the specific chemicals you will be involved with. Learn the behavior characteristics of chemicals before you use them. This will help you insure that your operations are both effective and safe.

Literature Cited


As any high school biology student knows, insects are animals having all the usual organs of animal life such as the brain, heart, stomach, central nervous system, and others which function as kidney and liver. This means that poisons designed to kill insects must be aimed at the same kind of body functions as those possessed by the higher animals. Insecticides as a class, therefore, are more to be feared than certain other pesticides.

There are, of course, fundamental differences between insects and vertebrate animals and these provide the margins wherein insecticides can be used without harming the higher animals. The main difference is in the body covering of the insect, and in the fact that just beneath this skeleton lies an open blood stream. Thus, modern insecticides penetrating the cuticle of the insect can be likened to intravenous injection of such poisons in higher animals.

Response to toxic substances:

Everyone is familiar with the bell-shaped curve which is used to show how some characteristic of an organism will vary in a population of that organism. Visible evidence of such variation includes such characteristics as weight, height, or color. This same type of distribution occurs with invisible traits such as response to a poison. The lesson we learn from this is that response to a poisonous material varies within a species in such a way that it will produce a bell-shaped curve. An example of such a curve is shown in Figure 1, curve no. 1. We could look upon such a curve as if it were a profile of a population’s response to a poison. This curve indicates that there will be a few individuals in the group which will be highly susceptible to the poison and a few others which will be tolerant of the poison, and that most of the individuals will lie between these extremes.

If a population is quite uniform in its response to a poison, the bell-shaped curve representing that population will be narrow and tall. A population which shows a wide divergence in response to a poison will have a curve which is broad and short. When we plot the results of an experiment in which small groups of animals or plants are each treated
with a different level of a toxicant and the mortality response noted, we do not obtain the bell-shaped curve, but instead we see the sigmoid curve (Figure 1-2). This curve is difficult to use and so the toxicologist has learned to plot the data in a different way. By converting the percent mortality values into probits, which are related to the “response” axis of the bell-shaped curve, and the dosage units into logarithms, the data now plot in a straight line such as shown in Figure 1-3. If the bell-shaped curve for the population under study is narrow and tall, the line which is plotted will have a steep slope and if the more divergent population is involved, the line which is plotted will have a low slope. In either case the line represents the population just as accurately as the sigmoid and bell curves and it is a lot more useful. For example, one can compare several species

Figure 1. Graphical methods of expressing dosage mortality relationships.
by plotting their dosage-mortality lines side by side on a graph, Figure 1-4. Also an estimate can be made of the amount of poison which will kill some portion of a population. This is the way the LD$_{50}$ values are obtained.

These straight line plots can be used to study the species response to a toxicant as is illustrated in Figure 1-4 where species A, B, and C are compared. It is clear that population A is more susceptible to the poison being tested than populations B or C, and it should be clear, too, that population B has a wider range of response to the poison than does A or C. In other words, we say that population B is more heterogenous, i.e. its bell-shaped curve is broad and flat, compared to populations A or C.

Variation in species response to poisons:

The emphasis in the previous section was on the way in which individuals of a single population of one species could be expected to vary in their response to a toxicant. Another type of variation, i.e., in the way in which different species may respond to a toxicant, is more commonly understood. It may be instructive for the person who uses pesticides to compare their toxic doses. The following tables were made from a booklet recently published by the U. S. Department of Interior (1) and are of a special interest because they deal with wild life species. In order to simplify these tables, data on age, sex, and statistics have been omitted. Anyone who is interested can obtain the booklet for more detailed information about these poisons.

In Table 1 we see that aldrin is approximately 30 times more toxic to pheasants than to mallard ducks, and dieldrin is about 4 times more toxic.

Table 1. Toxicity of some chlorinated organic compounds to ducks, pheasants, and deer.

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Mallards</th>
<th>Pheasants</th>
<th>Mule Deer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldrin</td>
<td>520</td>
<td>16.8</td>
<td>--</td>
</tr>
<tr>
<td>Arochlors</td>
<td>&gt;2000</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Chlordane</td>
<td>1200</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>DDT</td>
<td>&gt;2240</td>
<td>1296</td>
<td>--</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>381</td>
<td>79.0</td>
<td>75 - 150</td>
</tr>
<tr>
<td>Endrin</td>
<td>5.64</td>
<td>1.78</td>
<td>--</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>70.7</td>
<td>40.0</td>
<td>139 - 240</td>
</tr>
</tbody>
</table>
to mule deer than to ducks. The extremely high toxicity of the organophosphorus insecticides to most forms of life is illustrated in Table 2. The standard aspirin tablet weighs about 300 mgs. If mallards and pheasants weigh approximately 1 kg (2.2 lbs), then the amount of any of the compounds listed in Table 2 which would be fatal to 50% of the birds in the population would range from 1/150th to 1/3rd of the weight of an aspirin tablet. Although these may seem like very small amounts indeed, we should look at the picture from another angle before becoming alarmed. Let us consider how much browse a mule deer would have to eat to obtain a toxic dose of zectran (Table 3). As a rough approximation we

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Mallards</th>
<th>Pheasants</th>
<th>Mule Deer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abate</td>
<td>80 - 100</td>
<td>31.5</td>
<td>--</td>
</tr>
<tr>
<td>Azodrin</td>
<td>4.76</td>
<td>2.83</td>
<td>25 - 50</td>
</tr>
<tr>
<td>Baytex</td>
<td>5.94</td>
<td>17.8</td>
<td>--</td>
</tr>
<tr>
<td>Diazinon</td>
<td>3.54</td>
<td>4.33</td>
<td>--</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>41.7</td>
<td>--</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Parathion</td>
<td>2.13</td>
<td>12.4</td>
<td>22.0 - 44.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Mallards</th>
<th>Pheasants</th>
<th>Mule Deer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baygon</td>
<td>11.9</td>
<td>20.0</td>
<td>--</td>
</tr>
<tr>
<td>Furadan</td>
<td>0.397</td>
<td>4.15</td>
<td>--</td>
</tr>
<tr>
<td>Lannate</td>
<td>15.9</td>
<td>15.4</td>
<td>11.0 - 22.0</td>
</tr>
<tr>
<td>Sevin</td>
<td>&gt;2179</td>
<td>&gt;2000</td>
<td>200 - 400</td>
</tr>
<tr>
<td>Zectran</td>
<td>3.0</td>
<td>4.5</td>
<td>20 - 30</td>
</tr>
<tr>
<td>Ceresan L</td>
<td>&gt;2000</td>
<td>1190</td>
<td>--</td>
</tr>
<tr>
<td>1080</td>
<td>9.11</td>
<td>6.46</td>
<td>0.30 - 1.00</td>
</tr>
<tr>
<td>CIPC</td>
<td>&gt;2000</td>
<td>---</td>
<td>--</td>
</tr>
<tr>
<td>Atrazine</td>
<td>&gt;2000</td>
<td>---</td>
<td>--</td>
</tr>
</tbody>
</table>
will assume that browse in an area where zectran had been used will contain this pesticide at about 10 ppm (10 mg/kg of browse). To obtain the acute dose of about 625 mgs of zectran a 55 lb mule deer would have to eat 137 lbs of browse. Those who are familiar with the mule deer’s eating habits can estimate the margin of safety afforded, but it is obvious that a deer would have to be ravenous to eat himself into the grave by way of zectran.

For still another practical (but hypothetical) example, let us consider the case of pheasants eating treated seed grains. From Table 3 we can see that the insecticide furadan is toxic to pheasants at about 4 mg/kg. This means that a pheasant weighing 1 kg would have to eat about 4 gms of furadan-treated seed grains (assuming a concentration of 1000 ppm) to obtain a toxic dose. This seems to be well within the realm of possibility and explains why pheasants, or their young, are sometimes killed by such exposures.

**Personal safety in the use of insecticides:**

When handling pesticides it is important to remember that routes of exposure other than by mouth can also be dangerous. Many pesticides are liquids in their natural form at ordinary temperatures and they are often soluble in fatty materials. This means that a toxic substance may be able to penetrate the skin in large enough quantities to be toxic. A comparison of the toxicity of two groups of insecticides to white rats by dermal and oral routes is given in Tables 4 and 5 (2).

<table>
<thead>
<tr>
<th>Compound</th>
<th>Oral LD&lt;sub&gt;50&lt;/sub&gt;, mg/kg</th>
<th>Dermal LD&lt;sub&gt;50&lt;/sub&gt;, mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>Co-Ral</td>
<td>41</td>
<td>15.5</td>
</tr>
<tr>
<td>DDVP</td>
<td>80</td>
<td>56</td>
</tr>
<tr>
<td>Diazinon</td>
<td>108</td>
<td>76</td>
</tr>
<tr>
<td>Disyston</td>
<td>6.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Guthion</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Malathion</td>
<td>1375</td>
<td>1000</td>
</tr>
<tr>
<td>Parathion</td>
<td>13</td>
<td>3.6</td>
</tr>
</tbody>
</table>
Table 5. Acute oral and dermal LD₅₀ values of chlorinated hydrocarbon insecticides for male and female white rats.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Oral LD₅₀, mg/kg Males</th>
<th>Oral LD₅₀, mg/kg Females</th>
<th>Dermal LD₅₀, mg/kg Males</th>
<th>Dermal LD₅₀, mg/kg Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldrin</td>
<td>39</td>
<td>60</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Chlordane</td>
<td>335</td>
<td>430</td>
<td>840</td>
<td>690</td>
</tr>
<tr>
<td>DDT</td>
<td>113</td>
<td>118</td>
<td>--</td>
<td>2510</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>46</td>
<td>46</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>Endrin</td>
<td>17.8</td>
<td>7.5</td>
<td>--</td>
<td>15</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>100</td>
<td>162</td>
<td>195</td>
<td>250</td>
</tr>
<tr>
<td>Lindane</td>
<td>88</td>
<td>91</td>
<td>1000</td>
<td>900</td>
</tr>
<tr>
<td>Thiodan</td>
<td>43</td>
<td>18</td>
<td>130</td>
<td>74</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>90</td>
<td>80</td>
<td>1075</td>
<td>780</td>
</tr>
</tbody>
</table>

The most striking example of toxicity by the dermal route is seen in the case of disyston and parathion (Table 4) both of which are approximately as toxic by one route as the other. On the other hand, there are several examples in the table where the oral route is much more dangerous than the dermal route, e.g. guthion and diazinon.

The same point is illustrated in Table 5 which shows some toxicities of some chlorinated hydrocarbon insecticides. Another point illustrated in these two tables is the sex difference in the toxicity of such compounds. In Table 5, for example, both endrin and thiodan are considerably more toxic to females than to males, whereas heptachlor is more toxic to males than to females. These and many other examples which could be shown indicate that there are many factors involved in the toxicity hazard of a pesticide.

Another very dangerous route of exposure is by inhalation. If their physical properties are suitable, toxicants entering the lungs can readily enter the blood stream. As one authority described this possibility, “It is like receiving an intravenous injection.”

**Detoxication:**

Detoxication is a metabolic process which has evolved as life progressed through the various ages of the earth. It usually results in the conversion of fat soluble substances into water soluble substances which can be excreted from the body. During these transformations the molecules are usually,
but not always, made less toxic. For a compound to be poisonous it is usually necessary for it to possess a subtle blend of properties which permit it to move into the animal, through a variety of membranes, and finally to bind in an appropriate manner with some sensitive body constituent such as an enzyme. This blend of properties may exist in only one structure. If the organism can cause a change in this structure, it may thus survive.

Since detoxication is done by enzymes and enzymes arise from genes, it is understood why detoxication would be a hereditary trait. The ability to detoxify a given poison would thus depend upon the genetic makeup of the animal or plant. If the right detoxifying enzymes are present, the plant or animal might survive the poison. If not, the poison can survive inside the organism long enough to exert its toxic action.

The evidence now available from the study of detoxication mechanisms indicates that the ability of a class of organisms to detoxify depends upon their place in the evolutionary ladder. For example, animals which have always existed in the ocean are at the bottom of this ladder and those which have become most mobile on the land masses are at the top. The explanation for this difference is that the changing environment of our planet has been a selective force and that "survival of the fittest" has been the law. Gene mutations have provided the variety within a species and the changing chemical environment — toxic gases, toxic plants and animals, venoms, and so forth — have been the selective agents. Thus the organisms which remain in the same environment, e.g. the oceans, have had less opportunity to evolve detoxication mechanisms than those which have moved from the seas to the land.

Examples of these differences in ability to detoxify can be provided by the biochemist. Detoxifying enzymes are found in greatest concentration in the liver. If we compare the ability of liver tissue from the various classes of animals to detoxify a given drug, we will see that the fishes have a low capacity, the amphibians and reptiles next in order, and the birds and mammals the greatest capacity. Such a comparison is shown in Table 6. The enzyme which was studied in these experiments was prepared from the liver of the various organisms shown, and it was used to detoxify the same drug, an azo compound, in all cases (3). It is seen that fish and amphibians are about 1/10 as active in production of this enzyme as the birds and mammals and that the reptiles are intermediate in this capacity. Many other examples such as these can be shown to illustrate the point that differences in ability to survive a poison reside in the animal's basic physiology.
Table 6. Azo reductase activity in liver of various species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Sex</th>
<th>Azo reductase, μM sulfanilamide formed/gm liver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lemon Shark</td>
<td>M,F</td>
<td>0.605 ± 0.09</td>
</tr>
<tr>
<td>Sting Ray</td>
<td>M,F</td>
<td>0.757 ± 0.12</td>
</tr>
<tr>
<td>Amphibia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frog</td>
<td>M</td>
<td>1.34 ± 0.15</td>
</tr>
<tr>
<td>Reptile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turtle</td>
<td>M,F</td>
<td>1.44 ± 0.20</td>
</tr>
<tr>
<td>Horned Toad</td>
<td>M</td>
<td>4.48 ± 0.40</td>
</tr>
<tr>
<td>Bird</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pigeon</td>
<td>M</td>
<td>7.05 ± 0.66</td>
</tr>
<tr>
<td>Mammals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rat</td>
<td>M</td>
<td>5.88 ± 1.34</td>
</tr>
<tr>
<td>Guinea Pig</td>
<td>M</td>
<td>8.97 ± 0.27</td>
</tr>
</tbody>
</table>

These studies on the detoxication mechanisms help answer other questions about toxicity. They have helped us to realize that a sort of “evolution” occurs in the development of the young. In other words, not all of the enzymes of detoxication are available at birth with the consequence that young animals are often more susceptible to poisons than mature animals. An example of this is seen in Table 7 where the

Table 7. Rates of metabolism of various drugs by mice at different ages.

(Results expressed at the % of administered drug which disappeared in 3 hours)

<table>
<thead>
<tr>
<th>Age, days</th>
<th>Aminopyrine</th>
<th>Phenacetin</th>
<th>Hexobarbital</th>
<th>Acetanilide</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>23</td>
<td>11</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>21</td>
<td>70</td>
<td>51</td>
<td>27</td>
<td>17</td>
</tr>
<tr>
<td>Adult</td>
<td>79</td>
<td>49</td>
<td>39</td>
<td>38</td>
</tr>
</tbody>
</table>
ability of mice of different ages to detoxify four different drugs is shown (4). It can be seen that at one day the mouse has no measurable enzyme activity, and it is not until the 21st day that this ability is equal to that of the adults.

Detoxication helps us to explain many other phenomena of toxicity, resistance which develops in insects and other animals exposed to insecticides, selective toxicity, synergism, and induction. All of these phenomena occur because of differences in individuals and in species in the type and activity of those metabolic processes by which foreign toxic compounds are attacked. The most important point to be gained from these considerations is that living organisms vary considerably in the way and the extent to which they respond to toxic substances. The variation may be due to age, sex, species, or to the genetic makeup of the individual. The fact that such variation does exist and is often unpredictable should make us understand why poisonous materials such as pesticides must be handled very carefully.

Literature Cited


SECTION III
ENVIRONMENTAL EFFECTS
Chairman: Leon Terriere
To kill or not to kill. This is the question facing many practitioners of land management strategy, and the question that almost none of us are prepared to answer. Research scientists are being asked to conduct experiments that will provide airtight answers to well-defined pest problems; they are finding out that the problems are not so well defined after all, and with the lack of precise definition, there is no precise answer.

Acknowledgement of lack of precision in findings does not admit that we know less than previously about insect or weed control. It simply recognizes that we have naively overlooked the complete interrelationship of all the living things in the ecosystem, and admits that many factors other than population levels of target organisms are influencing success of pest control strategy. Land managers are discovering that degree of kill is a poor criterion for success, and that the changes in the entire ecosystem, of which the crop is a part, determine whether goals have been met. The purpose of this presentation is to bring into focus the relations among the main components of disturbed ecosystems, and to illustrate in simplified terms how manipulation of the system produces predictable sequences of events during recovery.

Simplification of Ecosystems

The ecosystem concept considers the sum of all the interrelationships among the organisms in a community with each other and with their physical surroundings. Obviously, we cannot handle all the relationships; most of the subtle interactions may never be understood, or perhaps even defined. However, inability to understand the whole system should not discourage us from using the concept of ecosystem in some simplified form. Even incomplete, the ecosystem approach to pest management is far more sound than consideration of pest-crop-chemical relations alone. But simplification is not easy, nor is it obvious which parts of the system we have to consider at first glance. I will address myself to some of the more important functions of ecosystems, and offer my version of what happens when we treat them and when they subsequently rebound.
Primary production

Let us ignore, initially, the things we have been taught about pests and poisons, and examine a few basic principles of biology. Given a seed source, every acre of forest and range land is capable of producing some vegetation. The amount of water and nutrients (given a non-hostile temperature regime), largely determines the amount of vegetation that will grow on a site. The quantity of vegetation that grows (each year) is called primary production. Primary production may be the same regardless of whether the growth contributes to increases in stands of trees or shrubs or whether it dies annually. Primary productivity is generally related much more closely to site productivity than to the species involved in production, and can be used as a measure of growth with any combination of species. Thus, for a given site, we may assume that productivity is more or less constant for any combination of herbs, shrubs and trees; if shrubs and/or trees are present, biomass, the weight sum of a living organisms, will increase with time until the dominant stands mature.

Population dynamics of species

Insects and mammals rely entirely on primary producers. They are totally unable to synthesize their own food. Animals are responsive, both qualitatively and quantitatively, to changes in vegetation, both in quantity and in species. Because of animal mobility, these responses do not have to originate on-site.

Behavior of virtually all individual organisms is influenced by population level. When a species is present in low numbers relative to the supply of food or suitable space, it tends to propagate rapidly and consists of large, vigorous individuals. The tendency to propagate causes crowding, which increases total biomass, but decreases the contributions of individuals to total mass. With continued crowding, there arrives a point at which limits of space, exhaustion of food supply, epizootics, insect epidemics or analogous disasters tend to reduce population levels to endemic status.

The discussion of population dynamics is fundamental to pest management for this reason: the suppression of an organism reduces its numbers, but not its ability to increase. Thus, killing insects, for example, creates a more vigorous breeding population without decreasing the basic reason (i.e., favorable habitat) for the insects reaching epidemic levels. As long as the habitat is suitable for epidemic levels, no amount of killing will prevent trouble, although trouble may be postponed. The same principle holds for animal browsing damage in forest plantations; as long as the habitat is ideal for deer and rabbits, they will be present regardless of
hunting pressure. Repellants do not solve the problem, and represent almost a blind alley for research because of non-consideration of the source of the trouble.

Plants in some ways behave similarly to animals. Low densities relative to food and habitat tend to promote fast-growing, prolific individuals. Normal yield data for conifers always point to the tendency for stands to increase in stocking with increasing age, but for stands to decrease in density when they become too crowded. With the exception of species that have evolved in pure stands, epidemic populations (i.e., extensive pure artificially propagated stands), have a tendency to be prone to beetle attack, disease or similar fate. Continuing the analog, thinning a forest, like harvesting some deer or killing some insects, stimulates more rapid growth of individual residual trees. Spraying brush, similarly, may result in profuse sprouting of the residual stand.

Plants are different from animals in the important sense of being immobile, hence unable to invade rapidly. Depression of animal populations results in an increase in propagation rate plus immigration. Depression of a plant population may result in an increase in propagation, or the plant may be replaced in the community by a less-affected competitor. Thus, damage to a plant community is much more likely to result in a change in community structure than when animals bear the direct effects of treatment.

In summary, behavior of individual species after treatment depends on mobility, habitat, residual numbers, their innate capacity to grow and reproduce, and (frequently least of all), direct effects of pesticides.

**Community dynamics**

Interaction among species in a typical ecosystem stimulates the observation that the whole system cannot be described as the simple sum of its individual components. The large number of components in any system, however, necessitates grouping by species characteristics in order to reduce the numbers of interactions that we must visualize.

Components of forest and range ecosystems can be grouped legitimately into a relatively small number of groups, as follows:

1. Fauna
   a. Insects
   b. Mammals
   c. Other
2. Flora
   a. Microorganisms
   b. Herbs
   c. Shrubs
   d. Trees
3. Abiotic
   a. Climate, both macro- and micro-
   b. Soil
   1) Moisture retention capacity
   2) Nutrient capital
   c. Water
Obviously, there are some components of this system that are not subject to change, or for which changes have relatively little impact on the general system. Thus, we may simplify the system being manipulated to that consisting of insects, mammals, herbs, shrubs, trees, soil moisture, soil nutrients, flowing water and microclimate. In simplifying to this degree, we must not ignore the presence of other features of the ecosystem, and recognize that our consolidation of factors is only a necessary effort to simplify a complex system to some level of complexity which can be handled.

The way any given component of the system affects others depends on the specific component. Insects, for example, are generally host-specific. Thus, the host and weather determine the habitat suitability for the insect, in response to which the insect may influence the host. The insect effect on the rest of the system, however, depends on the changes in host species that the insect brings about. Consider the role of the spruce budworm, and its impact on a system dominated by balsam fir. The defoliator stays endemic during periods of adverse weather, and where balsam is a minor part of the forest. With continued freedom to grow without pestilence, the balsam assumes an increasing position of dominance in the stand, to the point where habitat for the budworm becomes continuous. At this point, the occurrence of several years of favorable weather for insect reproduction gives rise to a large increase in population, which causes damage to the balsam. Defoliation of the overstory changes the microclimate of the understory, and releases moisture and nutrients that can be used by associated species of trees and shrubs. Thus, the impact of the insect is to increase the role of non-balsam plants in the system, but the direct effect of the insect is exclusively restricted to balsam fir. The indirect effect may be traced through every component of the system, including the effect on mammals of increased understory shrub and herb production.

The above insect example illustrates how an organism may have a direct effect on only one other part of the system, which subsequently affects other organisms. In contrast, consider the role of the balsam fir itself. This species may dominate the system entirely, influencing the ability of virtually all other vegetation to develop, hence influencing the habitat of all animals and insects present. Changes in the dominant forest canopy species influence virtually all components in the system directly, including the insects that prey on the trees.

In the absence of trees, shrubs enjoy an analogous position of dominance; where neither shrubs nor trees are present, herbs determine the dynamics of the entire system. Mammals and insects have an influence on the vegetation, but are primarily responsive to it.
Within the broad categories discussed above, manipulation produces different changes on fauna and flora. Decimation of an insect population tends to produce a rebound of the same insect population. The same phenomenon is general among animals because of host or habitat specificity. Decimation of a plant population, conversely, may result in the space being occupied by other species, perhaps in a different general group. Thus, removal of Douglas-fir from a forest dominated by Douglas-fir may result in domination of the site by herbs and shrubs. Similarly, removal of bluebunch wheatgrass from a system where sagebrush is present will result in some of the wheatgrass habitat being utilized by sagebrush. Herbs may replace herbs, shrubs may replace shrubs and trees may replace trees within layers.

In summary, an impact on some member of an ecosystem will be translated through the entire system. If the impact is to some component of the fauna, the species composition of fauna will not change drastically as the result of the treatment, but is likely to rebound to former levels if habitat is unchanged. In contrast, damage to a component of the plant community will likely result in changes in community structure as relatively unaffected species utilize the common substrate. In both situations, production in the system tends to remain nearly constant despite suppression of some component. Specific examples will be used in illustration below.

**Ecosystem Response to Management**

**Sagebrush control for range improvement**

Typical rangelands on which sagebrush control is anticipated do not support appreciable tree growth. The systems are generally dominated by shrubs, including sagebrush and rabbitbrush, with varying amounts of annual and perennial grass. Insects are not involved substantially in the parts of the system with which we are concerned. Animals, in the form of livestock, are very important in terms of impact on grass. We will not ignore game animals, but assume their role is largely superimposed on the effects of livestock. Thus, we will characterize the system in terms of shrubs, grass, livestock, water and nutrients.

Application of 2,4-D to this system directly affects only the shrubs. We will assume that if timing is right, rabbitbrush and sagebrush suffer to the same degree, and that typical control amounts to 90 percent reduction in shrubs. The response of the system clearly is not dependent exclusively on the fact that brush was damaged. To begin with, examination of existing grass may reveal that there is an even mixture of downy brome and
bluebunch wheatgrass. The annual downy brome is capable of reproducing and responding to release with a rapid increase in population. The perennial also responds, but more slowly. Moreover, the occupation of site by brome will severely restrict the ability of the perennial to occupy the site vacated by the shrubs. Eventually, the perennial will increase its coverage at the expense of the annual until shrubs recover and reestablish their positions of dominance. After many years, some sort of equilibrium will be established between perennial grasses and shrubs, with very few annuals able to survive. Unfortunately, this system excludes impact of animals thus far, and can be expected to follow the described succession only in their absence.

Livestock prefer perennial grasses to shrubs and annuals. Excessive grazing influence will prevent the perennial grasses from establishing a position of dominance in the above grass community. Without occupation of site by perennials, annuals will increase to form the basis for most of the primary production, sharing the released nutrients and water with recovering shrubs. The impact of livestock is most severe early in establishment of perennials, when the rate of increase is maximum, but absolute increase is low. With low availability of forage, livestock will take a high proportion of the available supply, which severely reduces the ability of the perennial to increase.

To summarize the rangeland situation, the degree to which sagebrush control practices are successful in growing desirable perennial grasses is dependent on a) the ratios of desirable grasses to other species at the time of treatment, b) the aggressiveness of these other species in colonization of released sites, c) the period of non-use by livestock, and d) the regulation of stock usage such that desirable grasses are not utilized at any time to the degree that other species are promoted, with the effect of reducing water and nutrients available for the perennials.

Resiliency of the range ecosystem is expressed here in terms of the rapidity of colonization of released substrate by non-target species, and the short term of low primary production conditioned by elimination of shrubs.

**Release of Douglas fir from mixed shrubs**

The concept of release implies the presence of conifers in numbers sufficient to form a coniferous forest. Although the conifers are certainly trees, at the moment they are codominant or less with shrubs, and must be considered part of the shrub layer. Thus, the biological components important from the standpoint of release are those that are competing for
position in the shrub layer, and those that influence the degree of success in competition, including trees and browsing animals.

Introduction of 2,4,5-T into the system is a typical strategy for promoting growth of conifers. Let's examine response of the generalized system to this treatment. There is evidence that 2,4,5-T has a very selective effect on species. Some shrubs are damaged severely, some slightly and some are not injured visibly. Hardwood trees are frequently unaffected; conifers are not injured. Deer are very responsive to an increase in herbs and sprouting shrubs caused by reduction in shrub layer; it is likely that deer populations in the shrub-dominated community are high at the time of treatment, and become higher.

Unaffected and mildly injured species will rapidly reoccupy substrate vacated by dead and severely injured shrubs; the conifers will tend to be among this group. Conifers and palatable shrub sprouts within reach of the burgeoning deer population will be severely suppressed by deer while the shrub canopy reforms. The increase in herbs will be temporary, and will subside as shrubs regain dominance. The increase in deer population is likely to be followed by substantial decrease when shrubs reform a continuous canopy above browsing levels.

Within the shrub layer, susceptible species will be replaced rather quickly by resistant species. Conifers out of reach of deer, and not suppressed by resistant shrubs, develop rapidly so long as resistant hardwood trees do not dominate the shrub layer above the conifers. The sum effect of such a release treatment is conditioned by three primary factors: a) the degree of hardwood domination of shrubs and conifers, b) the size of conifers with respect to utilization by animals, and c) the degree to which changes of species composition are conditioned by the herbicide. Optimization of release strategy involves recognition of the factors restricting emergence of conifers, and minimizing them without intensifying other adverse factors. Key among the factors to be minimized are hardwood cover and species that attract deer. The concept of planting attractive browse species to provide for preferential browsing is unrealistic, because it promotes deer usage of the area.

**Scarification of brush**

Complete removal of all vegetation from a forest ecosystem previously dominated by shrubs is a very drastic event. Entire populations of mammals are decimated or forced to move to areas already occupied. Soil cover is destroyed, organisms tying up nutrient capital are removed, and disturbance to the ecosystem is extensive.

In areas of moderate climate primary production tends to be restored reasonably quickly after scarification. Extreme severity of temperature or
drought, however, may retard recolonization by herbs substantially.

An immediate response to initiation of primary production is utilization of forage by animals. Animal populations resident on the area at the time of scarification are forced to utilize the scant residual or peripheral cover, but find excellent feed present on cleared sites supporting pioneer vegetation. Virtually all vegetation is within reach in early years after disturbance, and forage developing in full sunlight under these conditions tends to be highly nourishing. Deer populations sometimes increase to such levels that vegetation is essentially stabilized in near-pasture status for several years before non-palatable shrubs increase in dominance. Success of conifers in dominating such a system is very remote, however, unless a species is introduced that is non-palatable, tolerant of full sunlight, and capable of dominating the other non-palatable species present. If the process of scarification includes brush piling, deer are joined by rabbits, and the trees must be unpalatable to both deer and rabbits to achieve dominance, yet still fulfill all the other requirements of a successful pioneer species.

Circumstances that prohibit establishment of vegetation after clearing also suggest that establishment of conifers will be difficult. Moreover, failure of vegetation of any kind to occupy the site is likely to result in loss of productivity of major proportions. Reoccupation of the site with preferred browse species is also likely to prevent the domination of the site by conifers because of browsing and eventual stabilization of cover in non-palatable shrubs. Thus, if necessary for some reason to scarify, the key to optimizing the technique relates to success in avoiding a large component of attractive forage while establishing non-palatable conifers.

Clearcutting

Clearcutting differs from brushfield scarification in two principal respects: 1) resident populations of deer and rabbits tend to be much lower in mature forests than in brushfields, and 2) sprout clumps of brush and residual herbs are far less abundant. Consequently, development of the pioneer community tends to be less influenced by animal activity than on scarified areas, and conifers tend to occupy a large place in the community that develops. Optimizing reforestation practices appears to be related to prompt establishment of conifers before animal problems develop, and before pioneer shrubs and hardwoods form a complete canopy.

Brushfield reclamation sprays

The use of herbicides for general brush control in preparation for planting accomplishes the following: a) reduces demands on soil nutrients and water, thereby promoting heavy development of herbs and shrubs, b)
has no direct effect on wildlife, hence permits animals to become directly responsive to increased availability of food without loss of cover, and c) does not damage resistant shrubs severely, with the resulting shift in species composition, as in release. Because this technique is used in connection with planting, it is probable that the seedlings will be introduced into an environment where intense utilization by animals is inevitable. Unless the seedlings are protected, unpalatable, or too large for animals to damage, the plantation is unlikely to be successful. Typically, community development after spraying and planting is dominated by resistant shrubs and hardwood trees, deer populations are likely to wax and wane as in a release operation, and conifers seldom reach a position of dominance. Optimization of this technique is related to the introduction of non-palatable conifers (in this case not necessarily tolerant of full sunlight, but necessarily tolerant of shade), with the capacity to outgrow woody plants resistant to herbicides.

Involvement of Ecosystem Resiliency in Planning — A Summary

Charges of biocide notwithstanding, ecosystems are resilient. The rapidity of recovery depends on general site productivity and status of biota at the time of disturbance. The various strata occupied by organisms at the time of treatment will be reoccupied, in the case of animals and insects, by largely the same species, and in the case of plants, by the same or different species. The manipulator of the system has the power to control species composition after treatment by deliberate introduction of species.

Simplification of the general system to a few structural components focuses attention on several important interactions within the system that need to be understood in the planning phase of any manipulation strategy. These may be enumerated and used by examining the following questions with respect to a proposed treatment:

a) What species will be affected directly?

1. Will affected species replace themselves, or will they be replaced by others?

2. Will the reoccupation of the vacated niche interfere with treatment objectives?
b) What species will be influenced indirectly?

1. Will affected species, e.g. deer, cows, etc., interfere substantially with development of a stable and desirable vegetation complex?

2. Will corollary treatment of antagonistic species be possible without jeopardizing favorable species (predators, etc.)?

c) What crop species can be utilized in support of management objectives that require minimum disturbance for their establishment?

d) Are we overlooking important plants or animals?

Recognition of normal changes occurring in disturbed ecosystems will help substantially in avoiding practices doomed to failure. Consideration of the concept of ecosystem in even a simplified form also helps plan disturbances that are consistent with changes that occur normally. These can be deliberately utilized to hasten normal changes, rather than to attempt to reverse succession. We have had our fling at bludgeoning problems. Experience thus gained has demonstrated the cost of misjudging the factors limiting success. A grasp of the processes involved in resiliency of ecosystems is likely to overcome many of the errors of problem evaluation, with the result of more sophisticated prescriptions.
HERBICIDE SELECTIVITY

Herbicide selectivity refers to the ability of a chemical to injure or kill one plant without harming another. Chemical selectivity is not a new or unique occurrence. Many examples can be drawn from everyday life. For example, a person using an antiseptic mouthwash is attempting to kill certain biological organisms without injuring himself. A gardener spraying fungicide on his roses hopes to destroy living organisms, the fungi, without damaging the rose bush. In these examples there are large differences between the organisms treated. A rose bush is quite different from a fungus organism.

In the case of herbicide selectivity, we are often attempting to eliminate one plant without harming a very closely related crop. Wild oats, a grass plant, growing in wheat, another grass plant, can be killed without injuring the wheat. Common vetch, a legume, growing in crimson clover, another legume, can be killed without harming the clover. Selectivity can be demonstrated between plants even more closely related than this. Annual bluegrass can be killed without injuring perennial bluegrass.

Although the reasons for selectivity of some herbicides lie hidden in complex and obscure biochemical reactions, the basis for several types of selectivity has been worked out. Herbicide selectivity is a result of a chemical reaching and disrupting a vital process in one plant and not in another. The key words in that statement are reaching and disrupting. Let's take a look at some of the different reasons for selectivity and some examples of how certain plants can be controlled without injury to others.

To be effective a herbicide must successfully fulfill four major steps:

1. It must come in contact with the plant to be controlled.
2. It must be absorbed into the plant.
3. It must move to the site within the plant where it can act.
4. It must remain intact (not be broken down) long enough to disrupt some vital plant function.
Selectivity can depend on differences in any of these four steps.

**Contacting the plant.** Selective contact can be arranged in a variety of ways. Directed sprays are often used to spray small seedling weeds growing in larger crops. An example would be pigweed control in corn. Drop nozzles are used to spray only the small weeds and the lower portion of the corn plant while avoiding application of the herbicide to the top part of the corn plant. Small brush in a forest can be sprayed with a hand gun without injury to the older trees. Special equipment with shields can be used to prevent contact between the herbicide and the desirable plants. This can perhaps be called a type of mechanical selectivity.

Selective contact may be brought about by differences in rooting depths of the weeds and the desired crop. Annual weeds growing in a forest obviously have much shallower rooting systems than the large established trees. If herbicides are applied which remain in the uppermost part of the soil, the small weeds may be killed without injury to the trees even though the trees might be sensitive if their roots were exposed. This is a very common way of selectively controlling weeds and many examples could be cited. These could include the control of downy brome in established crested wheatgrass with atrazine, control of pigweed in established alfalfa with simazine, control of annual bluegrass in perennial bluegrass with diuron, etc.

Selective contact might also be brought about through the use of careful timing of herbicide applications. Paraquat is a highly effective herbicide which kills most plants on contact. However, it has little or no activity through the soil. Therefore, paraquat can often be used to control fast-emerging weeds by applying the material before the crop plant emerges from the soil. The paraquat is inactivated by the soil before it can injure the emerging crop plant.

**Penetration into the plant.** The basis for selectivity of some herbicides lies in their ability to penetrate weedy plants without penetrating into the leaves of the desirable plant. Most plants have a thin layer of wax called the cuticle covering the leaves. This waxy layer can present a barrier to the penetration of herbicides. If the desirable plant has a thick, impenetrable cuticle while the weedy plants have a thin layer, selectivity may be achieved through differences in penetration. An example of this type of selectivity is the use of dinoseb for weed control in peas. Dinoseb would kill nearly all plants if it were injected inside the plant. However, peas have a thick, waxy cuticle and the dinoseb is not absorbed into the leaves. Small broadleaf weeds such as pigweed or lambsquarters have much less protection against the dinoseb and are, therefore, killed.

Some plants have extremely hairy leaf surfaces which prevent the herbicide from penetrating the leaf. Common mullein is such a plant. Its
very fuzzy leaves are difficult to wet and consequently many herbicides do not perform satisfactorily on this weed. The use of wetting agents can be very helpful in overcoming this difficulty.

**Movement within the plant.** Once inside the plant the herbicide must move to its site of action. There are two distinct transport systems within a plant, one for conducting food materials and the other for conducting water and minerals. Some herbicides move exclusively in one and some herbicides move in the other. For example, 2,4-D moves primarily in the food-conducting system while herbicides such as atrazine move entirely in the water transport system. Some herbicides may move more readily in one species than in another. Broadleaf weeds seem to move 2,4-D more readily than grasses which may help contribute to the selectivity of this compound in grasses. Also, the growing point is more exposed in broadleaf plants than in grasses where it is below the soil surface for many weeks. Some materials seem to be bound within the plant rather than being carried along efficiently. In general, although these differences in transport ability may exist, selectivity is not usually entirely dependent upon differences in movement.

**Disruption of vital processes.** Once a material has been absorbed into the plant and has moved to its site of action, it must remain intact long enough to effectively disrupt essential plant processes. There are considerable gaps in our knowledge at the present time as to how all herbicides are effective in killing plants. However, it is known that some biochemical pathways differ from one plant to another. If a herbicide is applied which blocks a reaction present in a weedy plant but not in a crop plant, selectivity would result.

One way that a plant may escape injury from a herbicide is to break it down rapidly. Corn absorbs atrazine just as rapidly as a sensitive plant such as pigweed. The atrazine moves readily into and throughout the corn plant. However, corn has the ability to rapidly convert the atrazine into a form which is not harmful to the plant. Pigweed and other sensitive species are able to make this conversion only very slowly, and, as a result, the level of atrazine soon reaches a toxic level. Here is another example. Propanil is used to control barnyardgrass in rice. We know now that the rice can efficiently convert the propanil to a non-lethal form whereas the barnyardgrass cannot and is killed. Certain insecticides block the conversion of the propanil to its non-toxic form, causing the rice plants to lose their selectivity. Douglas fir can absorb 2,4,5-T during the dormant season but by the time spring growth begins, the herbicide has been broken down or tied up in the plant. Vine maple, on the other hand, is unable to rid itself of the 2,4,5-T and the top growth is generally killed.
An alternate example could be the requirement for a plant to convert a non-toxic chemical into a toxic one. Plants which are sensitive to 2,4-DB have the ability to rapidly degrade the non-active 2,4-DB to active 2,4-D. Legume plants are much less efficient at making this conversion and therefore are spared from the injury which would be caused by the conversion. Douglas fir is resistant to 2,4,5-TB because it cannot convert the compound to 2,4,5-T rapidly enough to cause injury. Pine trees can make the conversion and are injured.

We should recognize, however, that all of the above mechanisms of selectivity are not absolute. Each of these can be affected by genetic and environmental factors. The selectivity of dinoseb in peas, mentioned above, can be destroyed by mechanical damage from equipment passing over the peas or from wind storms which may cause blowing sand to damage the waxy cuticle on the leaves. Absorption into the plant may be influenced considerably by the addition of wetting agents in the solution. Temperature can have a very marked effect on the movement and the activity of the herbicide within a plant. This may result in reduced selectivity between two plant species.

From the mouthwash user to the grower applying atrazine to his corn, the selective action of chemicals can be highly beneficial to society. More knowledge must continually be sought in order to most effectively use the selective properties of our modern herbicides.
Robert F. Tarrant
Forestry Sciences Laboratory
U.S. Forest Service

PERSISTENCE OF SOME CHEMICALS IN PACIFIC NORTHWEST FORESTS

Introduction

"Persistence" is the tendency of a chemical compound to remain in an unaltered form. Results of research on persistence of DDT, phorate, and a number of herbicides indicate that environmental factors, characteristics of application method and rate, and nature of the chemical used are all important factors in determining length of persistence. Persistence of a given chemical cannot be assumed for one area on the basis of results from use in dissimilar localities.

In a paper included in the proceedings of this course, Norris (7) defined "persistence" as the tendency of a chemical compound to remain in an unaltered form. He also covered in some detail the various factors which determine persistence.

In this presentation I will summarize observations of persistence of several insecticides and herbicides used operationally in Pacific Northwest forests. Results of these field and laboratory studies are most valuable in assessing the environmental effects of economic chemicals used to increase forest production.

Persistence of Two Insecticides in Oregon Forests

DDT

The largest all-helicopter insect spray project ever conducted by the U.S. Forest Service was carried out between June 10 and July 1, 1965, in eastern Oregon. To control a serious outbreak of the Douglas-fir tussock moth (Hemerocampa pseudotsugata McD.), 66,000 acres of forest were sprayed with DDT at the rate of 12 ounces per acre.

Since shortly before the spraying, we have studied persistence of the aerially applied DDT in the forest floor and soil (11). A very small amount (0.13 ppm) of "apparent" DDT was found in prespray samples of the forest floor (Table 1). One month after spraying, concentration of DDT in the forest floor was slightly more than 7.5 ppm. Based on weight of the
Table 1. — Concentration of total DDT in the forest floor before and after aerial spraying.

<table>
<thead>
<tr>
<th>Months After Spraying</th>
<th>Total DDT (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.130</td>
</tr>
<tr>
<td>1</td>
<td>7.540</td>
</tr>
<tr>
<td>12</td>
<td>5.437</td>
</tr>
<tr>
<td>24</td>
<td>4.412</td>
</tr>
<tr>
<td>36</td>
<td>3.324</td>
</tr>
</tbody>
</table>

Forest floor, this concentration amounted to 3.08 ounces per acre. Thus, about 26 percent of the intended DDT application of 12 ounces per acre reached the forest floor shortly after spraying.

DDT in the forest floor decreased steadily with time. At the end of the third year after spraying, more than half the DDT originally added to the forest floor had disappeared. Mechanisms of removal of DDT from the forest floor may include volatilization, chemical or photochemical degradation, or bacterial decomposition.

DDT did not leach from the forest floor to underlying soil (Table 2). Concentration of apparent DDT in prespray samples was 0.006 ppm at the forest floor.

Table 2. — Concentration of total DDT in surface soil before and after aerial spraying.

<table>
<thead>
<tr>
<th>Months After Spraying</th>
<th>Total DDT (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3-inch depth</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.006</td>
</tr>
<tr>
<td>1</td>
<td>.006</td>
</tr>
<tr>
<td>12</td>
<td>.029</td>
</tr>
<tr>
<td>24</td>
<td>.012</td>
</tr>
<tr>
<td>36</td>
<td>.006</td>
</tr>
<tr>
<td>3-6-inch depth</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>.002</td>
</tr>
<tr>
<td>1</td>
<td>.002</td>
</tr>
<tr>
<td>12</td>
<td>.006</td>
</tr>
<tr>
<td>24</td>
<td>.003</td>
</tr>
<tr>
<td>36</td>
<td>.002</td>
</tr>
</tbody>
</table>

134
0-3-inch depth and about 0.002 ppm at 3-6 inches. One month after spraying, these DDT levels had not changed, indicating that the forest floor effectively intercepted the spray solution. One year after spraying, DDT in the surface soil was at 0.029 ppm and in the lower soil, 0.006 ppm. This small increase is attributed to the physical action of soil animals and, most probably, to minor, unavoidable contamination during sampling. DDT has a solubility in water of only about 1 ppm (2, 8, 9).

At the end of the second year, DDT had decreased to 0.012 and 0.003 ppm, respectively, in the upper and lower soil depths. By the end of 3 years, DDT in mineral soil was at prespray levels.

DDT concentration in litterfall decreased with time at a greater rate than it did in the forest floor and soil (Table 3). Photochemical decomposition and volatilization may be effective mechanisms of chemical degradation in tree canopies exposed to sunlight. DDT concentration is also reduced in successive litterfall samples because of the constantly decreasing proportion of needles and twigs originally subjected to the spray.

Table 3. — Concentration of total DDT added to the forest floor in litterfall after aerial spraying.

<table>
<thead>
<tr>
<th>Months After Spraying</th>
<th>Total DDT (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>11.32</td>
</tr>
<tr>
<td>7-12</td>
<td>10.32</td>
</tr>
<tr>
<td>13-18</td>
<td>7.12</td>
</tr>
<tr>
<td>19-24</td>
<td>7.49</td>
</tr>
<tr>
<td>25-30</td>
<td>3.92</td>
</tr>
<tr>
<td>31-36</td>
<td>3.08</td>
</tr>
</tbody>
</table>

The input of DDT to the forest floor from litterfall after spraying did not contribute strongly to total amount observed. Total loss of DDT from the forest floor over 3 years amounted to 2.46 ounces per acre, more than three times the amount brought down in litterfall over the same period.

Additions of DDT to the forest floor by throughfall precipitation were insignificant—0.02 ounce per acre for the 3-year period following application. Concentrations varied with season (summer-fall vs. winter-
spring) and, in general, showed a gradual decrease with time (Table 4). DDT concentrations in samples representing the dry summer and fall months were approximately three times greater than those for the wet winter-spring season. Precipitation samples for the 12- to 18-month period after treatment contained higher DDT concentrations than expected relative to the amount of rainfall for the period and the concentrations found at 6 and 30 months. However, the DDT levels, their seasonal variations, and the total range in concentrations found in this study are consistent with normal climatological variations and similar to those reported for other regions (1, 10, 13).

Table 4. — Concentration of total DDT added to the forest floor in throughfall precipitation after aerial spraying.

<table>
<thead>
<tr>
<th>Months</th>
<th>Total DDT Residue (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>0.176</td>
</tr>
<tr>
<td>7-12</td>
<td>0.075</td>
</tr>
<tr>
<td>13-18</td>
<td>0.364</td>
</tr>
<tr>
<td>19-24</td>
<td>0.066</td>
</tr>
<tr>
<td>25-30</td>
<td>0.103</td>
</tr>
<tr>
<td>31-36</td>
<td>0.036</td>
</tr>
</tbody>
</table>

At the end of 3 years, DDT concentrations in throughfall precipitation had decreased appreciably but still were five to 10 times greater than levels found in samples from an untreated forested area in western Oregon (unpublished data). But the total amount of DDT brought down over this period in throughfall precipitation is infinitesimal compared with that part of the intended application that initially reached the forest floor or was deposited in litterfall. Thus, throughfall precipitation was not a significant factor in determining the fate of applied DDT or in maintaining DDT concentrations in the forest floor.

Of a total aerial application of 12 ounces of DDT per acre, 26 percent reached the forest floor initially, 6 percent was brought to the forest floor in litterfall over a 3-year period, and a fraction of 1 percent of the total was washed from the tree canopy over 3 years (Table 5). Thus, about one-third of the total application reached the forest floor.

In Arizona, less than 50 percent of insecticides aerially applied during the summer months was deposited on-target in agricultural spraying. The
Table 5. — Total DDT deposited on the ground surface (forest floor) over 3 years after aerially spraying DDT at 12 ounces per acre.

<table>
<thead>
<tr>
<th>Source of DDT at Ground Surface</th>
<th>Total DDT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ounces per acre</td>
</tr>
<tr>
<td>Initial deposit</td>
<td>3.08</td>
</tr>
<tr>
<td>Total deposit over 3 years from:</td>
<td></td>
</tr>
<tr>
<td>Litterfall</td>
<td>.74</td>
</tr>
<tr>
<td>Throughfall precipitation</td>
<td>.02</td>
</tr>
<tr>
<td>Total, all sources</td>
<td>3.84</td>
</tr>
</tbody>
</table>

distance from the spray aircraft to the target was shown to be inversely correlated with amount of on-target chemical application (12). Aircraft spraying forest lands must fly at far greater heights than those operating over level agricultural fields. Thus, the comparatively high amount of DDT reaching the forest floor is not surprising. This finding reaffirms that efficient methods of aerial spraying must be developed if we are to avoid undue loss of chemical to nontarget areas.

**PHORATE**

Phorate (Thimet) is a highly toxic systemic organophosphate insecticide used heavily in cotton production and also on some truck crops in southwestern United States. This chemical controls insects on cotton for up to 5 months, but residues in soil have disappeared long before harvest. Climatic conditions in southwestern United States, of course, are greatly different from those in the Douglas fir region of the Pacific Northwest.

Phorate was applied broadcast on the forest floor at rates of 1, 10, and 100 pounds per acre in a stand of young Pacific silver fir at each of two western Oregon locations in May 1966 (3). Persistence of phorate and its metabolites (measured as phosphorothiolate sulfone) was determined at the end of each of the first two growing seasons after application. The purpose of this experiment was to determine whether phorate would protect young trees against aphids and whether residue persistence was similar to that in warmer climates.

Mean concentrations in the forest floor after 6 months were 2.04-, 0.58-, and 631-ppm phorate and 2.78-, 26.56-, and 238-ppm metabolite for the 1-, 10-, and 100-pound-per-acre rates, respectively. Complete degradation was quite rapid at the two lower rates as indicated by total
residues of 8.40 and 9.98 percent of chemical applied for the forest floor and surface 12 inches of soil combined. At the 100-pound rate, however, 98 percent of the total chemical applied was still present in the forest floor and soil as phorate or its metabolites. Some downward movement had taken place, but less than 4 percent of the total residue was found below the 3-inch soil depth. After 18 months, measurable levels of both phorate and its metabolites were still present in the forest floor and soil. At the highest rate of application, the mean total residue was 4.50 pounds per acre.

This study shows again that we cannot predict the behavior and persistence of an economic chemical in a forest situation from previous experience under agricultural conditions. Residues in this forest study persisted beyond the first growing season probably due to a combination of factors. During the summer months, microbial activity is low because of dry conditions in the forest soil. Chemical degradation did take place at lower rates, but the highest rate of chemical applied was sufficiently toxic essentially to stop the already low level of microbial metabolic activity. By the time the soil moisture supply increased with fall rains, soil temperatures had already dropped to less than optimum and microbial activity remained low until the following spring.

**Persistence of Herbicides**

Four herbicides are commonly used in the Pacific Northwest to control unwanted vegetation: 2,4-D, amitrole, 2,4,5-T, and picloram. These chemicals are listed in order of persistence. All of them are degraded in the forest floor but at different rates (6).

In red alder forest litter, 2,4-D degrades most rapidly of all (Figure 1). In laboratory studies, after 35 days’ incubation, only 6 percent remained of a total application of 2,4-D at the rate of 2 pounds per acre and only 5 percent remained of a 4-pound-per-acre application. The rate of 2,4-D degradation is slowed somewhat when either 2,4,5-T or picloram is applied with 2,4-D, but after 35 days, total degradation is the same as for 2,4-D alone.

Amitrole also degrades rapidly. After 35 days’ incubation, only 20 percent of a 2-pound-per-acre application of amitrole remained in forest floor material. Persistence of amitrole was not affected when 2,4-D was applied concurrently.

Degradation of 2,4,5-T is somewhat slower than that of 2,4-D or amitrole, but after 120 days, only 13 percent of a 2-pound-per-acre application and 18 percent of a 4-pound-per-acre application remained in red alder forest floor material.
Picloram (trademark Tordon) is a relatively new herbicide of considerable potential use in controlling unwanted vegetation. It is normally applied at a lower rate than 2,4-D or 2,4,5-T but frequently in combination with them. When picloram was applied at 0.5 pound per acre with and without 2,4-D at 2 pounds per acre, there was no significant difference in persistence of picloram (6). After 180 days, however, more than 60 percent of the initial application of picloram remained in the forest floor.

Results of these laboratory studies have been confirmed by field studies of operational spraying. A number of monitoring observations in western Oregon and Washington have indicated that when forest lands are sprayed with herbicides during the spring growing season measurable quantities of herbicides are not present in streamwater during the first fall rains. Such rains did not introduce measurable amounts of herbicides in the streams flowing through the small scattered treatment units resulting from operational vegetational control measures. These findings are true for 2,4-D, 2,4,5-T, and amitrole. Even in cases where a fairly large proportion of a single watershed is treated with herbicides and where the treatment unit is oriented for a considerable distance along the stream, no measurable amount of herbicide was found after the first fall rains (4). Thus, unless a heavy application of chemical is made directly into the stream, the major potential for stream contamination from herbicide use
in the forest is from heavy rain or soil movement resulting in overland flow of water and sediment shortly after application. Such conditions occur only rarely.

Picloram is sometimes applied with phenoxy herbicides in the summer for brush control on powerline rights-of-way over forest lands. The effect of such summertime spraying on streamwater quality after the first few fall storms has been studied.

Runoff of picloram and phenoxy herbicides can occur after the first heavy autumn rains if the chemicals are applied in mid- or late summer. The greatest potential for herbicide runoff appears when early fall storms are sufficiently intense to cause overland flow rather than infiltration of water. The resulting amount of stream contamination is determined largely by the proportion of the watershed that is treated (5). In our studies, contamination was very low—a maximum of 6 ppb was found in only one sample.

Summary

In an eastern Oregon forest, more than half of the DDT originally reaching the forest floor after aerial spraying had disappeared at the end of the first 3 years after spraying. None of the applied DDT was present in the mineral soil at the end of 3 years.

Under western Oregon conditions, residues of the highly toxic systemic organophosphate insecticide phorate degraded quite rapidly when application rate was either 1 or 10 pounds per acre. However, at an application rate of 100 pounds per acre, about 98 percent of the chemical was still present in the forest floor and soil after 6 months. At the 100-pound-per-acre rate, a total residue of 4.50 pounds per acre was still present after 18 months. Findings from this study under forest conditions are entirely at variance with those for the same chemical used on agricultural crops in a warmer climate.

Of four herbicides studied, 2,4-D degrades most rapidly. Amitrole also degrades rapidly, but 2,4,5-T and picloram are of somewhat longer persistence. Studies of streamwater following first rains after application of these chemicals indicate, however, that 2,4-D, 2,4,5-T, and amitrole residues are not available for transport to streamwater after having weathered over one summer.


When some kinds of pesticides are diluted and released into the environment, the chemicals tend to accumulate and become highly concentrated in the tissues of certain organisms. For a specified chemical and set of environmental conditions, the results of this process are predictable within broad limits, because the pathway of accumulation is essentially the same pathway by which nutrients and energy are transferred in ecosystems. Mechanisms of nutrient and energy transfer from organism to organism in food chains have interested ecologists for a long time. The basic pathway is as follows:

Solar Energy
  (Photosynthesis)
  Producers (Plants)
    Primary Consumers (Herbivores)
      Secondary Consumers (Omnivores, Carnivores)
        Tertiary (etc.) Consumers (Carnivores, Parasites)
          Decomposers (Bacteria, Fungi, etc.)

The actual number of links or trophic levels varies, but is limited by efficiency of energy transfer. Generally, only about 10% of the energy in any trophic level is transferred to the next level—the remainder is used to maintain life's processes or is lost through waste products.
The term “food chain,” which is often used to describe food relationships among organisms, implies a straight line pathway and is, therefore, seldom appropriate. In practice, nutritional relationships are usually a complex network, more accurately described as a food web. Thus, a kind of grass may be consumed by various animals including cows, insects, rodents, and other organisms; one species of insect may provide food for many kinds of birds, spiders, other insects, or even fish.

Regardless of the actual pathway involved, certain generalizations apply to trophic levels and energy transfer in natural ecosystems. In simplest form, these state that the number of individuals, the amount of energy, and the amount of biomass tend to decrease from lower to higher trophic levels. Estimates of annual productivity (tons dry weight) for a 30,000 square mile area off the coast of Southern California illustrate this decrease: phytoplankton 42,000,000, zooplankton 3,000,000, fishes 100,000, and sea mammals 300 (Frost, 1969). Although there are some exceptions, these generalizations apply to most fundamental food webs. Thus energy and nutrients are passed in decreasing amounts from producers through succeeding trophic levels to a relatively few top carnivores near the top of the food web.

A pesticide having the right chemical and physical properties will be accumulated in the various trophic levels and transferred in additive fashion from one level to the next. This process, often termed biological magnification, may result in large amounts of pesticide residues reaching top carnivores, the terminal predators who are not themselves prey to other kinds of organisms. Note that the concentration of pesticide in various trophic levels increases as other ecological parameters such as number of individuals and amount of energy and biomass decrease.

What properties of a pesticide favor the process of accumulation in succeeding trophic levels? The basic prerequisites are availability and persistence.

**Availability.** Obviously to be accumulated, a chemical must be available to organisms capable of doing the accumulating. Aquatic environments are ideally suited for accumulation because organisms are actually emersed in the medium containing pesticide. In a simple system involving algae being eaten by small crustaceans, these by fish, and these by eagles, all organisms except the eagles remove large amounts of pesticide directly from the water. Peterle (1969) found that an alga accumulated 218 ppm DDT only 3 days after a marsh was treated. This amount was 3,000 times the mean level applied to the environment. In addition to direct uptake from the environment, each kind of organism passes a portion of its accumulated pesticide to the next trophic level.
Although pesticides occur and are transported in air, the concentration tends to be minimal and there is limited opportunity for terrestrial organisms to accumulate significant residues directly from the atmosphere. Large amounts of pesticide residues occur in soils, particularly in agricultural areas, and many terrestrial organisms accumulate pesticides directly from soils.

**Persistence.** For a pesticide to accumulate in succeeding trophic levels, it must be capable of persisting in the environment and within the tissues of organisms.

Some pesticides are termed non-persistent because they tend to decompose quite rapidly in the environment. Usually within several days to about 12 weeks. Natural processes such as the activity of sunlight or exposure to air may hasten decomposition. Other pesticides are biodegradable and may be chemically altered and detoxified by various organisms. Most pesticides are moderately persistent with lifetimes of 1 to 18 months, e.g., 2,4-D and Atrazine.

Among pesticides, only the organochlorine insecticides and various inorganic compounds have proved to be troublesome because of persistence. DDT and its metabolites are apparently the most persistent of the modern synthetic pesticides. Other commonly used organochlorine insecticides having notable persistence properties include aldrin (which breaks down to dieldrin), chlordane, dieldrin, endrin, heptachlor, mirex, Strobane, and toxaphene. Others, such as methoxychlor, may be moderately persistent, as contrasted with certain organo-phosphate compounds, but seldom are considered a hazard because of persistence in the environment.

Persistence in the environment does not insure that an insecticide will be accumulated in succeeding trophic levels. A further requirement is that the compound be retained without significant modification within the tissues of organisms. If the chemical is metabolized or excreted, the rate of intake must exceed these losses. In practice, many of the chlorinated hydrocarbons are fat soluble and virtually insoluble in water. Once inside an organism, these insecticides accumulate in fat deposits and tissues containing high amounts of lipids. Because the excretory systems of most organisms depend upon transport and removal of substances in water, these insecticides tend to be retained. Stored in fat, the residues persist until the organism is consumed by another, whereupon some portion of the stored insecticide becomes incorporated into the fatty tissues of the new animal. Highly persistent insecticides are capable of recycling through the ecosystem again and again.

Certain inorganic substances used as pesticides, such as arsenic and mercury, may accumulate in tissues of animals and defy normal excretory
processes. Unlike persistent chlorinated hydrocarbons, these inorganic materials accumulate in various tissues—not just in fatty deposits.

With these general concepts of biological magnification in mind, we can examine some examples of data illustrating how the process works.

Butler (1968) estimates that 1 ppb pesticide in sea water may be concentrated to 70 ppb in plankton, 15,000 ppb in fishes, and 800,000 ppb in porpoise blubber.

In a Long Island estuary, plankton contained 0.04 ppm DDT, fish about 1 ppm, and birds about 5 (range 3-76) ppm (Woodwell, Wurster, and Isaacson, 1967).

Hickey, Keith, and Coon (1966) reported the following DDT residues in a study of a freshwater ecosystem (Lake Michigan): sediments 0.0085 ppm, small invertebrates 0.41 ppm, fish 4-8 ppm, Herring gulls 99 ppm (up to 3,177 ppm in fat).

In 1961 Davis Lake in Oregon was treated with an estimated 88 ppb toxaphene to eradicate fish and lampreys (Terriere et al., 1966). In 1963 average toxaphene residues in various parts of the Davis Lake ecosystem were as follows: water .00041 ppm, bottom mud 0.8 ppm, aquatic plants 0.21 ppm, aquatic invertebrates 0.47 ppm, and rainbow trout 7.72 ppm. A deeper lake treated with 40 ppb toxaphene could not be restocked with trout for 6 years.

In terrestrial environments, soil inhabiting animals such as earthworms are important concentrators of pesticides. In areas sprayed with DDT for control of Dutch elm disease, residues (dry weight) in the top inch of soil were 19 ppm, but earthworms in the same soil contained 157 ppm (Hunt, 1965).

Fish-eating and raptorial birds, salmonid fishes, and certain filter-feeding invertebrates are particularly efficient accumulators of large body burdens of residues of chlorinated hydrocarbon insecticides. Oysters are able to accumulate in their tissues up to 70,000 times as much DDT as is present in ambient sea water (Butler, 1970).

Clear Lake in California was treated three times with DDT concentrations intended to result in 0.02 ppm in the water. A large breeding colony of Western Grebes failed to return to Clear Lake a year after the first treatment, and many wintering grebes died when they visited the lake. As much as 1,600 ppm DDT was found in the visceral fat of dead grebes (Hunt and Bischoff, 1960).

Reinert (1970) reported that concentrations of DDT in water samples from Lake Michigan ranged from 1 to 3 ppt, but large lake trout (16-21 inches) contained 6.61 ppm DDT in the whole body and 35.62 ppm in extractable oils.
The significance of biological magnification of pesticide residues in succeeding trophic levels depends upon numerous extenuating circumstances. Animals having a restricted diet may be more vulnerable than those having a diversified diet. For example, robins, which feed predominantly on earthworms, were particularly vulnerable to DDT poisoning after trees were sprayed for Dutch elm disease control.

Sensitive organisms in higher trophic levels may be endangered by residue accumulation, an example being the production of thin-shelled eggs in raptorial and fish-eating birds. Brown pelican populations along the coast of California appear to be in danger of extinction because of this process (Risebrough, Davis, and Anderson, 1970).

High body burdens of residues may be tolerated by healthy, well fed birds, but mortality may occur on a starvation diet as fat reserves are depleted and residues released (Stickel, Hayne, and Stickel, 1965).

Certain non-target organisms in intensively sprayed agricultural areas in the Southeast exhibit resistance to persistent chlorinated hydrocarbon insecticides. Resistance has been documented in certain aquatic invertebrates, amphibians, and several kinds of fishes (Ferguson, 1968). Resistance further complicates the already serious problem of accumulation of residues in the trophic levels since resistant fish are able to tolerate exceedingly high concentrations of certain pesticides in their tissues. When resistant mosquitofish were exposed to endrin and force-fed to various predators, most of the predators died, even though some weighed over 700 times as much as the mosquitofish (Rosato and Ferguson, 1968).

Although use of persistent pesticides has declined in favor of nonpersistent ones, large amounts of persistent materials continue to occur in the environment. Woodwell (1968) estimated that there were 1,500 million pounds of DDT and its metabolites circulating in the biosphere. Current information indicates that DDT in the environment may remain toxic up to 20 years. If all persistent pesticides were immediately removed from the market, the problem of biological magnification would persist for many years as currently existing residues recycle in natural ecosystems. This prospect should concern us because man derives a portion of his food supply from meat, fish, and other animal products—we too feed at the top of the food web!

**Literature Cited**


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2,4,5-T, A CASE HISTORY IN EVALUATION OF A POSSIBLE PUBLIC HAZARD

This is a case history on 2,4,5-T, but I prefer to use it as a model for the similar situations which arise sooner or later with all pesticides. With that in mind, I will call this presentation “2,4,5-T, a Case History in Evaluation of a Possible Public Hazard.” The current 2,4,5-T question, is still unresolved, but it will serve as an example to give you some thoughts about environmental toxicology. I am a toxicologist, not a bio-chemist as the original title might imply. As a matter of fact, I am a veterinarian; you don’t often see veterinarians and foresters fretting about the same problem.

Most of the fuss about 2,4,5-T did not arise from forestry and range use, particularly the kind of use you are accustomed to, where application of the agent may only be made once or twice in the production cycle of the tree or perhaps once every several years on grasslands. I am also not talking about problems such as the Globe, Arizona affair that Dr. Norris will discuss shortly, nor am I talking about the spectacular stories in the popular press which associate some illness with use of the herbicide. It is difficult to associate cause and effect in such cases, but it is easy to lead people to unrealistic conclusions by a few careless remarks.

I expect that you are aware of the action of the Secretary of Agriculture last spring in which he suspended or cancelled certain uses of 2,4,5-T. I would like to give you a little of the background of this situation because it is an excellent example of the problems we face when the spectre of a potential health hazard arises.

To begin with, there is a continuing effort by government and industry to learn more about the adverse effects of pesticides, although we are sometimes inclined to ignore compounds which appear to be safe. The problem is that it is scientifically impossible to prove that a pesticide or drug or chemical is absolutely safe. It is impossible to design a toxicological screening program that can assure absolutely that a compound will do all that it is asked to do as an economic poison, but at the same time will also do nothing as an environmental poison. We are
therefore left with the problem of determining that very delicate balance of risk versus benefit. Because it is impossible to quantitatively relate potential toxicity to potential improvement in the human condition, the only acceptable relationship is one of apparent very low risk opposed to apparent very high benefit.

In the 2,4,5-T case the National Cancer Institute contracted with a private research organization to conduct screening tests on more than 50 agents, most of which were herbicides and insecticides. The purpose of these tests was to find any evidence that the compounds might be carcinogenic, that is capable of inducing cancer, or teratogenic, which means capable of inducing birth defects. They found that at certain high doses, 2,4,5-T apparently caused birth defects in laboratory animals. This effect was caused only at high doses which were administered to pregnant animals during about the sixth to thirteenth day of pregnancy in animals whose gestation period was on the order of three weeks. The sequence of embryonic development is such that there is a characteristic period for each species early in pregnancy when an embryo is extremely sensitive to interference. In some cases even temporary starvation of the mother may cause a fetal abnormality. These initial experiments were conducted in 1966; they were repeated with 2,4,5-T of the same purity, and still later NIH scientists completed preliminary studies with 2,4,5-T of higher purity.

The Secretary of Agriculture, advised by the Secretary of Health, Education and Welfare and the Secretary of the Interior, all acting on information transmitted by government scientists who had analyzed the results of those experiments suspended uses of liquid formulations of 2,4,5-T around the home and around water courses. This meant that the agent could not be marketed for the proscribed uses and the label instructions had to be changed immediately. A cancellation order was issued for uses of 2,4,5-T on certain food crops and for uses of granular material around the home. Under this order the use could continue for 30 days or until an appeal had been filed and decided.

The difference between cancellation and suspension is in a sense one of degree. The suspension required an immediate cessation of all uses identified under the order. The cancellation simply stated that unless a good reason for not cancelling could be provided marketing would be prohibited. In the first case it was suspected that there was an imminent hazard to human health. In the second case it was considered that there was a possibility of hazard, and that the evidence available had to be examined to determine whether hazard does in fact exist.

Those laboratory tests represented a strictly artificial situation. However, unlike situations in the field the conditions of such an experiment can be controlled. A probability can be calculated that the
effect of a given dose represents what should happen in the real world under similar circumstances to the particular species tested. From this, some estimate of the likelihood of human hazard in the field may then be made. Unfortunately, even the best of science is laced with ignorance and in this case we cannot really make accurate estimations, so safety factors must be plugged in. For this reason, if a compound has a toxic effect at doses many times greater than one should expect to encounter in the field, it is assumed that there is danger in field exposure simply because there is no certain knowledge that there is no danger.

The suspension and cancellation orders caused distress to the manufacturers and users of 2,4,5-T. Distress notwithstanding the protective mission of the federal agencies must be fulfilled if any evidence of hazard or potential hazard appears. At the same time industrial firms who have been restrained from selling the compound are protected by a system of hearings and advisory committees. The mechanism for assuring a proper decision is as complex as a judicial review and makes it possible to incorporate all available evidence into the ultimate decision on the use of the compound.

In protesting the restrictions on 2,4,5-T the firms involved emphasized three points. 1) The 2,4,5-T used in the early tests turned out to be contaminated with a derivative of one of the chemicals used in the synthesis of 2,4,5-T. This contaminant is present in most current production of 2,4,5-T at a concentration of less than one part per billion. Its concentration was about 27 parts per million in the sample used in the tests which initially raised the question of possible hazard. The subsequent test with limited contamination was considered to show teratogenic effects only at very high doses. Since the contaminant itself is teratogenic in certain cases and was known to be able to cause effects similar to those observed in the tests in question, it was argued that the initial tests were not valid. It was argued furthermore that it was not possible to eat the vast quantities of rice or other treated crops necessary to get enough 2,4,5-T to do harm even if it were teratogenic at the dose levels suggested by the second tests, and besides 2,4,5-T was almost impossible to find on market rice. The third argument was that the contaminant itself existed in such low amounts that the demonstrably unmeasurable residues of 2,4,5-T would be accompanied by infinitely small amounts of the contaminant, and would not endanger the person eating the crop.

Why did all this come up in the first place? It should be possible for us to know enough about these compounds to predict any potential danger instead of being confronted in this way. Other than falling back on the disclaimers I have already made, I would answer in this way: Each
compound has its own peculiar pattern of effects. Some effects are easily seen. Growth inhibition is obvious, if it occurs behavior and performance changes or physical symptoms of illness or even death are clearly visible. But to get to the core of a toxicology problem, particularly one where the victim may be exposed to very low levels over long periods of time, it is necessary to understand in detail how the compound exerts biological effect; we must understand what biological systems it interferes with. This often takes a long time. Trying to find the critical biochemical or physiological defect resulting from intoxication has been the downfall and frustration of most toxicologists, I think.

There is an extension to this problem. Even if we learn about a compound, using laboratory animals we really have no way of predicting what effects an economic poison might have on humans as a species. Even in the rare and unfortunate circumstances where gross poisoning of humans has occurred, great care is needed to identify the source of the damage. The drug Thalidomide caused very unusual birth defects, but even then many damaged infants were seen by physicians before anyone paid attention.

The actual teratogenic potential of 2,4,5-T is disputed but to the limited extent that it may be effective, it apparently causes cleft palate and cleft lip. These defects are frequent in humans and have been for centuries. If these changes were to appear in humans as a result of an environmental intoxication, they would probably never be noticed because they would represent a very, very small increase in a defect which is already rather common. There is also no satisfactory epidemiological data bank to provide historical and current information on this kind of disease on a nationwide basis. The communicable disease center has statistics available on tuberculosis, scarlet fever and measles, as examples, which allow it to identify at anytime a suspicious increase in the incidence of these diseases. In the case of teratologic changes we have no way of knowing whether the advent of the age of pesticides actually increased the incidence of such damage.

There is still a worse problem. These are drastic differences among species in susceptibility to toxic effect. Again the thalidomide case is a good example. The dose required to cause defects in an experimental rodent is very high; some animals are almost insensitive to this compound. Humans are highly sensitive. In any given case, humans may be vastly more sensitive or they may even be insensitive. Unless you wish to volunteer as experimental subjects we have very little capability for predicting effects on humans.

You can imagine what this does to the nervous system of people who must make decisions on the regulation of such agents. They have little
choice. When there is doubt, they must restrict use.

It may be that someday we will have a system which actually can be expected to detect all possible toxic manifestations of a drug or pesticide and it may be that someday there will be enough money available to operate this wonderful system. I suspect that it is going to be quite awhile.

I really haven’t yet said anything about the toxicity of 2,4,5-T and since we are using it as a situation model I think that the least we can do is talk about it a little. It actually isn’t extremely toxic. It causes skin rashes and is very painful in contact with the eyes. But the lethal single dose of the agent to rodents is in excess of 350 mg/kg and in some experiments with sheep and cattle fairly large doses have been fed daily for a year or so without apparent effect. These experiments would suggest that the material is excreted just as fast as it is administered. Some experiments have been done in which the material was found to be disposed of in the urine in a short time and other work has shown that it will apparently not build up even with prolonged feeding. Other things of course are not known. For example, are there metabolic products in plants which are formed and which remain in the plants to be eaten by range animals or even by people? If these compounds do exist, are they potentially dangerous or are they of no concern? At the moment this appears not to be a problem, but complete information is not available. Our world is full of compounds in very high concentrations which apparently are not hurting us. The word “apparently” should worry us.

A short time ago I mentioned a contaminant of 2,4,5-T. This particular compound is a tetrachlorodibenzodioxin and it is quite interesting. It is difficult to keep extraneous compounds out of even highly purified reagents for the laboratory. In production lots, when a material is manufactured by the ton, this is obviously a major problem. In the case of 2,4,5-T there apparently is less than 0.5 ppm dioxin in production from modern factories, but this contaminant is toxic beyond imagination. The median lethal dose to the guinea pig is on the order of six μg/kg. If you will allow me to over-dramatize, this dose related to the weight of the animal is about six parts in one billion. Furthermore, doses of a little more than one tenth of a μg/kg for a few days cause observable embryonic toxicity. The same material is about 5 times less toxic to rats. At concentrations like this a five-fold difference does not really mean much, but the implication is that since we don’t know what the toxicity of the material is to humans we can ask a number of questions. Is the human 5 or 50 times again more sensitive than the guinea pig or is he 50 times less sensitive than the rat? There is no way of predicting. For comparative purposes, this toxicity is in the area of 100,000 times the toxicity of 2,4,5-T itself.
What I am getting at is this. The dioxin has been studied very little because we haven’t paid attention to it. No one knows how it acts precisely. No one knows whether it stores in the body. We have in other words been caught looking the other way because the potential for intake of dioxin seems so small that no one in his right mind should expect harm from it. I hope this is so, but I would certainly like to be a little more certain.

I would recommend to you in closing that you do not get all worked up when people condemn a compound that you need and trust. People may or may not be ignorant of the real situation, but by and large they aren’t stupid. They are worried. Remember that even the people who are best informed about these compounds may not know everything they really need for complete understanding of the problem. No matter how well accepted a compound might be, it must be examined continuously for safety, and at the same time better, safer ways of doing the same job must be sought.
Monitoring is the process of checking for quality and keeping track of any changes in quality with time. It has become the major means by which we determine the present level of contamination of our environment. Almost daily we hear or read new reports on mercury residues in grain or water, organochlorine residues in fish, eutrophication in the Great Lakes, or destruction of our estuarine resources by accumulated pollutants.

Monitoring programs have been initiated all over the country and at all levels of government. Some are nationwide and involve only monthly, quarterly, or even less frequent sampling, but others examine a very local problem and may include weekly, daily, or continuous sampling. Regardless of whether we are assessing the level of air, soil, water, or even noise pollution, all monitoring programs have the same primary objective.

Formal monitoring of the impact of pesticides on the environment was initiated less than 10 years ago. DDT residues had been measured in crops as early as 1945, and the storage of DDT in one man was first reported in 1948 (4). This early monitoring of pesticides in food and people was done to enforce various Federal and State laws, not to determine the impact of pesticide use on environmental quality.

In May 1963, the President's Science Advisory Committee issued a report entitled "Use of Pesticides" (6). A major recommendation of this report called for developing and coordinating a pesticide monitoring program, conducted on a continuing basis by Federal agencies, to obtain "an assessment of the levels of pesticide in man and his environment." Four Federal departments — Agriculture; Defense; Interior; and Health, Education, and Welfare — organized the Interdepartmental Federal Committee on Pest Control. In 1964, this Committee, through its Subcommittee on Pesticide Monitoring, implemented a National Pesticide Monitoring Program. Figure 1 illustrates the extent of the National Pesticide Monitoring Network as of 1967 (1). Most of the programs have been expanded since that time.

Even when every known precaution is taken, pesticide usage always carries a certain amount of unpredictable risk because no effective pest
Figure 1. Nation-wide network of sampling points for pesticide monitoring — June 1967. (Source: (1).)
control chemical is completely selective. Therefore, pesticide monitoring programs are carried out as an integral part of forest pest control projects. Their purpose is to determine the distribution of pesticides in various elements of the forest environment and to observe changes in residue levels with time after application. This information provides the basis for evaluating the potential impact of the pesticide on nontarget organisms.

Planning a Monitoring Program

Intense public concern over possible adverse effects of chemicals on fish, birds, mammals, wildlife habitat, and man demands that all chemical control projects be conducted in a manner fully consistent with the objectives of multiple-use management and protection of the environment. Effective control of the target organism must not be obtained at the expense of a detrimental impact on other environmental components. These goals can be met only by thorough planning which includes preparations for monitoring any critical environmental component in or adjacent to the control unit.

To illustrate the planning and coordination of a monitoring operation, let’s take a brief look at the surveillance program carried out by the Forest Service during the 1965 Burns Tussock Moth Control Project (2, 3). In early fall 1964, as soon as it became evident that aerial insecticide applications might be necessary to control the insect outbreak, meetings were organized to plan monitoring programs. All interested persons, organizations, and agencies were notified of the proposed control project and invited to participate. In addition to State and Federal land management and research agencies, contacts included private land managers, livestock associations, and sportsman, civic, and conservation organizations. Several meetings were held in the months that followed, and by early May 1965 a monitoring plan, based on individual agency proposals, was prepared by the coordinator. The proposed control project, using DDT, had been approved by the Federal Committee on Pest Control in March.

Potential hazards to nontarget biota were many since the entire control area included 66,000 acres in five separate units ranging in size from about 600 to 23,000 acres (Fig. 2). The area provides summer range for deer and elk, and livestock also are permitted to graze on timbered lands and the many interspersed meadows. Most streams in the treatment areas are intermittent so fishery resources are minimal. However, one stream, located adjacent to the smallest of the five units, does support a small run of anadromous fish. In addition, the vast Malheur National Wildlife Refuge is located about 25 miles south of the southern-most treatment unit (Fig. 3). Because of this distance, and since flow from the only waterway from
the insect control area is seldom sufficient to reach the refuge, there was little danger of contamination from the forest spraying, but the possibility did exist.

Final plans for the control project called for application of DDT by helicopter rather than fixed-wing aircraft. This decision permitted the application of insecticide only to those areas specifically needing treatment and simplified the problem of avoiding streams, livestock watering places, meadows, and other nonforested sites. Final plans for the
Figure 3. Malheur National Wildlife Refuge in relation to the Burns Project. (Source: (2).)
monitoring program called for sampling before, during, and after spraying to gather information on the effects of DDT application on big game, range cattle, forage, water, aquatic insects, and fish. Long-term research investigations were included to determine the persistence of DDT in an aquatic environment and to follow movement and persistence of DDT isomers and metabolites in the forest canopy, litter, and soil. A total of 10 different administrative and research branches of State and Federal agencies participated in the monitoring program. Agencies conducting field studies included:

State of Oregon
  Game Commission
  Fish Commission
Oregon State University
  Department of Agricultural Chemistry
  Department of Fisheries and Wildlife
U. S. Department of the Interior
  Fish and Wildlife Service
    Bureau of Sport Fisheries and Wildlife
    Bureau of Commercial Fisheries
U. S. Department of Agriculture
  Agricultural Research Service
    Entomology Research Division
  Forest Service
    Division of Watershed Management, Recreation, Range Management, and Wildlife Habitat Research
National Forest Administration, Pacific Northwest Region
  Division of Range and Wildlife Management
  Malheur National Forest

Coordination of the project was complicated by the fact that actual aerial spraying began on June 10 and continued intermittently through July 1, 1965. Adverse weather delayed the insect hatch, disrupting spray schedules and monitoring studies. Day-to-day planning was then necessary to insure that monitoring personnel could be notified when their study area was scheduled for spraying.

Most of the monitoring studies were completed within 1 year following treatment, although some continued for at least 2 years and one study is still in progress. Experience gained from the Burns Project emphasizes the importance of making the monitoring program an integral part of any chemical pest control project.
Monitoring Water Quality

Perhaps the most important expression of forest environmental contamination that can result from pest control projects is degradation of water quality. Streams originating in forested watersheds not only provide the habitat for many biological communities but also serve as the major source of water for all downstream users. We have an obligation, therefore, to insure that the aquatic habitat is not adversely affected and the quality of water leaving the forest is maintained.

Monitoring water quality is essentially a sampling procedure carried out to determine if stream contamination has occurred and, if so, to what extent. During a chemical brush control project, for example, we wish to determine the maximum concentration of herbicide that aquatic organisms have been exposed to and how long the herbicide persists in the stream. To obtain this information, appropriate sampling stations must be established and representative stream samples must be collected on a previously determined schedule before, during, and after herbicide application.

Treatment area layout. — The degree of stream contamination is greatly influenced by the orientation of the treatment unit, so the need for monitoring must be considered in laying it out. If at all possible, spray boundaries should be so laid out that live streams are not included. Figure 4 and Table 1 will illustrate the level of contamination that might be

<table>
<thead>
<tr>
<th>Sample Point 12</th>
<th>Sample Point 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours after spraying</td>
<td>Hours after spraying</td>
</tr>
<tr>
<td>2,4-D ppb</td>
<td>2,4-D ppb</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>0.83</td>
<td>1.33</td>
</tr>
<tr>
<td>33</td>
<td>62</td>
</tr>
<tr>
<td>1.83</td>
<td>2.3</td>
</tr>
<tr>
<td>13</td>
<td>71</td>
</tr>
<tr>
<td>2.8</td>
<td>3.3</td>
</tr>
<tr>
<td>13</td>
<td>58</td>
</tr>
<tr>
<td>54.0</td>
<td>4.3</td>
</tr>
<tr>
<td>9</td>
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<td>115.0</td>
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<td>0</td>
<td>25</td>
</tr>
<tr>
<td>115.0</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: (5).
Eddyville treatment area watershed. 71 acres (10 percent) of a 710-acre watershed were treated with 2,4-D at rates ranging from 2.2 to 3.0 lb/acre. (Source: (5).)

Expected when the sampled stream flows from or through the treated area. Compare this with the situation in Figure 5 where the spray boundaries are close to but do not actually include live streams. Table 2 shows that under these conditions the level of contamination is greatly reduced.

Avoiding larger streams during spray application is usually not difficult, but it may be impractical to avoid all of the small streams in an area that requires brush control. Special precautions may be necessary if the treatment unit is within a municipal watershed and when a stream flowing from the unit to be sprayed serves as the source of water for a fish.
Figure 5. Camp Creek treatment area watershed. 300 acres (23 percent) of a 1,300-acre watershed were treated with 2 lb/acre 2,4-D. (Source: (5).)

<table>
<thead>
<tr>
<th>Hours after spraying</th>
<th>ppb 2,4-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>T</td>
</tr>
<tr>
<td>2.0</td>
<td>25</td>
</tr>
<tr>
<td>5.4</td>
<td>1</td>
</tr>
<tr>
<td>8.7</td>
<td>1</td>
</tr>
<tr>
<td>84.5</td>
<td>3</td>
</tr>
<tr>
<td>1 week</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: (5).
hatchery or a private landowner. In other situations the need for monitoring may not be so obvious, but water monitoring should be done on any stream where the potential for contamination and deterioration of quality exists.

**Sampling points.** — Selection of an appropriate sampling station is extremely important since the value of the information obtained is only as good as the sample collected. The sample should be representative of the volume of water passing the sampling point, and it should be possible to collect a sample without stirring up bottom sediments or kicking surface debris into the stream. When the treatment unit lies adjacent to the stream to be sampled, the sampling point must be downstream of all small side channels flowing from the treated area. At the same time, however, we want to sample the stream as close to the lower boundary as possible so that the samples will represent the maximum herbicide concentration to which aquatic organisms may have been exposed.

Control samples are normally collected at the same sampling station prior to spraying, but in some situations it will be possible to obtain these samples from a point above the spray unit. In either case, the sampling point should not be subject to contamination by aerial drift during the sampling period. In critical situations such as spraying brush above a water intake for a fish hatchery or private water supply, a second sampling station should be established just above the intake. Under normal conditions, a chemical spray project would not be carried out in an area where a water intake is located less than 2 miles downstream.

**Collection of samples.** — Before the project is begun, appropriate sample containers must be obtained. If the herbicide used is 2,4-D, 2,4,5-T, picloram, or combinations of these materials, samples should be taken in glass containers and treated with sodium hydroxide (NaOH) to prevent loss of any herbicide residue that may be present. NaOH is a strong base and will prevent microbial activity by raising the pH of the sample. This treatment will also hydrolyze any volatile formulations of the herbicides listed and thus stabilize any residues in the samples during transport and storage. When amitrole is the active chemical used, samples should also be taken in glass containers. However, this chemical is highly soluble in water and stable so treatment with sodium hydroxide is not needed.

As indicated earlier, the sample should be as representative as possible of the total volume of water flowing past the collection point. For small streams, this requirement can best be met by collecting a grab sample at the lower end of a straight, narrow length of channel carrying a steady flow of water. On larger streams, the samples should be taken near the center of the channel at a depth of 2-4 inches. The individual collecting
the samples must not have any herbicides or other contaminants on his hands or clothing, and the sample containers must also be free of contamination. These precautions are extremely critical because the method used to analyze the samples can detect residues of less than 0.5 parts per billion acid equivalent in water.

Each sample must be clearly identified and all pertinent information correctly and completely recorded on a tag or label securely attached to the container. In addition to assigning an identifying number, the attached tag or label should show the date and time collected, location, weather conditions since time of application, and name of collector. Other information that may be recorded is the rate of application, chemical formulation used, and size of area treated.

Timing of collection. — The number of samples collected and the timing, or sampling interval, will depend in part on the particular project being monitored. Following is an example of the sampling sequence that might be used for most chemical brush control projects using a single sampling point below the unit:

<table>
<thead>
<tr>
<th>Hours after spraying is begun</th>
<th>1. Control (prespray)</th>
<th>2. 15 minutes to 1 hour</th>
<th>3. 3 hours</th>
<th>4. 24 hours</th>
<th>5. 48 hours</th>
<th>6. 72 hours</th>
</tr>
</thead>
</table>

Timing of the collection of sample number 2 depends on the distance between the lower unit boundary and the sampling point. If this point is immediately below the unit, sample 2 should be taken within 15 minutes after spraying is started. If the sampling point is downstream some distance below the unit, collection of sample 2 can be delayed, but not beyond 1 hour after spraying begins. This timing also applies when the unit is sprayed in late evening to take advantage of good weather conditions. Sample 2 should be taken at the time interval indicated and sample 3 can be delayed until the next morning. In this case, samples 4, 5, and 6 would still be taken at 24-hour intervals from the time spraying started.

Due to poor weather, equipment failure, or the size of the area, it is often necessary to spray a unit over a period of several days. Should this occur during a monitoring program, samples 2 and 3 should be taken each
day that spray is applied. Samples 4, 5, and 6 then would be taken at 24-hour intervals after the last application on the unit.

When the treatment unit lies within a municipal watershed or in a watershed that supplies a fish hatchery, at least two additional samples should be taken. One sample should be collected 5 days after herbicide application and one, after 7 days.

Another situation that may require the collection of additional water samples is heavy storm activity any time within the first 3 to 4 weeks after completion of a chemical control project. Herbicide chemicals tend to be tightly held in the forest floor and soil, but it is possible that herbicide residues along the riparian zone could be moved into the stream channel by subsurface or overland flow. At least one sample should be taken during the period of peak flow.

Transport and storage. — Sample containers, whether empty or full, should not be transported or stored with pesticidal chemicals. The chance of sample contamination can also be greatly reduced by assigning to sample collection and handling a person who is not involved in any other part of the spraying operation. As soon as sampling has been completed, the accumulated samples should be shipped to the laboratory for chemical analysis. If for some reason the samples are not analyzed immediately, they can be stored without deterioration of any residues present for up to 6 months after collection.

Chemical analysis for pesticide residues is an expensive proposition because of the time and equipment required. It may be desirable, therefore, to reduce the cost of monitoring on less critical pest control projects by compositing some of the samples and thereby reducing the number of analyses required. This can be done by combining equal parts of each of several samples taken at a monitoring point, excluding the control sample. No more than four or five samples should be included in a composite and the remainder of each individual sample should be saved in case the analytical results on the composite show that more detailed information is needed. The composite sample must be so marked and a complete identification included with it when submitted for analysis.

Safety measures. — All pesticidal chemicals, and samples that may contain their residues, are potentially poisonous and should be handled accordingly. They are selected for their toxic properties toward a specific target and every effort must be made to insure that nontarget components of the environment are not adversely affected as the result of misuse or carelessness. In the case of an accidental spill or drop of herbicide into open streams, lakes, or other body of water, all interested persons should be notified and monitoring procedures should be started immediately.
Conclusions

The purpose of a pesticide monitoring program is to determine the relative safety of any forest management practice that introduces pesticide chemicals into the forest environment. If the monitoring program reveals that a management practice does pose a threat to environmental quality, the next step is to modify the practice as required.

I have reviewed the objectives of monitoring programs and, by using actual insect and brush control projects as examples, have examined the problems of planning and conducting a pesticide monitoring study. The intensity of sampling outlined is insufficient to fully characterize the distribution of herbicide residues in stream samples with time after application. However, by comparing the data obtained from the few samples collected with information developed through research programs, it is still possible to adequately define the maximum level of contamination and also how long the residues will persist.

Literature Cited


SECTION IV
APPLICATION OF PESTICIDES
Chairman: Robert Tarrant
Bohdan Maksymiuk

U. S. Forest Service
Corvallis

KINETICS AND PHYSICS OF PESTICIDAL AERIAL SPRAYS

Abstract

Fundamental knowledge of the kinetics and physics of sprays is essential for improving aerial application of pesticides. Spray kinetics deals with production of spray drops, while spray physics deals with spray behavior, pattern of dispersal, and deposition. Effectiveness and safety of aerial application of pesticides depends on maximum target coverage with minimum dose and spray volume, and reduction of drift hazards.

Factors affecting target coverage (spray formulation, atomization devices, spray atomization, swath deposit patterns, aerial application methods) and spray deposit assessment are discussed. Improved aerial application technology will result in more efficient plant coverage, which in turn, will culminate in a more favorable cost-benefit ratio for the pest control programs.

Introduction

Increasing human population and shrinking land base call for more intensive forest and range management. The forest practitioner needs different materials (pesticides, herbicides, fertilizers, and others) as management tools to protect forests from pests and to increase carrying capacity of forest lands for future economic and social needs.

Chemical and biological insecticides, herbicides, and other forestry chemicals are commonly applied as sprays on forest and range lands by fixed- or rotary-wing aircraft. All uses of pesticides should be ecologically acceptable. Relatively toxic materials can be safe if applied properly, and relatively non toxic materials can be harmful to man and his environment when applied improperly. Researchers and forest practitioners must jointly assume more responsibility in improving current practices in use of pesticides.

To achieve this, it is important to understand theoretical and practical aspects of kinetics and physics of aerial sprays. This knowledge is necessary for conceiving, developing, and applying improved technology for more efficient and safe use of pesticidal sprays. It is a well-established fact that a sizable proportion of aerial sprays does not reach the target areas. Improved practices will result in maximum deposition of pesticides on target areas. The major payoff will be in reduction of dose and drift. This, in turn, will minimize adverse environmental impacts and provide economy in operations.
The terms, spray kinetics and spray physics, are occasionally used interchangeably. Kinetics involves production of drops. It deals primarily with the action of forces in breaking liquid sheets into drops by the aid of an atomizing device. This process is called spray atomization. The degree of spray atomization is affected by mechanical and physical factors including the nature of the spray formulation. The spray atomization (drop size) affects the efficiency of plant coverage. Spray physics is concerned with drops after they have left the atomizer. Spray physics involves studies to determine the effect of interrelated factors (formulation, atomization, meteorological conditions, etc.) on spray behavior and pattern of deposition. Characterizations of the drop size spectra, as they are produced by atomizers, dispersed in the air, and deposited on target (foliage, insects) and nontarget (drift) areas, are essential for studies of spray kinetics and physics. The spray deposit assessment is essential in evaluating the coverage and biological effectiveness of pesticidal sprays.


The main purpose of this presentation is to outline the practical aspects of the key factors of spray kinetics and spray physics affecting the efficiency and safety of aerial applications of pesticides for managing insect and undesirable vegetation on forest and range lands.

Spray Formulation

Pesticides are diluted in carriers for obtaining needed volume for adequate target coverage. Various surfactants are added to sprays to obtain desirable physicochemical properties needed for aerial application and to protect the active materials from inactivation or breakdown by light or other factors. The concentration of active ingredient and carrier must be nonphytotoxic to desirable plants.

Spray formulation entails an art and a science. Most formulations contain various surfactants to change the viscosity for spray atomization purposes, to reduce evaporation, to minimize drift, to decrease surface tension of the liquid for better wetting and spreading, to obtain better plant coverage, and to increase penetration in and adherence on target surfaces. Compatibility of these ingredients with each other and with the active principle(s) must be known under different field situations in order to reduce the chance of unexpected or undesirable results. It is important
to establish criteria¹ for specific formulations and to characterize complete spray formulation as to their physical, chemical, and toxicological properties. This is necessary for increasing the effectiveness of control programs and for reproducibility of results.

Most pesticides are applied in oil-base, water-base, and emulsion formulations. In deciding what type of formulation to use, one should consider mode of action of the pesticide, nature of target organism, timing of application, and safety to nontarget biota. If possible, oil formulations should be avoided near aquatic environments.

Chemical insecticides, especially those exhibiting contact action, are commonly applied in oil-base formulations. Biological (microbial) insecticides such as insect viruses and bacteria are applied in water-base spray formulations primarily because insect larvae need to ingest treated foliage to be diseased. Certain oils can repel insects from feeding.

Herbicides are usually formulated as normal or invert emulsions. They usually contain thickening or particulating agents to decrease drift by increasing spray viscosity which results in coarse spray atomization. The role of surfactants in herbicidal formulations is treated by Ford and Furmidge (1969), Foy and Smith (1969), Maas and de Lange (1970), and others.

Physicochemical properties of spray formulations directly affect spray atomization and indirectly affect target coverage and drift. It is important that physical, chemical, biological, or toxicological properties of spray formulations be tailormade to achieve the predetermined objective.

**Atomization Devices**

Conventional boom and nozzle arrangements and, more recently, rotating atomizers are used for applying pesticidal sprays (Isler and Maksymiuk 1961, Maksymiuk 1964a, Bals 1970, Akesson et al. 1971, Boving et al. 1971). In the case of conventional nozzles, a liquid sheet of formulation is atomized into drops by utilizing pressure in the spray system and by encountering air resistance during the flight of aircraft.

Now, rotating atomizers are frequently used for ultra-low volume (ULV) applications. In this case, the liquid sheet is atomized into drops by utilizing centrifugal energy (Fraser 1958). The rotating atomizers (spinning discs or rotating cage of wire mesh) can be powered by electric current or driven by a windmill principle utilizing blades. Rotating atomizers powered by electric motors offer more control and versatility.

¹Bohdan Maksymiuk. 1971. Criteria and specifications for aerial Bacillus thuringiensis formulations to control forest insects. (Unpubl. paper, 4 p.)
Spray Atomization

The degree of atomization affects spray behavior, evaporation, drift, convention, and pattern of deposition which in turn affect the frequency and intensity of target coverage. Fine spray drops are more affected than coarse drops by meteorological factors. Most of the time, these factors are unpredictable and beyond control in forest spraying. Micrometeorological factors include windspeed, horizontal and vertical air movements, temperature gradient profile (stable, inversion, lapse), and relative humidity. These factors affect the behavior of spray drops suspended in the air and the pattern of dispersal and deposition including the percent recovery of active material on target areas.

All atomizing devices used in pesticide applications produce a drop size range which is called the drop size spectrum. In each drop size spectrum, regardless of degree of spray atomization, the number of spray drops decreases with an increase in drop size.

The spray atomization is commonly expressed as mass median diameter (MMD) or volume median diameter (VMD). These parameters are synonymous. Mass median diameter is the drop diameter that divides the spray volume into two equal parts. For example, an MMD of 150 microns means that 50 percent of the spray volume is in drops smaller than 150 microns, and the remaining 50 percent is in drops larger than 150 microns. Rapid and improved methods for determining atomization of aerial sprays have been developed by Maksymiuk and Moore (1962), Maksymiuk (1963a, 1964a, 1964b), and Moore et al. (1964).

Spray atomization, with flat spray and hollow cone nozzles, can be varied by several mechanical factors used singly or in combination, as follows:

a. Direction of nozzle orifice in relation to the thrust line of the aircraft—nozzle orifices pointed forward will produce a fine atomization pointed down, an intermediate atomization; and pointed to the rear, a coarse atomization.

b. Speed of aircraft—the faster the speed, the finer the atomization.

c. Size of nozzle orifice—the larger the orifice, the coarser the atomization.

d. Spray pressure—the higher the pressure, the finer the atomization.

Spray atomization, using rotating atomizers, can be varied by the rotational speed—the higher the speed, the finer the spray atomization.

Theoretically, finer spray atomization should result in better spray coverage as far as number of spray drops per unit area is concerned (Table...
1). However, since small drops contain a larger surface area than big drops per same volume of spray, they evaporate more and are subject to drift by wind or convection currents (Table 2). Data in this table, from Potts (1958) and others, are based on assumption that there is no spray evaporation. Therefore, compromise and “educated” judgment must be used in selecting the workable spray formulation, equipment, and application techniques to do each specific job efficiently and safely by minimizing drift.

Table 1. — Calculated drop size and coverage

<table>
<thead>
<tr>
<th>Drop diameter (microns)</th>
<th>Number of drops per gallon, X10^6</th>
<th>Number of drops per square inch at 1 gallon per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>600</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>400</td>
<td>113</td>
<td>18</td>
</tr>
<tr>
<td>200</td>
<td>904</td>
<td>142</td>
</tr>
<tr>
<td>100</td>
<td>7,230</td>
<td>1,164</td>
</tr>
<tr>
<td>20</td>
<td>904,000</td>
<td>143,190</td>
</tr>
<tr>
<td>10</td>
<td>7,230,000</td>
<td>1,148,100</td>
</tr>
</tbody>
</table>

Table 2. — Time and rate of fall of oil spray

<table>
<thead>
<tr>
<th>Drop diameter (microns)</th>
<th>Time to fall 1</th>
<th>Drift from 50 feet in wind 1 mile per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 feet</td>
<td>Minutes</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------</td>
<td>---------</td>
</tr>
<tr>
<td>600</td>
<td>0.03</td>
<td>&lt;1</td>
</tr>
<tr>
<td>200</td>
<td>.25</td>
<td>31</td>
</tr>
<tr>
<td>100</td>
<td>1.0</td>
<td>90</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>1,900</td>
</tr>
<tr>
<td>10</td>
<td>96</td>
<td>7,200</td>
</tr>
</tbody>
</table>

^1Stoke’s Law.
Swath Deposit Patterns

More uniform spray deposit distribution across the spray swath is needed to achieve wider biologically effective swaths. This would permit wider swath spacings in field applications thus reducing spraying cost and time. Degree of spray atomization, physicochemical properties of spray formulation, meteorological factors, location of nozzles on spray boom, spraying height, and other factors affect the patterns of spray deposit distribution. Since there is more variation in deposit distribution across the spray swath than along the swath, sampling for deposit and resulting biological effectiveness (insects, weeds) should be made across the single swath or multiple swaths, as the case might be.

Both fixed- and rotary-wing aircraft produce swath deposit patterns resembling a biomodal curve when spraying is done upwind or in still air. Crosswind flights result in a heavy deposit on the upwind side and wider swaths. Attempts have been made to identify factors affecting swath deposit patterns (Isler and Thorton 1955, Chamberlin et al. 1955, Isler and Maksymiuk 1961, Isler and Yuill 1963, Isler and Yuill 1964, Young et al. 1964, Boving et al. 1971, and others). Despite these efforts, a great deal of engineering research needs to be done to obtain more desirable swath deposit patterns. In upwind flights, there is an overdose at two peaks of deposit due to wing vortexes and an underdose at the middle of the swath (trough). These undesirable effects can be reduced with increased spraying heights which will result, unfortunately, in more drift.

Aerial Application

Pilot's skills, adequate briefing, and thorough familiarization with spray area are key elements for satisfactory and safe aerial applications. Essential information for pilots is well summarized by the International Agricultural Aviation Centre, The Hague (1968). This information will also be of value to persons conducting or supervising spray programs. Markers for boundaries of spray blocks and for swath spacings are essential guides for accurate and precise applications.

Spraying height should be adjusted according to meteorological conditions, degree of spray atomization, size of spray area, topography, and characteristics of target considering safety of application, spray behavior, deposition, and drift. For example, increased spraying height can result in more uniform spray deposit distribution, but more spray will be lost mainly as drift due to the meteorological conditions. Additional practical considerations of aerial application are well presented by the Agricultural Research Service (1965).

The terms, application rate and dose, are confused with each other. Application rate is amount (volume) of formulation applied per acre,
usually expressed as gallons per acre. Dose (dosage) is the amount of active material applied per acre regardless of application rate. By varying application rates and dosages, one can obtain high or low concentrated sprays that can be applied in high, medium, low, and ultra-low volumes. Only the ULV application is well defined. It consists of an application rate of 0.5 gallon or less per acre of specially formulated (undiluted) spray concentrate.

Spray Deposit Assessment

Physical, chemical, and biological spray deposit assessment methods are used to determine the adequacy of target coverage (spray omissions and commissions) and the amount and extent of drift. Only a small percentage of the insecticidal and herbicidal sprays reach the target areas. The amount of spray deposit reaching the target area and resulting in pest mortality must be correlated in order to improve aerial application control methods by using the minimal dose for maximum effectiveness.

Qualitative and quantitative spray deposit assessment methods have been developed and/or modified by author and co-workers for assessing oil-base and water-base sprays applied in forest situations. These methods utilize different fluorescent dye-tracers, and can be universally used for aerial application of biological and chemical insecticides and herbicides to determine target coverage and drift. Bioassays are also valuable to quantify spray deposit and toxicity of active ingredients in various formulations under different microenvironmental conditions over a desired period of time.

The amount of biological and chemical insecticides can be directly determined on foliage or at ground level by means of cards or aluminum plates supported by cardholders (Maksymiuk 1959). Fluorescent dye-tracers can also be used to determine the atomization of aerial sprays (Maksymiuk and Moore 1962, Maksymiuk 1963a and 1964a). Some uses of fluorescent tracers are described by Yates and Akesson (1963) and White and Argauer (1970).

Conclusion

Success in aerial application of pesticides depends on an interdisciplinary approach. This approach utilizes knowledge from different disciplines mainly belonging to the biological and physical sciences. They are: entomology, plant physiology, silviculture, chemistry, physics, engineering, meteorology, biometrics, microbiology, insect pathology, toxicology, ecology, sociology, and others.
Improved aerial application technology will permit minimum dose and drift hazard (undesirable impact on environment), maximum effectiveness of pest regulation, and fulfillment of forest and range land management objectives. This, in turn, will result in a more favorable cost-benefit ratio for pest control programs.

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HOW TO MINIMIZE DRIFT OF PESTICIDAL SPRAYS

Abstract
Drift from herbicides and insecticides poses a potential hazard to sensitive non-target organisms and increases residue problems in plants, animals, air, and water. In general, the potential drift hazard is greater from aerial application of herbicides (such as 2,4-D, 2,4,5-T, and amitrole) than from insecticides because of the chemical nature of herbicides and their patterns of use (low selectivity, higher doses and application rates, and lack of specific aerial application technology).

The quantity and extent of drift can be reduced by a combination of several interrelated factors such as spray formulation, equipment, and atomization, meteorological factors, and spraying method. Research for developing effective and safe technology for aerial application of herbicides in forestry is lagging behind that for aerial application of insecticides.

Introduction
Safe use of herbicides and insecticides has become increasingly important in intensified forest and range land management. Due to their chemical nature, herbicides pose more problems of drift hazard than insecticides. Several herbicides such as 2,4-D, 2,4,5-T, and amitrole (singly or in combination) are commonly used on forest and range lands. Main uses of herbicides are for site preparation before tree-planting, release of conifers from hardwoods, and control of undesired woody vegetation to improve range lands, especially for grazing.

Herbicides and insecticides are commonly applied as aerial sprays by airplanes and helicopters. Only a portion of these sprays is deposited on the target areas. A certain fraction of the spray is lost as drift. Drift of pesticides poses potential hazard to susceptible non-target biota, aggravates a residue problem in plants, animals, and water, and contaminates air.

Drift can be defined as the portion of spray that is moved away from the target area by wind or other meteorological factors. In general, the same basic factors are affecting the drift of insecticidal and herbicidal sprays. Due to the nature of materials and patterns of use, more potential hazards are associated with aerial application of herbicides than insecticides. Aerial application technology of herbicides is lagging behind that of insecticides despite the fact that herbicides are used in forestry in greater quantity than insecticides.

The main purpose of this presentation is to discuss briefly the drift hazard, factors affecting drift, and how to minimize it. The factors considered include spray formulation, spray equipment and atomization, meteorological factors and application methods. Special reference is made to herbicides.

Drift Hazard

The potential drift hazard depends on the chemical nature, specificity, and mode of action of the herbicide. The hazard of drift is also associated with the presence of susceptible biota, biological timing of the applications, size of treated areas, dosage, frequency of treatments, and other factors.

Herbicides are applied in coarser spray atomizations (larger drops) and in greater volumes than insecticides. The coarser spray atomizations only reduce the number of fine drops—they do not eliminate them. There is still sizable drift of herbicidal sprays mainly because of high application rates. The coarser spray atomizations require higher application rates to obtain adequate target coverage than are required for the finer atomizations. This poses a logistics problem. Well-balanced research and development is needed to solve the ever-increasing problems in aerial application of herbicides to reduce drift and dose.

Several references can be helpful in considering drift hazards—(Yates et al. 1966, Montgomery and Norris 1970, Bohmont 1971).

Spray Formulation

Physical and chemical properties of spray formulations such as viscosity, evaporation and volatilization, specific gravity, surface tension, and temperature affect drift.

Increasing the viscosity of spray formulations by using thickening or particulating agents or by other means results in coarser spray atomizations. These coarser drop size spectra contain a smaller ratio of fine to big drops as compared with finer atomizations. A method for determining drop size spectra is described by Maksymiuk (1964b).
Increased surface tension and colder temperatures of spray formulations can also result in the production of a lesser number of fine drops.

Decreasing the evaporation by using various anti-evaporants or using a non-volatile type of formulation can result in the reduction of drift. Invert emulsions can be used instead of normal emulsions when they pose no problems in field applications. In invert emulsions (water-in-oil), oil is the external or continuous phase and water is the internal or dispersed phase. In normal emulsions (oil-in-water), the phases are reversed. Since oils evaporate more slowly than water, invert emulsion formulations will therefore drift less.

When the specific gravity (density) of the spray formulation, is increased, less time is required for the deposition of spray drops, thus resulting in less spray drift and volatilization of the active ingredient.

Several adjuvants (thickeners) have been used to increase the viscosity and reduce the evaporation of spray formulations (e.g., Kaupke and Yates 1966, Butler et al. 1969, Elkins 1970, Haagsma 1971). The following thickening agents are most commonly used: Dacagin (Diamond Alkali Co.), Norbak (Dow Chemical Co.), and Vistik (Hercules Powder Co.). There are some problems in mixing these thickening agents, and instructions should be carefully followed.

Highly viscous sprays will reduce drift but result in less efficient plant coverage and require higher dosages and application rates. For example, if the drop size is doubled, the number of drops per unit of spray volume will be reduced eight-fold. Somehow a balance must be established based on the potential drift hazard and other practical considerations.

**Spray Equipment and Atomization**

Spray equipment, together with the spray formulation, offers a great potential for producing drop size spectra that will result in a reduction of drift. Selecting nozzles (hollow cones, flat spray, etc.) with large orifices pointed to the rear in relation to the thrust line of the aircraft will produce coarser sprays containing fewer fine drops. Decreasing the spray pressure and the speed of the spraying aircraft will also result in coarser spray atomization.

A recently developed Microfoil spray boom system for helicopters appears to offer a great potential to substantially reduce drift. It has been reported by Kirch (1971) that this spray system produces nearly uniform drops with a minimal amount of small droplets using conventional spray carriers without thickening or particulating agents or invert emulsions.

1The mention of brand names does not imply endorsement of the product by the Forest Service.
Needle-like nozzles are used for the spray atomization. It is essential that this new spray equipment should be properly evaluated for factors affecting the drop size spectra and its performance determined under variable forest conditions. (Maksymiuk and Moore 1962, Maksymiuk 1963, 1964a, 1964b, Moore et al. 1964, Akesson et al. 1971, Liljedahl 1971).

**Meteorological Factors and Application Methods**

There is an urgency to develop workable meteorological criteria for guidelines for field applications of herbicides and insecticides. To do this, there is a need for a better understanding of the spray behavior and pattern of deposition (spray physics) of different spray formulations and atomizations in relation to the required target coverage under variable forest and range conditions.

The combination of meteorological factors such as wind speed, convection and thermal air currents, temperature gradients (inversion or lapse), and relative humidity affects the direction, distance, and quantity of drift.

Spraying should be done at lower wind velocities, preferably early in the morning because increasing ground temperatures later in the day will result in convection and thermal air currents which can lift small particles and cause more potential drift. Also, spraying should be avoided during a strong inversion, since this condition might prevent deposition of the small drops picked up by the horizontal air movement and carried away from the target area.

The effects of meteorological factors on drift are described in several publications (e.g., Scotton 1965, ARS 1965, De Marrais et al. 1968, Christensen et al. 1971).

For an effective and safe aerial application of pesticides, a number of controllable and uncontrollable factors must be considered. Controllable factors are factors such as spraying height, type of aircraft, equipment, formulation, and atomization. The uncontrollable factors are mainly meteorological conditions and topographical, forest, or range characteristics—including the size of the spraying area and proximity to sensitive non-target crops, water reservoirs, and streams.

The higher the spraying height, the longer the spray drops will be suspended (float) in the air. Thus they are more subject to such meteorological factors as wind and air movements which will result in more drift and residue potential. If safety permits, the spraying height should be reduced when higher wind velocities and other less favorable meteorological conditions exist. However, the low spraying height will
result in a poor deposit coverage ("skips") when the swath spacings are unprecise and when the coarser atomizations are used.

Coarser spray atomizations should be used when wind or upward air currents due to heat radiation exist, when layers of heavy, humid air are above the tree tops, or when irregular and rough topography is anticipated (Potts 1958). Theoretically, with wind speed of 3 miles per hour, water drops of 50 microns in size will drift about 890 feet while falling from a 50-foot height. Doubling the height or windspeed should double the distance of drift. It would take 5 days for a drop size of 1 micron, having a specific gravity of 1, to fall 50 feet in still air at a temperature of 23°C; it would take only 13-51 seconds for 200- and 100-micron drop sizes, respectively. Data (IAAC 1968) on drift, terminal velocity, and evaporation of water drops are presented in Tables 1, 2, and 3. Additional information on drift can be obtained from several publications: Reimer et al. 1966, Plumb et al. 1966, Eaton et al. 1970, Yule and Cole 1971, and others.

Table 1. Drift distance of various drop sizes released from the 10-foot height at air flow of 3 mph, assuming no evaporation.

<table>
<thead>
<tr>
<th>Droplet diameter (microns)</th>
<th>Classification</th>
<th>Distance drifted</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>light rain</td>
<td>7 feet 2.1 meters</td>
</tr>
<tr>
<td>200</td>
<td>drizzle</td>
<td>16 feet 4.9 meters</td>
</tr>
<tr>
<td>100</td>
<td>mist</td>
<td>50 feet 15.25 meters</td>
</tr>
<tr>
<td>30</td>
<td>cloud</td>
<td>500 feet 152.5 meters</td>
</tr>
<tr>
<td>15</td>
<td>coarse aerosol</td>
<td>2,000 feet 610 meters</td>
</tr>
</tbody>
</table>

1 micron = 0.001 mm.

Table 2. Terminal velocities of different water drop sizes.

<table>
<thead>
<tr>
<th>Droplet diameter (microns)</th>
<th>Terminal velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>feet per second</td>
</tr>
<tr>
<td>500</td>
<td>6.93</td>
</tr>
<tr>
<td>100</td>
<td>0.89</td>
</tr>
<tr>
<td>50</td>
<td>0.24</td>
</tr>
</tbody>
</table>

1 micron = 0.001 mm.
Table 3. — Evaporation of different water drop sizes in air at 15°C and 40 percent relative humidity.

<table>
<thead>
<tr>
<th>Initial diameter (microns)</th>
<th>Time to evaporate (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>4</td>
</tr>
<tr>
<td>100</td>
<td>16</td>
</tr>
<tr>
<td>200</td>
<td>63</td>
</tr>
</tbody>
</table>

**Conclusion**

A combination of complex and interrelated factors affect drift hazard and residue problems. Therefore, an interdisciplinary approach in research and development must be used to improve aerial application technology to decrease dose and the amount and extent of drift. Production of a desirable drop size spectra offers the greatest possibilities. This can be accomplished mainly by engineering and formulation research.

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APPLICATION EQUIPMENT

Introduction
This presentation will be primarily concerned with the basic spray equipment used for aerial application of pesticides and herbicides. The equipment to be discussed can be used for either type application as the basic equipment is the same except for possible selection of atomizing devices. Also, no distinction will be made between helicopter and fixed-wing as the equipment is the same except for possible size and configuration.

Before discussing the equipment a brief history of the development of spray equipment should be presented.

The fixed-wing airplane and helicopter have been used for years in the application of pesticides and herbicides. The fixed-wing airplane being in use the longest, however, during the last decade the helicopter has come into prominent use. Both types being used today for pesticides and herbicide applications such as spraying the forests and range lands for insect control and brush for thinning and right-of-way control.

The spray systems of the past were crude by today’s standards but were better than no control at all. The original orifices were just large holes drilled in a pipe through which the liquid passed. The application rates were high in the range of 5-10 gallons per acre which required large flow rates so that large holes drilled in the boom were necessary. Not too much thought was given to droplet size. Some of the insecticides used were inexpensive and their effect on the environment was not considered, so the application rates were of little consideration.

However, efforts were made to reduce costs by reducing the application rate. This could be achieved only by better break up of the material into smaller drops, in order to get at least the same results with less material. Why use a 500 micron drop to kill an insect when a 50 micron drop will do the job. A 500 micron drop could be broken up into 1000 ea - 50 micron drops and therefore theoretically kill 1000 times as many insects.

In order to get better break up of the material, better equipment was needed. The large hole in the boom was replaced with a nozzle containing...
a spray tip with a machined close tolerance orifice, which precisely controlled the flow rate through the orifice and effected some control on drop size. As development continued various means of controlling drop sizes were devised along with the spray tip, there are rotating screen cages, spinning steel disks and many other devices all in use to some degree today.

Pumps were used to pump the spray media from the tanks to the boom and out the nozzles. They are still in wide use today, however, some systems have replaced the pumps. These are the pressurized systems. The pressurized system along with the rotating atomizers will be discussed later on.

Conventional Spray System Equipment

Probably if one had to describe a conventional spray system it would include nozzles, boom, on-off valve, pump and tank. (Figure 1)

A nozzle is technically defined as a device through which liquid passes and is discharged from the open end. In spraying operations the nozzle is defined as an assembly containing a diaphragm check valve, strainer or filter, and the spray tip. (Figure 2) Whereas an atomizer is usually construed to mean a rotating device such as the screened cage or spinning disk atomizer.

Spray Tips

The spray tip contains the orifice which actually meters the flow of the spray media from the system. These orifices are precision made and thus provide excellent flow control. The flow of spray media through a given size spray tip orifice can be changed by varying the spray pressure. Increasing the spray pressure increases the flow rate and decreasing the spray pressure decreases the flow rate.

These spray tips come in different orifice configurations in order to produce different spray patterns. Some of the most common spray tips used in aerial application are the flat spray tips and the cone spray tips. The flat spray tips produce a flat fan shaped spray pattern and the cone shaped spray tips produce a cone shaped pattern which is what their names imply. (Figure 3)

These spray tips can determine to a degree the atomization obtained. The size of the orifice and the pressure both produce a change in the drop size. The larger the orifice the larger the droplet produced and vice versa. Pressure above 40-50 psig has very little affect on drop size, especially on the smaller size orifices in the range up to 1 GPM flow rate. On the large size orifices high pressures can reduce drop size considerably. (Figure 4)
Figure 1  CONVENTIONAL SPRAY SYSTEM
Probably the biggest factor in changing drop size on an aerial spray system, is the airplane speed and the orientation or direction in which the spray tip is pointed in relation to the direction of flight or its position in the air stream. According to a report by Isler and Carlton\(^1\) increasing the airspeed 2½ times from 80 to 200 MPH decreased the drop size (mmd) 60%. Also, when the spray tip is orientated perpendicular to the air stream or slightly forward, a further reduction in atomization was realized. It was also pointed out that at speeds below 80 MPH, such as with the helicopter, the speed and direction of the spray tip will have less of an effect on atomization; pressure and orifice size being more dominant factors.

Drop size or atomization can also affect swath width. The finer the atomization the greater the swath width. This works up to a point, because finer atomization also drift more and evaporates easily. The material may possibly drift out of the spray area.

These spray tip orifices can become plugged during operation and the orifice itself can show signs of wear caused by the eroding action of the spray media passing through the orifice. Therefore, during operation they should be checked periodically for plugging and if the orifice shows signs of excessive wear they should be replaced.

Strainers of Filters

Strainers or filters are usually placed in the nozzle just ahead of the spray tip to trap any foreign material carried by the spray media and
Figure 4

SPRAY PARTICLE SIZE VS. PRESSURE

PARTICLE SIZE (MVD - μ)

0 10 20 30 40 50 60 70 80 90 100

PRESSURE – P.S.I.G.

0.5 GPM NOZZLE

5.0 GPM NOZZLE
prevent it from plugging the orifice. These strainers are usually of the screen type varying in size from about 50-200 squares per inch. There are also some porous metal type filters available. Strainers are very effective in preventing clogging of the spray tip orifices particularly the smaller size orifices.

However, the strainer can become blocked with foreign material so they should also be checked periodically during operation. They can be cleaned by back flushing or by simply rubbing them, thereby removing the foreign material. Plugging of the spray tip orifice or the strainer can seriously affect the calibration of the airplane and thus the spray operation.

Diaphragm Check Valve (Figure 5)

The device for holding the spray tip and strainer and connecting them to the boom is the diaphragm check valve. In addition this device
functions as a valve to provide positive shut off of spray media to the spray tip. When the spray on-off valve (to be discussed later) is closed, stopping the flow of spray media the nozzles continue to spray momentarily until the pressure in the boom drops below approximately 5 psig. At this pressure the diaphragm check valve closes, preventing further spray media from dribbling through the orifice and also keeps the boom primed (full of spray media). When the spray on-off valve is opened, allowing the boom pressure to increase above 5 psig, the check valve will open. This allows the spray media to flow through the orifice again. This feature of keeping the boom primed gives the system an instant-on feature, while maintaining positive shut-off. This positive shut-off feature of the diaphragm check valve is very important especially when flying to and from the spray area, to prevent contamination of the non-spray area.

The diaphragm seal in the check valve is made of a soft synthetic material and should be checked for any serious deformity. The deformed seals are caused by the seal retaining cap being left tight over long periods of time such as from one spray season to the next. These showing excessive deformities should be replaced. It is very easy to determine which ones need replacing by simply observing which nozzles continue to dribble after the system has been shut off.

Boom

The boom is used to distribute the spray media from the pump to the nozzles and provide support for the nozzles. It must be of sufficient size to carry the desired flow to the nozzles with a minimum pressure drop. For example, based on water at 60°F. and a flow of 50 GPM a 2 inch and 1½ inch diameter pipe, 25 feet long will have a pressure drop of approximately 0.5 and 1.8 psig respectfully.

The boom should be located on the airplane where the drag is minimized. Preferably located behind the trailing edge of the wing, however, this is not always possible due to wing construction.

On-Off Valve

The spray on-off valve is used to stop the flow of spray media from the pump to the boom. These valves are generally a ball type valve actuated manually, electrically, hydraulically or pneumatically. The valve should be located between the pump and boom.

Pumps

Centrifugal pumps are used to transfer the spray media from the tank to the nozzle. They can operate with a blocked outlet such as when the spray on-off valve is closed, without building up excessive pressure. These
pumps can be driven by auxiliary gas engines, when using cargo type planes such as the C-47 or hydraulically on most TBM's or windmill driven on most small airplanes, and in the case of the helicopter, driven directly from helicopter engine.

Pump pressure and flow is regulated by controlling the RPM of the pump, in hydraulic and auxiliary gas engine driven systems. A bypass line from the pump outlet through a pressure regulator to the inlet of the pump is used on windmill driven and helicopter systems to control the pressure and flow.

Location of the inlet piping from the tank to the pump should be from the bottom of the tank in order to pump all the contents from the tank. On some pumps a bleed line must be fitted from the pump case back to the pump inlet or tank in order to bleed off trapped air collecting at the high point of the pump impellor.

From the point of view of total power consumed the windmill driven pump is the most inefficient. The poor efficiency of the windmill, plus the added frontal and parasite drag, consumes more horsepower than that required to drive the pump alone.

Spray Pressure Indicator

A pressure gauge is used to measure boom pressure and should be located where the operator can observe it readily. This will allow the operator to assure that the boom pressure is being maintained by frequent observation. Also it can be used to indicate possible pump problems and indicate when the tank is empty. This gauge should be checked for accuracy before a spray operation; this can be done by comparing it with another gauge of known accuracy. The hole drilled in the boom for the pressure gauge pickup should be approximately 10 pipe diameters downstream from any sudden enlargements or changes in flow direction to insure an accurate gauge reading.

Capacity

The capacity of the spray system is usually referred to as the number of gallons of liquid the spray tank (or tanks) will hold. This tank capacity is based on such factors as the payload of the airplane, weight of spray media and spray equipment. Once the capacity of the tank has been established, provisions must be made for various openings for filling of tank, outlet to pump, cleaning, vent, dump system and other accessories. If the tank is located inside the fuselage of the airplane it must be vented to the outside to allow spray media vapors to escape. Otherwise the vapors could reach the pilot and possibly affect his performance or be detrimental to his health. This is also a good reason for venting the fuselage of the airplane.
just in case of leaks, the vapors can escape. The tank must also be fitted with a dump system so that in case of an emergency the pilot can jettison the contents of the tank. The dumping system should meet FAA regulations, which in general state that, the dumping system must be capable of reducing to one half the maximum cargo in a period of 45 seconds.

**Controls**

The controls for the spray system should be located for convenience and easy access by the operator allowing complete control of the system. They should also be easily identifiable particularly the emergency controls, such as the dump control.

**Pressurized Spray System (Figure 6)**

Essentially this system uses the same equipment as used in the conventional spray system except that the spray tank should be constructed to withstand pressures up to 100 psig. The spray pump has been replaced by a compressed gas cylinder and a pressure regulator. By removing the spray pump, the associated equipment for driving the pump such as hydraulic system, windmill, and auxiliary gas engine has also been eliminated from the system. (Compare Figure 6 with Figure 1.)

The compressed gas, generally air or nitrogen, forces the liquid out of the tank into the boom and out the nozzles. The compressed gas cylinder must store a sufficient volume of gas to displace the liquid volume of the spray tank at the desired pressure. The size or capacity of the compressed gas cylinder required can be computed from the general gas law:

\[ PV = P_1 V_1 \]

or cylinder pressure

\[ P = \text{tank pressure (P}_1\text{)} \times \text{sum of the cylinder and tank volume (V}_1\text{)} \]

Volume of cylinder (V)

Note: assume a cylinder pressure or volume

The pressure regulator regulates the pressure and flow of the gas from the cylinder to the spray tank. It must be large enough to maintain a sufficient flow of gas in order to force the liquid out of the tank at the desired pressure and flow. The tank must be constructed with sufficient strength to withstand this pressure without bursting. They should be constructed according to the ASME Unfired Pressure Vessel Code. A safety device such as a relief valve should be installed on the tank, and adjusted to relieve at approximately 10-15 psig over the spray pressure but always less than the tank design pressure.

The disadvantages of the pressurized spray system is that in the larger capacity tanks weight can become a problem. Also, the compressed gas
Figure 6

PRESSURIZED SPRAY SYSTEM

PRESSURE REGULATOR

COMPRESSED GAS CYLINDER

PRESSURE REGULATOR

PRESSURE RELIEF VALVE

SIGHT GAUGE

FILL

DUMP

SHUT OFF VALVE

BOOM

NOZZLES
cylinder must be replaced when empty.

Some advantages of the pressurized systems are less probability of mechanical problems because there is no pump or pump drive system to leak or malfunction. The system is very easy to operate from the pilot's point of view and once the pressure regulator has been adjusted by use of the pressure regulator it does not require readjusting.

**Other Type Atomizers and Nozzles**

Many other type atomizers are being used besides the spray tips. Probably the most common ones are the electric motor drive spinning disks and the windmill driven rotating screen cage. They are usually used for low volume insecticide applications with normally no more than four units on an airplane. Each unit contains its own orifice and generally a check valve. Some attach directly to the boom, others have special mounts depending on type of airplane. The claimed advantages for these atomizers are that they produce a smaller and more uniform droplet spectrum according to E. J. Bals\(^2\) than spray tips. They do not plug up as easily as the smaller size spray tips, that would be required to give the same atomization.

The spinning disks work on the principle that as a stream of liquid strikes a flat disk, rotating at high speed, the liquid will build up to certain size before centrifugal force will throw it off the disk as droplets. The higher the rotational speed of the disks the smaller the drop size produced and the more uniform the droplet size. The rotating screen cage works on the principle that as the liquid stream or droplets formed inside the cage strike the screen, which is rotating at high speed, it shears the drops into smaller droplet, slinging them off in a more uniform droplet spectrum. Supposedly as the rotational speed is increased the droplet size decreases.

**Factors Affecting The Spray Operation**

Many factors affect a spray operation. Those to be considered here are equipment controlled such as swath width, droplet size, and flow rate. The type airplane, atomization, boom length and boom location affect the swath width. The boom length and location become important by introducing the spray into the vortices created at the wing tips of an airplane or by the rotor tips of the helicopter. These vortices continue to roll and spread out laterally in back of the airplane carrying the spray along, providing the atomization is small enough, and depositing it over a larger swath width. The swath width for each airplane should be determined by testing, using the atomization and equipment configuration

that is to be used on the project. The best swath width would be that determined from biological results such as insect mortality.

The atomization can be varied by the type and size of atomizing device or nozzle. It has already been established by D. A. Isler and J. B. Carlton that orientation of the nozzle with respect to direction of flight, nozzle size, and flight speed influence atomization. The speed of rotation of the spinning disk and rotating screen cages affect their atomization. Atomization is usually measured in terms of droplet size expressed as mass median diameter (mmd) which is defined as the drop diameter that satisfies the condition that half the spray volume is of drops larger and half is of drops smaller than that drop. These droplets are measured in microns which is equal to \(1 \times 10^{-6}\) meters or 3.937 x \(-5\) inches. The average human hair is 50-70 microns in diameter, talcum powder 10 microns, table salt 100 microns, which will give some idea of the size of a micron.

Once the swath width has been established the flow rate from the airplane must be determined. Knowing the application rate (GPA) and the airplane speed (MPH) and the swath width in (feet), the flow rate can be determined by the following formula:

\[
\text{Flow Rate (GPM)} = \frac{\text{application rate (GPA)} \times \text{speed (MPH)} \times \text{swath width (feet)}}{495}
\]

Knowing the flow rate required the number of nozzles to place on the airplane must be determined. Given the nozzle size and flow rate per nozzle, use the following formula:

\[
\text{Number of Nozzles} = \frac{\text{Flow rate (GPM)}}{\text{Flow rate of nozzle (GPM/nozzle)}}
\]

Note: The exact number of nozzles will be determined during calibration.

**Preliminary Equipment Checks**

**Before operation:**

1. Check cleanliness of tank (inside).

2. Check and make sure spray tips are all the same size.

3. Check and clean spray tips and filters.

4. Check and replace spray tips showing excessive orifice erosion.

5. Check and replace defective diaphragm in check valves.
6. Check all controls for operation (especially dump system).

During operation: (fill system with water or solvent and operate system)

1. Check for leaks at all connections.

2. Check pump operation (will it give desired flow rate and pressure).

3. Check accuracy of pressure gauge.

4. Observe individual nozzle spray patterns (can easily detect defective spray tip).

5. Shut the system off, observe all the nozzles. Any that continue to drop indicates a loose or defective diaphragm seal (tighten or replace).

6. Recheck spray tips and filters.

Conclusions

The conventional spray system and the pressurized spray system are in use today. The conventional system being most widely used. Probably the most popular nozzles are the spray tips that produce the flat fan and cone shaped spray patterns. However, these are not the only ones since there are many different types of atomizers or nozzle devices available. Some of these devices are available for only one type application such as herbicides or insecticides work and others are for either type application. The spray tips covered herein can be used for either type application while the atomizers are used mainly for insecticide application.

Cleanliness of the spray equipment is a very important factor in a spray operation. A dirty system, one contaminated with other chemicals or foreign material will cause many problems during the spray operation, with considerable time being spent cleaning spray tips and filters after each load. This problem can be eliminated by a thorough inspection of the equipment.
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CALIBRATION OF SPRAYERS

What is a sprayer?
A sprayer is a piece of equipment used to apply an active ingredient (pesticide) in a carrier (water or oil) at a specific rate (pounds or ounces) per area (acre). This piece of equipment can be a simple backpack sprayer, a tractor pulling a mist blower, a mobile spray boom, a helicopter, or spray plane.

What is meant by calibrating a sprayer?
Calibration of a sprayer is the adjusting of one or more of several factors so the proper amount of the pesticide is applied per unit of area.

What do we need to know before any attempt can be made to make these calibration adjustments?
We must know the required rate of application which is the amount of active ingredient to be applied to the unit of area. In simpler terms – pounds of pesticide per acre. In addition, before any adjustments are made, we need to know what volume of spray the spray apparatus is applying per acre at a certain speed. This is the current rate of application.

How do we find the current rate of application of a sprayer?
First we fill the spray tank with water and at a selected speed, spray for a known distance. Then measure the volume of water required to refill the tank. We now know the volume of water used to spray a given area, this area being the swath width times the distance covered. For example:

Problem – Find the current rate of application.
Given – Swath width = 25 feet
     Sprayer speed = 20 miles per hour
     Distance sprayed = 1 mile (5,280 feet)
     Spray used = 12 gallons
Solution

Swath 25 feet x 5,280 feet covered = 132,000 sq. ft. sprayed

Square feet sprayed 132,000

Square feet in acre 43,560 = 3 acres sprayed

Gallons of spray used 12

Acres sprayed 3 = 4 gallons per acre

Current rate of application is 4 gallons of spray per acre at 20 miles per hour.

Now what adjustments can be made so the current rate of application can be changed to the required rate of application?

During the calibration of a sprayer there are four main factors that may be altered so the pesticide will be applied at the required rate:

1. Alter the concentration of active ingredient in the spray.
2. Change the width of the swath.
3. Increase or decrease the pump pressure.
4. Change the speed of the sprayer over the area.

Let’s examine the effects of an adjustment of each of these four factors.

1. Altering the concentration of active ingredient in the spray. If the amount of pesticide being applied currently is low, then additional active ingredients can be added to each tank of spray. In this manner the required dosage level can be reached without other alterations. Conversely, if we are applying too much pesticide, the amount of active ingredient in each tank load can be reduced to get the required dosage. That may not be practical if more than one spray applicator is being used and the concentration of pesticide is different for each sprayer or if the spray has been premixed in large volumes.

2. Changing the width of the swath being sprayed. To increase or decrease the rate of application the spray nozzles can be moved farther apart or closer together but keeping the same number of nozzles. This will change the size of the area being sprayed but when the width is being increased we must make sure the complete swath width is properly covered with spray. In spray planes or helicopters, we can reduce the swath width but this will increase the flying time and the cost. It is also impossible to increase a plane’s swath width past certain limits which are governed by the plane’s design.
3. **Increase or decrease the pump pressure.** Increasing the pump pressure will increase the rate of application and reducing the pump pressure will reduce it. In many cases this is an easy and excellent method to use but in some cases it is not possible, such as wind driven pumps on small spray planes or small pumps with fixed pressure valves, or you may find you can’t keep the pump pressure up without driving the sprayer at an excessively high rate of speed.

4. **Change the speed of the sprayer over the area.** Just remember as you increase the speed, you *decrease* the rate and as you slow the speed you *increase* the rate of application. This, too, has its limits as your spray plane pilot may not care to fly at 35 miles per hour, or, with a ground rig at 3 miles per hour, it may take all summer to spray 1,000 miles of roadside.

Now let’s see if we can solve a few calibration problems.

Problem — We wish to calibrate a sprayer to apply a pesticide to a roadside at a required application rate of 15 pounds per acre. On this problem the calibration will be made by adjusting the amount of active ingredient in the spray.

**Given** — Required rate of application = 15 pounds per acre
Current rate of application = 5 gallons per acre
With/Swath width .30 feet
Speed 15 miles per hour
Active ingredient 1 pound per gallon
Pump pressure 20 pounds per square inch

**Solution** —

\[
\frac{\text{Required rate of application}}{\text{Current rate of application}} = \frac{15 \text{ pounds}}{5 \text{ gallons}} = 3 \text{ lbs. per gal. required}
\]

Using the sprayer with the current rate of application we need 3 pounds of active ingredient in each gallon. We know we have only 1 pound in each gallon so we will need to add 2 additional pounds of active ingredient for each gallon the spray tank holds.

Problem — Same spray project only this time we find the spray has been received premixed in a large quantity and it is not practical to alter its composition. This time we shall try to calibrate the sprayer by altering the size of the spray swath.
Given – Required rate of application = 15 pounds per acre
Current rate of application = 5 gallons per acre
With/ Swath width 30 feet
  Speed 15 miles per hour
  Active ingredient 1 pound per gallon (fixed)
  Pump pressure 20 p.s.i.

Solution –
Since we can’t increase the amount of pesticide from 1 pound to 3 pounds a simple solution would be to reduce the swath width from 30 feet to 10 feet and cover only 1/3 as much area with the same amount of spray. This may not be practical as we are only doing a 10 foot strip and the contract calls for a 30 foot strip along the road. This would require three trips over the road and boom adjustments.

Problem – We are still on the same roadside spray project but we are required to spray a 30 foot swath in one pass as time is short. We are still using the premixed spray so we will try to calibrate the sprayer by altering the pump pressure.

Given – Required rate of application = 15 pounds per acre
Current rate of application = 5 gallons per acre
With/ Swath width 30 feet (fixed)
  Speed 15 miles per hour
  Active ingredient 1 pound per gallon (fixed)
  Pump pressure 20 p.s.i.

Solution –
At the current rate we are putting on 5 gallons per acre with each gallon containing 1 pound of pesticide or 5 pounds per acre. We need three times the 5 pounds so, in theory, if we increase the spray flow 200 percent or from 20 pounds to 60 pounds p.s.i. pump pressure, we should get an increase from 5 gallons per acre to 15 gallons per acre. This is in theory, in practice we will probably find it will take more than a 200 percent pump pressure increase to get a 200 percent increase in flow.

Problem – We are still trying to get that 30 foot roadside strip sprayed in one pass using the premixed spray. The sprayer has a fixed pressure valve so the pump pressure cannot be altered from 20 p.s.i. This leaves only one route to go so we will calibrate the sprayer by altering its speed.
Given — Required rate of application = 15 pounds per acre
Current rate of application = 5 gallons per acre
With/ Swath width 30 feet (fixed)
   Speed 15 miles per hour
   Active ingredient 1 pound per gallon (fixed)
   Pump pressure 20 pounds (fixed)

Solution —
At 15 miles per hour we are spraying 5 gallons per acre with each
gallon containing 1 pound of pesticide or 5 pounds per acre and we
need three times that amount. Remembering that coverage is
increased as speed is decreased let’s reduce our speed from 15 miles
per hour to 5 miles per hour. This should increase our coverage by
200 percent from 5 gallons per acre to 15 gallons which contains the
required 15 pounds of pesticide.

But our plane can’t fly at 5 miles per hour!

In summary, remember in order to properly and safely apply a
pesticide, we need to know the required amount of active ingredient per
unit of area (pounds per acre). We first find out the current rate at which
the sprayer is applying the pesticide. Then by adjusting either the swath
width, pump pressure, sprayer speed, amount of active ingredient or any
combination of these factors we can calibrate the sprayer to apply the
pesticide at the required rate.
In order to use pesticides safely, one must understand the principles affecting drift outside the target area. The immediate and difficult problems created by drift can then be avoided. If an application program can be managed so that there will not be any drift, it can be defended against allegations of environmental damage. Such an allegation can be made easily, but the proof is difficult and time consuming.

There are a number of controllable factors that reduce drift. Drift can not be entirely eliminated, but it does not need to be so severe as to cause an environmental problem. Be observant, think about the pesticide and any potential problems. Forest use is different from agricultural use in that the avoidance of drift in the forest will not ensure freedom from all environmental problems. Problems can also occur within the forest target area.

Drift problems have occurred ever since mechanical equipment came into general use for pesticide application. There were some drift problems as early as the 1920's when lead arsenate drifted from orchards to pastures in sufficient quantities to cause toxicity problems with livestock. In the early 1940's when Paris Green was used for mosquito larvae control, the drift problem was under study. In the late 1940's the problem began to assume immense proportions. The drift of phenoxy herbicides came to our attention first (and is still a concern) because of the heavy, easily observed plant damage. There was some confusion as to whether the observed damage came from drift, from misplacement of phenoxy herbicides, or from volatility and then atmospheric transport. From the 1950's to the 1960's, studies on drift increased because of our ability to detect the problems associated with the use of chlorinated hydrocarbon insecticides.

The percentage of the applied dose of insecticide or herbicide that gets to the target area from an aircraft is about 25 percent in forest applications and 75 percent in agricultural application. The reason for this variance is fairly apparent. During agricultural application, a plane will fly low, 2-6 meters at most. In the forest, the planes fly at about 300 feet in order to avoid getting their wheels down in the tree tops, which are about
200 feet high. The height from which a particle starts to fall is a very important factor in determining the lateral distance it will travel before landing. That were determined up to 600 feet downwind for oil in water emulsions in agricultural applications from an airplane at 60 to 45 feet altitude. In Table 1

<table>
<thead>
<tr>
<th>Target area vs. Downwind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqueous</td>
</tr>
<tr>
<td>54%</td>
</tr>
<tr>
<td>32</td>
</tr>
<tr>
<td>68</td>
</tr>
<tr>
<td>17%</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>28</td>
</tr>
<tr>
<td>Low Volume</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td>18</td>
</tr>
</tbody>
</table>

One instance, 54% was found in the target area, and an additional 17% downwind, accounting for a total of 71%. An additional 29% must have either drifted farther than the 600 feet, or the investigator was unable to sample in a way that would account for it. It is not always necessary to measure the quantity and distance of drift to discover that a problem exists; simply determining the amount on target and subtracting that from the amount applied has the same result. Everything that is not on the target is potentially an environmental problem.

After a spray or dust leaves the spray nozzle orifice, some of it descends to the target area, some travels laterally — partially in the target area but somewhat downwind, and some travels upward and is transported great distances. Pesticides have been found in the Antarctic icecap, in seals of the Antarctic, and at the Arctic circle. Dustfall and rainfall collected thousands of miles at sea have shown that pesticides are traveling over both the Atlantic and Pacific Oceans. Some are particles brought down by rain, and some from the vapor form. The particle size distribution curves show a high peak of small droplets, but when the mass median diameter is plotted, the distribution is slightly skewed. Most of the droplets are of such a small diameter that they could travel long distances before finally being deposited.

A small amount of drift can cause serious environmental problems. Assuming a one-acre application at a rate of one pound of chemical per acre, and that 1% of the pesticide might escape and accumulate in living
organisms, it can be calculated that this 4 grams of a chlorinated hydrocarbon insecticide could contaminate 20,000 ½-pound fish to a level of 1 part per million. One ounce, or 7% of the amount applied to one acre, has the potential of contaminating 150,000 such fish to 1 part per million. Even though the percentages of escaping pesticides appear small, they can be quite significant in the environment.

Figure 1, a hypothetical representation of droplet size distribution, shows a coarse spray with a mass median diameter of about 300 microns, and a fine spray of about 100 microns. In both coarse and fine spray distributions, there are a large percentage of the very small drops which are most likely to drift. One micron drops are very small, about the size of cigar smoke particles, but they can be significant. There might be many more small particles, even when computed as a fraction of the total mass, than what is represented in mathematical curves. A significant amount of material, in terms of mass rather than number of drops, might occur under the 10-micron size and not be identified since it is extremely difficult to measure droplets below this size. These tiny droplets will dodge plants, sometimes landing on the stems rather than on the top of the plant which is more often examined. There is an air-foil boundary around the plant stem or leaf which can prevent the droplets from landing. These tiny droplets will not settle out on a slide and are hard to trap in cascade impacters and bubbling devices, thus, there are probably a great many more of them present than have been measured.

The rate of fall of a droplet changes rather drastically with size, following Stokes Law — the smaller a droplet, the slower it falls. Friction in the air works to slow the fall of a particle. Friction operates according to the first power of the radius of a droplet, but gravity force is a function of the radius cubed. The calculations on the distance a droplet can drift shown in Table 2 assume a still air condition, while in any normal air system, turbulence from wingtips, thermal sources or other influences is present and causes the droplets to fall a short distance and then be carried back up, rather than falling steadily.

Assuming a wind of 3 miles per hour and a release from a height of 10 feet, a coarse spray with 400-micron particles will drift laterally for 8.5 feet; a fine spray with 100-micron particles will drift 48 feet. The distance increases rapidly for the very small droplets. A 10-micron droplet will drift ¼ mile while a 1-micron droplet will travel 84 miles, and there are a great many of these small droplets present in any spray application. Table 3 shows drift calculations for oil particles of various diameters released from a 50-foot height in a one-mile-per-hour wind. A 600-micron droplet takes 0.03 minutes to fall 50 feet, while a 10-micron droplet takes 96 minutes to
Figure 1

PARTICLE SIZE DISTRIBUTION

No. of Droplets

Diameter in microns

MMD = 100 μm
Table 2
Particle Type & Drift Calculations

<table>
<thead>
<tr>
<th>Type</th>
<th>Droplet Diameter in microns</th>
<th>Drift Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse spray</td>
<td>400</td>
<td>8.5 ft.</td>
</tr>
<tr>
<td>Fine spray</td>
<td>100</td>
<td>48 ft.</td>
</tr>
<tr>
<td>Dusts</td>
<td>20</td>
<td>1/4 mile</td>
</tr>
<tr>
<td>Fine dusts</td>
<td>10</td>
<td>3/4 mile</td>
</tr>
<tr>
<td>Aerosols</td>
<td>2</td>
<td>21 miles</td>
</tr>
<tr>
<td>Small aerosols</td>
<td>1</td>
<td>84 miles</td>
</tr>
</tbody>
</table>

Table 3
Diameter & Drift Calculations (Oil)

<table>
<thead>
<tr>
<th>Droplet Diameter in microns</th>
<th>Time required to fall 50 ft.</th>
<th>Distance 1 mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>.03</td>
<td>1 ft.</td>
</tr>
<tr>
<td>200</td>
<td>.25</td>
<td>31 ft.</td>
</tr>
<tr>
<td>100</td>
<td>1.0</td>
<td>90 ft.</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>1,900</td>
</tr>
<tr>
<td>10</td>
<td>96</td>
<td>7,200</td>
</tr>
</tbody>
</table>

fall the same distance, thus the small droplet will drift about 3000 times further. Depending on droplet size, the height of release and wind speed, various calculations can be made – the size of the droplet that will take 15 seconds to fall 50 feet – or the time involved in the fall for a certain size drop – or the distance of drift at a wind velocity of 1, 3, 5, or 10 miles per hour for 100 microns. As Table 4 shows, a 5-micron droplet takes 5.5 hours to fall 50 feet; a 1-micron particle takes 5 days. All of these calculations show the very great distance that the small droplets can drift.

The effects of evaporation, which are fairly surprising, must also be taken into account. As Table 5 shows, a 200-micron droplet of pure water at 86° Fahrenheit in an atmosphere of 50% relative humidity will evaporate in 56 seconds, a 100-micron droplet in 14 seconds, and a
Table 4

Time Required to Fall 50 feet

<table>
<thead>
<tr>
<th>Droplet Diameter in microns</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>13 sec.</td>
</tr>
<tr>
<td>100</td>
<td>51 sec.</td>
</tr>
<tr>
<td>50</td>
<td>3.4 min.</td>
</tr>
<tr>
<td>20</td>
<td>21 min.</td>
</tr>
<tr>
<td>10</td>
<td>1.4 hrs.</td>
</tr>
<tr>
<td>5</td>
<td>5.5 hrs.</td>
</tr>
<tr>
<td>1</td>
<td>5.0 days</td>
</tr>
</tbody>
</table>

(specific gravity 1.0)

Table 5

Evaporation Rate

$H_2O$, 86°F, 50% Relative Humidity

<table>
<thead>
<tr>
<th>Droplet Diameter in microns</th>
<th>Lifetime (sec)</th>
<th>Distance of Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>56 sec.</td>
<td>69 ft.</td>
</tr>
<tr>
<td>100</td>
<td>14 sec.</td>
<td>6 ft</td>
</tr>
<tr>
<td>50</td>
<td>3.5 sec.</td>
<td>1¼ in.</td>
</tr>
</tbody>
</table>

50-micron droplet in 3.5 seconds. In this length of time the same droplets would fall 69 feet, 6 feet and 1¼ inches, respectively. Part of a 50-micron water spray would only fall 1 inch in the first 3.5 seconds. However, given a droplet with 12% oil emulsion in water, the volume of oil to the volume of water ratio changes as a percentage of the water evaporates. As Table 6 shows, when 50% of a 100-micron spray droplet evaporates, an 80-micron droplet remains. If 87% or 7/8 of the spray is evaporated, the droplet diameter is reduced by half and almost pure oil is left. Thus, as a spray droplet starts to fall, it also starts to evaporate, and its rate of fall is diminished. The distance it will drift is much farther than would be predicted from its initial size or the droplet size spectrum.

Some data from my experiments in Arizona comparing sprays and dust provide information on the distance a given amount of spray will drift. As
Table 6
Effect of Evaporation on Drop Diameter

<table>
<thead>
<tr>
<th>% Evaporation by Volume</th>
<th>Droplet Diameter in microns</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>50</td>
<td>79.6</td>
</tr>
<tr>
<td>75</td>
<td>63</td>
</tr>
<tr>
<td>87.5 (7/8)</td>
<td>50</td>
</tr>
<tr>
<td>98.44</td>
<td>25</td>
</tr>
</tbody>
</table>

shown in Figure 2, dust has a lower initial deposit than a spray and drifts much further and leaves a heavier deposit of pesticide at all points along the drift line. Visual observation of drift from sprays and dusts can be somewhat deceiving. Dust drift can be observed for several miles, while spray can seldom be visually observed for more than a few hundred feet. Although drift from spray does not carry as far as does that from dust, it does carry farther than would be expected from visual observation. The evaporation of the water from the spray droplets occurs so rapidly that the small droplets decrease to a size below the visible range quite rapidly, but the pesticide containing particles are still present and, being smaller than their original size, have an even greater capacity to remain suspended and thus drift long distances.

Figures 3 and 4 show the same type of data as Figure 2, but it is presented on logarithm plots so that the range of deposit and the range of drift can be more clearly seen. The data show that spray drift can deposit from 0.2 to 0.5 ppm (under the conditions of the experiment) at a distance of ½ mile on low vegetation (alfalfa). The extrapolation of the drift line shows that sprays could deposit 0.1 ppm on low vegetation at distances of from 1 mile to 4 miles.

These distances are significant, particularly in forest applications where large areas without clear boundaries are being treated. Within the distance of significant drift, there might be a stream which might be damaged or a susceptible wildlife area.

Remember, drift is not likely to travel upwind. Be certain the wind is blowing away from susceptible areas. When the wind is only blowing at 2 or 3 miles per hour, the direction is variable but can be tested with a smoke device. For a routine brush control application, this testing of wind direction can be one of the most important safety factors.
Figure 2

DRIFT EXPERIMENT

SPRAY vs. DUST DOWNWIND CONTAMINATION

Treatment: Toxaphene, 4.0 lbs/acre, on alfalfa

Wind Velocity: 3-4 mph

Lapse Rate: 3.0°F/7 m

SPRAY:

DUST:
Figure 3

DRIFT EXPERIMENT
Insecticide: BHC

Treatment:
△ Spray - 1.25 lb/acre
○ Dust - 1.25 lb/acre

Graphic Representation
2.0 lb/acre

Distance Downwind from Border of Target Crop
Figure 4

DRIFT EXPERIMENT
Insecticide: Toxaphene
Treatment:
△ Spray - 2.0 lb/acre
○ Dust - 3.4 lb/acre

Graphic Representation
2.0 lb/acre
SAFE HANDLING OF PESTICIDES IN FOREST AND RANGE LAND AREAS

The pesticides which have seen most widespread use in forest and range areas have been compounds of relatively low acute toxicity and have not caused many health hazard problems for persons who come in contact with the materials. The greatest potential hazard to workers has probably occurred during handling of the concentrate forms of the few more toxic compounds used. Even though there is an effort to insure that pesticides produced and used in the future will be low in toxicity to warm-blooded animals and not persistent in the environment, there is no assurance that all compounds finding use in forest and range areas will be of low acute toxicity. Thus, we should not lessen our concern about the hazard to persons who come in contact with such compounds. Protection from exposure is necessary if a good record for safe use and handling of pesticides is to be maintained.

Although the hazard is greater when working with compounds of higher toxicity, it should be noted that many of the less toxic compounds can present some need for concern under conditions of gross misuse, accident, or carelessness and it is a wise practice to take precautionary measures to avoid excessive exposure. For example, malathion, while not a compound of high systemic toxicity, has been shown to be a skin sensitizing agent and a potential cause of dermatitis in exposed individuals (Milby and Epstein, 1964). The acute hazard during application of certain chlorinated hydrocarbon pesticides is comparatively low. However, these compounds are stored in body fat following absorption, and their presence in the body is sustained over a longer period of time. Although most of the newer herbicides are considered relatively safe as far as the applicator is concerned, it is advisable to avoid exposure because of the limited use experience with many of the compounds to date.

Much of the safety in relation to pesticides rests not only on the foreman and other supervisory personnel but on the worker who actually applies the materials. 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. He can also prevent excessive
contamination of the general environment. Thus, an important adjunct to safety in relation to pesticides is education of those persons who actually handle the materials.

There are several important indirect ways of protecting the worker such as providing education and medical supervision, stressing the importance of personal hygiene and cleanliness, emphasizing the importance of not being careless, and pointing out the need for reading and following directions on the pesticide label. However, direct protection of workers from absorption of pesticides through the routes of entry into the body is exceptionally important.

There are three main routes of entry of pesticide compounds into the body: (1) dermal, (2) respiratory, and (3) oral. The dermal route has been determined to be the most important route of entry into the body in field studies of pesticide applications (Wolfe et al., 1967). For example, during most exposure situations studied, over 97 percent of pesticide contamination of the entire body was deposited on the skin. Although any given amount of pesticide is more rapidly and more completely absorbed by the oral or respiratory routes, the disproportionate amount of contamination that can occur on the skin indicates the importance of wearing proper protective clothing.

The insidiousness of absorption by the dermal route adds to its hazard. Most persons are aware of the danger of swallowing or breathing insecticides, but the possibility of absorbing appreciable amounts of a poison through the intact skin is not so familiar.

Although much of the treatment of forest lands is by aerial application, ground equipment is also occasionally used. Whenever individual forest tree treatments are made by ground crews using power equipment and hand nozzles, there is opportunity for significant exposure from drift and dripping onto the workers, especially if trees are large enough to require directing the spray upward above the level of the head. This often thoroughly wets the protective or conventional clothing being worn and may result in gross contamination of exposed skin surfaces.

The warning statement on practically all pesticide labels indicates that prolonged skin contact should be avoided, and labels of the more toxic compounds even spell out certain specific articles of protective clothing that should be worn. Many different kinds of protective clothing are being used, and we have been attempting to evaluate some of them. Most people visualize that the ideally protected sprayman is covered from head to foot with heavy black rubberized waterproof clothing - the sou’wester hat, jacket, trousers, gloves, and boots in addition to a respirator and perhaps goggles. This type protection is advisable under conditions of exposure to some highly toxic pesticides even though there is much discomfort and poor acceptance as far as the worker is concerned.
The only skin area exposed under these circumstances is the face-neck area, and the brim of the hat provides some protection for that area. This type protective clothing is often worn during cooler conditions. However, as the temperature rises and these articles become unbearably hot to wear, the workers tend to take them off and work with less protection.

Several types or grades of lightweight water-repellent protective clothing are now available for the sprayman. These are much more comfortable and acceptable than the heavier rubberized clothing. The newer items are made of thinner synthetic materials. Although they will probably wear out or deteriorate more rapidly than will the heavy grade rubber clothing, they provide good protection. Workers find this lighter clothing more acceptable during hot weather. When workers are lax in the use of protective gear — for example, during application of compounds of low toxicity or during extremely hot weather when waterproof protective clothing is difficult to tolerate — workers should be encouraged to at least wear washable cloth jackets that will not readily absorb moisture. Many spraymen wear heavy grade long-sleeved cotton shirts or coveralls, often with no underclothing. These items of outer clothing provide a reasonable amount of protection where spray drift is light and the droplets are so small that they do not accumulate fast enough to penetrate through to the skin. Under such conditions the clothing should be changed and laundered daily. If spray clothing is merely hung up to dry after work and used repeatedly, pesticide material will eventually accumulate enough to contaminate underclothing and skin.

For head protection during warm weather a bill cap is commonly used. This item is popular because respirator straps can be easily adjusted over the outside of the cap. Although this type of headgear provides some protection for the face, it gives practically no protection for the rest of the face-neck area. It is not advisable to wear any type of cloth headgear which might easily become saturated with spray. A water-repellent hat with full brim provides some protection for all the face-neck area and is not particularly uncomfortable to wear. Plastic or metal “hard-hats” are acceptable if they have full brims. However, “hard-hats” which allow circulation of air over the head under the hat should not be used where exposure is to toxic dusts.

One question often raised relates to the protection afforded by gloves during pesticide application operations, since they easily become contaminated on the inside. Cloth-lined rubberized gloves, although more comfortable than unlined gloves, become more contaminated on the inside than do the unlined gloves and are more difficult to clean. However, spraymen wearing gloves of either type receive less contamination on the average than do those working without gloves. For example, in a series of
tests using dinitro compounds, spraymen received an average of 22.4 mg/hr contamination of hands when wearing gloves that were contaminated on the inside. When they worked without gloves the value rose to 91.1 mg/hr (Wolfe et al., 1961). If gloves are never removed there should be no problem of contamination on the inside; however, rare is the worker who does not remove his gloves to smoke, to adjust the spray machine engine, or even to tear open a bag of pesticide.

It is important to secure the correct grade of gloves. Those which provide the most protection are the gauntlet type. The gauntlet gives protection to the wrist area not covered normally by the sleeve. Gloves of various grades or thickness are now available. Heavy, nonflexible gloves interfere with movement of the hands. On the other hand, if gloves are very thin and pliable, they may tear or wear out easily and become uncomfortable from perspiration on the inside during hot weather. Natural rubber gloves are recommended when working with highly toxic organophosphorus compounds because they deteriorate more slowly, resulting in less chance of penetration by the toxic material.

As far as other articles of protective clothing are concerned, it is advisable to wear rubberized trousers under conditions of heavy pesticide drift. Rubberized boots should be worn during practically any type of application. Usually the ground cover becomes thoroughly contaminated and leather boots or shoes become soaked and deteriorate under repeated use allowing penetration of pesticides.

It is particularly important to avoid spillage of concentrated forms of pesticide onto the skin. One small spillage of concentrate, if not promptly removed, might result in more absorption than a worker would receive over a period of several days of normal spraying with the dilute formulation. Any such spillage should be thoroughly washed off with soap and water. In the case of the more highly toxic compounds, this should be done immediately. A bar of soap, a towel, and an extra canteen of water should be carried on every supply truck and spray machine for this purpose. Provision of these items in forest spray activities is of particular importance since normal washing facilities may be distant.

At the end of spraying activity for the day, it is important that each worker bathe thoroughly to remove any pesticide which has been deposited on the skin and thus preclude further absorption.

The above considerations apply to the dermal route of exposure — the one of primary importance for spraymen. However, attention should also be given to protection from respiratory and oral exposure.

Protection of the respiratory route of exposure is especially important where toxic dusts and vapors or very small spray droplets are prevalent. Respiratory exposure is greater during applications using fogging or
aerosol-type equipment because the droplets formed are much smaller than those produced by many conventional spray machines. Certain concentrate spray machine nozzles also produce relatively small droplets. Tests have shown that when operating an 8X (8 times normal concentration) concentrate airblast machine, the potential respiratory exposure is nearly three times greater than when operating a conventional dilute spray machine (Wolfe et al., 1966).

Respiratory protection can be provided by use of gas masks or respirators. The gas mask is more effective but also more uncomfortable to wear than the respirator. Gas masks should be used when high concentrations of toxic vapors are present or when there is prolonged exposure in confined spaces with no ventilation. The more commonly used respirators are the half-face mask with one or two cartridges attached which contain activated charcoal as an adsorbing material. Most respirators have filter pads over the cartridge units. Applicator pilots who risk the possibility of flying through drift of fine droplets or dusts should consider the use of some type of face mask equipped with a filter cannister attached either to their belt or to the inside of the cockpit.

Proper care of respirators is very important. The rubber facepiece 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 facepiece. Two of the more common offenses in the care of respirators are failing to wash the facepiece with soap and water and neglecting to change the filter cartridges regularly. Washing of the facepiece 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 of pesticide. Solvents should not be used for they may damage certain parts of the respirator. The general recommendation is that cartridges should be changed after 8 hours of continuous exposure. Under conditions of intense exposure the useful life of the cartridge is shorter. Thus, if breathing seems hampered, or if the odor of pesticide is detected, the filter cartridges should be changed immediately. If the filter pads are a separate removable unit, they should be changed more frequently than the cartridges.

Oral contamination may be brought about by drift of pesticide onto the lips or mouth area, by contamination of food items, or by careless actions such as attempting to blow out clogged spray nozzles with the mouth. A certain amount of oral contamination may also occur from smoking contaminated cigarettes. However, cigarette contamination is usually considered to be more closely associated with respiratory exposure. Although oral exposure is considered to be a minor occupational problem for pesticide spraymen, there has actually been little experimental
work done to define its magnitude. Adequate techniques for studies of this sort do not seem to be available. However, in limited studies designed to measure potential exposure associated with handling cigarettes or food with contaminated hands, our laboratory analyzed such items after handling by spraymen and fruit thinners. When smoking or handling cigarettes with contaminated dry hands, the content of endrin, parathion, or azinphosmethy! was found to be not more than 4 micrograms per cigarette in situations involving dilute spray. Higher levels of pesticide contamination (20 to 50 micrograms per cigarette) occurred rarely and only with spray-moist hands that were wet enough to leave moist spots on the cigarette paper (Wolfe et al., 1963; Wolfe, H. R., unpublished data). Contamination of sandwiches by thinners working in parathion residue was also very low. Obviously, greater hand contamination and correspondingly increased potential oral exposure could result from contact with the more concentrated pesticide formulations such as are encountered during mixing and loading.

The safety responsibilities of pesticide applicators go beyond the actual spraying and dusting operations. Contamination of water and soil should be avoided — for example, tanks for ground spraying should never be filled from streams. Even if an operation is some distance from a stream, tank run-over or spillage on the ground may eventually contaminate the stream through run-off during heavy rain or by particles of contaminated soil which may be carried to the stream by wind during dry conditions. If concentrated pesticide should be spilled on the soil, especially the emulsifiable form of any of the more toxic compounds, the contaminated soil should be dug up and buried in a safe location where there will be no contamination of water through seepage or surface run-off.

Special precautions to avoid spillage should be taken around picnic areas, camp sites, or other places where small children are likely to play. This is emphasized by the fact that over half of the deaths each year due to pesticides involve children (Hayes, 1960). One severe but nonfatal case involved a 2-year-old boy who nearly died from parathion poisoning after ingesting dirt from the driveway of his home (Quinby and Clappison, 1961). The contamination had occurred over 6 months previously when parathion concentrate leaked or spilled from a truck. At the point where the child had been digging, the soil was analyzed and found to contain almost 1 percent parathion.

Empty containers should never be discarded in forest or range areas or left in any place where they might be a hazard to children, pets, wildlife, livestock, or to adults who may convert them to other uses — for example, in forest areas campers may use discarded containers for water, cooking, etc. Metal drums should always be thoroughly rinsed with plenty of water
as soon as they are emptied. In this way the rinsings can be poured into the spray tank. Tests at this laboratory have shown that two thorough rinsings of a 5-gallon “empty” parathion drum with water will remove over 95 percent of the pesticide left in the unrinsed drum. After drums are emptied they should be punctured to make them unusable. This is easily done using a conventional hammer with a straight claw. In addition to puncturing the drums, it is advisable to crush them and bury them at least 18-inches deep in an isolated location away from water supplies. If containers are ever taken to a public dump, the caretaker should be informed so that they can be covered over as soon as possible.

In all types of pest control operations the integrity of stored supplies of the chemicals must be assured. All pesticides should be stored in a locked building or room where no food items are stored. Pesticides should never be stored in beverage bottles or in other small containers which have formerly contained food products. Each year tragic preventable poisonings occur when children have access to such containers filled with toxic materials. Storage should be in a dry place in the original, labeled containers and with the labels plainly visible. Herbicides should be kept apart from other pesticides to avoid cross-contamination and substitution errors. All lids and bungs should be tight and containers should be periodically checked for corrosion, leaks or breaks so that faulty containers may be detected and removed before they become a hazard. Avoid stacking pesticide drums and bags too high since the combined weight may break the packages or cause leaks of drums on the bottom. Glass containers of chemicals should not be stored in direct sunlight where heat rays from the sun may be concentrated and result in fire. The outside of storage sheds or warehouses should be plainly labeled with the words “Danger” and/or “Poison” along with the familiar skull and crossbones and the words “Pesticide Storage.”

As noted above, if recommended safety precautions are followed, no health problem should result from pesticide usage. However, in case of any illness suspected to be caused by pesticides, the patient should be taken to a physician as soon as possible. A label should be taken along to provide information on the compound involved. If the label does not remove easily the entire container should be carried. If the illness is diagnosed as having been caused by a pesticide he should not return to work until a physician advises that it is safe to do so.

In summary, workers must become well informed concerning the hazards involved in the use of pesticides if these chemicals are to be used safely. Information on the pesticide label represents the results of research and legislation in the interest of safety to the user and the general public. However, it is the individual user who must take personal responsibility to

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read the label and follow the directions. If this is not done, some hazards may exist, accidents and illnesses may occur, and there may be excessive contamination of the environment.

Literature Cited

PESTICIDE DISPOSAL

This report is limited to techniques which will facilitate the disposal of minimal waste pesticides and their containers generated by large farm operators, commercial pesticide applicators, and public agencies. It does not address itself to the household aspect of pesticide waste nor to the particular waste problems of the manufacturer or formulator.

First, consider that pesticide wastes/containers are a form of solid waste differing only in that they are more toxic than most. Consider also that there are, at present, no foolproof disposal methods. Until universally acceptable management processes are developed, some compromises must be made.

The magnitude of the problem is illustrated by a few production figures. Over one billion pounds of synthetic organic pesticides were produced in the United States in 1969. Of this total, 182 million pounds were fungicides, 374 million pounds herbicides, and 580 million pounds insecticides. These figures do not include exports or imports. Available statistics on these points are confusing in that they include inorganics as well as formulated chemicals.

The container generation has been estimated at over 250 million units in 1969. This does not include small containers for household use. For example, over 100 million pesticide aerosol units were manufactured in 1969.

The toxic residue remaining in so-called “empty” containers constitute a significant hazard and, at the same time, offer a partial solution to the disposal dilemma. Since the avowed purpose of pesticides is to mitigate pests, it is reasonable to expect that they be used for this purpose. It is not only unthrifty but also environmentally hazardous to do otherwise.

Studies measuring the quantity of pesticides in “empty” containers of sizes ranging from .5 gallons through 55 gallons reveal 1 percent to 2.8 percent toxicant remaining. Limited tests conducted at Oregon State University indicate that a simple, single water rinse of newly emptied containers will remove over 80 percent of the residue and a second rinse removes half the remainder. This rinsing procedure is receiving emphasis in
our educational pesticide safety programs. Extension Circular 762 titled “Don’t Be a Loser With Agricultural Chemicals” is available for your use. It should be emphasized that the rinse water should be used in the spray operation—poured into the spray tank—or the benefits are lost.

To be realistic, we must admit that thousands of empty containers with the above mentioned residues are casually discarded in Oregon each year. And where do they go? A survey we conducted indicates that most stay on the farm and are reused for a variety of purposes. Many are thrown in whatever convenient locations are available. A few go to municipal dumps or landfills. All these methods are immediately or potentially hazardous.

It is our contention, at present, that the pesticide user is responsible for safe use and disposal. It is illogical that pesticide containers should be returned to manufacturers at this stage. Transportation hazards would be considerable and quite probably illegal. The movement would serve no useful disposal aim.

Collection drives and mass burials have been a common occurrence in many states but they are but stop-gap measures. A logical, complete system is needed that will include accumulation, decontamination and recycling of these resources.

In terms of work in progress — The chemical industry is working toward the development of a one-way combustible container that will not result in intolerable air pollution. Water soluble packaging and plastic liners for metal containers are receiving some trial.

Incineration studies at Mississippi State University are promising but still in a developmental stage. Incinerators promise to be a partial answer but are very expensive and certain chemicals defy complete combustion at temperatures up to 900° C. The Mississippi State University results indicate a place for controlled incineration combined with soil-surface or soil incorporation of non-combusted residues.

Investigations are underway on a Federal level to determine the feasibility and location of regional disposal sites. Oregon State University has in operation a demonstration-grant investigation designed to manage user wastes and containers. It utilizes the concept of voluntary user transport to a controlled collection and decontamination site. It includes the treatment of containers by non-chemical and chemical means to convert toxic contents, to a degraded or non-toxic state, and the disposal of the wash fluids on the soil surface. At the soil surface, again under controlled conditions, chemical, physical and biological action of light, atmosphere, and microbes is expected to render the degraded chemical innocuous in a finite time period permitting reuse of the land for further disposal or reversion to other uses.
The ultimate disposal procedure will undoubtably be influenced by national, state, or local legislation. Disposal of toxic chemicals will be carefully controlled as to site and environmental impact under private or public operation. The accumulation at collection/decontamination sites will largely be voluntary but may be influenced by legislation that will prohibit casual disposal or reward compliance. Deposits on containers or new packaging methods and materials may influence this procedure.

A national Working Group on Pesticides at a meeting in Washington, D.C., in October of 1970, prepared interim guidelines for disposal of pesticide wastes and containers. A consensus there admitted that we are in a storage stage at present with methodology just now emerging that will permit acceptable disposal/recycling action.
SECTION V

PUBLIC AND ADMINISTRATIVE PROBLEMS
– LAWS RELATED TO PESTICIDE USAGE

Chairman: Jack Mounts
Few people realize how broadly pesticides are used for the control of pests of agriculture, livestock, natural resources, and humans, and how life would be without these chemicals. Long ago it was realized that because of their nature, these products required careful regulation at the Federal level. The ordinary citizen could not expect to be his own guardian against fraudulent claims and improper instructions nor could he know how to use such products without harming others. The environmental aspects of these agents was another reason for the development of regulations and the establishment of standards.

The initial laws have undergone several amendments and the process is still underway. Even now as we talk about the pesticide laws that are presently in the statute books, revisions are being proposed. With this evidence of the dynamic state of the laws dealing with pesticides it is probably unnecessary to warn that what is true today may not be true tomorrow.

The interstate commerce of pesticides is regulated by two laws: the Federal Insecticide, Fungicide and Rodenticide Act (FIF and R Act) which deals with the marketing aspects of pesticides; and the Federal Food, Drug and Cosmetic Act (FFD and C Act) which covers the human health aspects of pesticides. Both are aimed at the protection of the consumer, the one to insure that the pesticide product he buys is reliable and can be used safely and effectively, and the other to insure that the health of the consumer is not jeopardized.

The general philosophy and the main stipulations under which these laws are administered were established by Congress and are stated in the Acts. The details of regulation and enforcement and the interpretation of the generalities are left up to the agencies to which the acts were assigned for administration. Until recently, this was the Pesticide Regulation Division (PRD) of the USDA, for the FIF and R Act, and the Food and Drug Administration (FDA) for the FFD and C Act. The responsibility for these regulations has recently been given to the Environmental Protection Agency (EPA). This will be discussed later in this article.
The result of the above division of areas and responsibilities is that one who desires to become familiar with all aspects of these laws must read two Federal laws and two sets of regulations (1, 2, 3, 4).

The Federal Insecticide, Fungicide and Rodenticide Act:

This law was passed in 1947 and has been revised several times since. It defines "economic poisons" so as to include the usual pesticides as well as substances which regulate plant growth or which poison or repell amphibians, reptiles, birds, fish, mammals, and invertebrate animals.

Two main activities are conducted, registration of pesticides in interstate commerce and enforcement of the provisions of the Act. All of this is done under the Pesticide Regulation Division (PRD) formerly of the USDA and now under EPA.

Essentially, registration amounts to approval of the label under which a pesticide is sold. As anyone who has consulted such a label knows, it contains a variety of information. In addition to the name of the product, the manufacturer, and the ingredient statement, there are directions for use, warning or precautionary statements, and instructions for handling accidents.

The regulations give the details which guide the petitioner in the preparation of his label. For example, pesticides are divided into three categories with respect to their toxicity to higher animals. Category 1 contains those that are "highly toxic" (LD_{50}'s equal 50 mg/kg or less, in rats). The label on packages containing such products must carry the words "Poison" and "Danger" and the skull and crossbones, in a prominent place. The next category of poison need carry only the word "Warning" and the third category, the word "Caution."

Obviously the directions for use are an important part of the label and receive the close scrutiny of the PRD when they are considering the registration of a new label. These directions should be reliable and easy to understand. They contain all of the important information required for the effective use of the pesticide — dosage rate, timing, method of application, and, of course, the pests which the product is designed to control.

The PRD tries to guide petitioners regarding some of the "ethical" aspects of the labeling law. For example, it is unlawful for the seller to write his label in such a way that it implies endorsement by the USDA. Comments on the safety of the product run into certain taboos and the disclaimer clauses which are designed to protect the manufacturer from lawsuits also have to obey certain rules.

The FIF and R Act and the regulations supporting it recognize the need for experimentation with pesticides by providing for special labeling
procedure for the use of researchers. Under these paragraphs of the Act, a temporary permit can be issued for the interstate commerce of materials designed for experimental use only.

The Federal Food, Drug and Cosmetic Act:

The original FFD and C Act was passed in 1906 and has been amended several times since then. At present we deal primarily with two amendments, one covering raw agricultural commodities and the other processed foods.

The law is coordinated with the FIF and R Act in several ways: by using a common definition of "economic poison," by providing for temporary tolerances to cover pesticides registered for experimental use, and by providing that the two Agencies work together in arriving at decisions. A few years ago the Department of Interior was also brought into consultation with USDA and HEW.

The main purpose of this Act is to establish tolerances, i.e. maximum levels of pesticide residues on raw agricultural commodities or processed foods in interstate commerce. The Act, and the regulations which support it, prescribes procedures for establishing these tolerances. Foods which contain pesticide residues above these tolerances can be seized by Federal authorities.

When a pesticide comes up for consideration under this Act it will be handled in one of three ways: A definite numerical tolerance will be established; it will be exempt from consideration of a tolerance because it is regarded as safe; or, it will be given a zero tolerance. The latter action can be taken only when the pesticide has been shown to be carcinogenic and, under present interpretations, probably means that the pesticide cannot be marketed. The tolerances are calculated on a weight/weight basis and are given in parts per million (ppm).

Pesticides which are exempt for various reasons include ferrous sulfate, sulphur, lime sulphur, potassium polysulfide, sodium polysulfide; the botanical insecticides such as pyrethrum, ryania, and rotenone; the copper compounds (except copper arsenate); the insect disease organism bacillus theringensis; and several others.

Two kinds of finite (numerical) tolerances can be established, the regular tolerance such as those which have been employed for many years, and the negligible residue tolerance. The latter replaces most of the zero tolerances and the "no residue" registrations which were in effect until a few years ago. The only exception to this total replacement of the zero tolerances is in the case of the carcinogenic compounds already mentioned.
The main visible difference between these two types of tolerances is that the negligible residue tolerance is usually very low, e.g. 0.01 to 0.25 ppm, compared to the permissible tolerance which ranges from values as low as 0.1 ppm to 100 ppm. Technically, however, there is a more important difference — the negligible residue tolerance is set at a level which is considered "toxicologically insignificant." It takes into account all the ways in which humans are exposed to pesticides — in their food, in the air, and in drinking water — as well as the minimum level which can be detected by good analytical procedures. It is based on 90-day feeding studies with two species of test animals. The negligible residue will ordinarily "add to the diet an amount which will be less than 1/2000 of the amount that has been demonstrated to have no effect from feeding studies on the most sensitive animal species tested."

The FDA, in establishing regular tolerances, attempts to use the fraction 1/100 as a guideline. In other words, because it is impossible to conduct suitable toxicological tests on humans, the tolerances which are granted under these two procedures represent a 2,000-fold and a 100-fold margin of safety. Thus the FDA assumes that man is the most sensitive animal.

Hundreds of tolerances have now been granted. An example of the number given on typical crops is seen in Table 1.

Table 1. Examples of number of tolerances in effect on typical crops during 1969.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Number of Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grapes</td>
<td>54</td>
</tr>
<tr>
<td>Strawberries</td>
<td>52</td>
</tr>
<tr>
<td>Broccoli</td>
<td>40</td>
</tr>
<tr>
<td>Carrots</td>
<td>35</td>
</tr>
<tr>
<td>Oats</td>
<td>13</td>
</tr>
<tr>
<td>Wheat</td>
<td>19</td>
</tr>
<tr>
<td>Spearmint</td>
<td>2</td>
</tr>
<tr>
<td>Hops</td>
<td>11</td>
</tr>
</tbody>
</table>

OPERATING UNDER THE PESTICIDE LAWS

With this brief summary of the main objectives of the federal laws, we can now consider how a pesticide manufacturer must proceed in complying with them. Knowing that the PRD and the FDA will require a
variety of facts and data when they are asked to consider his pesticide for a label and a tolerance, the manufacturer launches a broadly based research effort as soon as he feels that he has a useful pesticide. This effort ranges from the development of a specific and sensitive analytical method for measuring the pesticide under a variety of conditions, to a study of the toxicology and pharmacology of the compound and to the pest control aspects of his product, i.e. the development of information on how and when to use the pesticide.

The effort will involve private laboratories (for the toxicology and pharmacology) and State Experiment Stations and USDA laboratories in all the agricultural regions where the pesticide is expected to be used. The manufacturer develops suitable formulations of the pesticide and obtains an experimental permit which allows him to ship the pesticide to his cooperating laboratories and field stations.

Registrations and tolerances are established on a crop by crop, or use by use basis. Thus, when the pesticide manufacturer thinks he has enough data to satisfy all the questions which will be asked he prepares a petition containing the following main parts: the chemical and physical properties and other pertinent data identifying the pesticide; the amount, frequency, and time of application; the toxicological and pharmacological aspects of the pesticide; the analytical methods and the amount of residue remaining on the crop; methods of removing residues; the proposed tolerance; and arguments in support of the petition.

This petition is submitted to the PRD which, under the FIF and R Act, must decide whether the pesticide is useful and whether the tolerance requested is reasonable and whether the claims made for the compound are reliable and should be permitted on the label. If all is in order, the petition is then sent to the FDA which considers it under the provisions of the FFD and C Act. After studying the toxicological and chemical residue data this agency decides whether to grant the tolerance requested. If a tolerance is granted, the petition is then returned to PRD who will proceed with the registration (granting of a label) thus giving the manufacturer permission to begin marketing his pesticide in interstate commerce.

The entire process of developing a pesticide and obtaining a Federal clearance for its use on a single crop requires several years and, by the time the pesticide becomes widely used, may occupy 15 or 20 years. Registrations are still being granted, for example, for the pesticide malathion which was first developed about 1950. The price tag for complying with these laws is high, estimates ranging from one to several million dollars per product.
ENFORCEMENT

FIF and R Act:

The PRD has four regional laboratories in the United States where the enforcement provisions of the Act are conducted. In addition, there are smaller laboratories located around the country including one at Oregon State University. Similar activities are carried on by the states and there is a cooperative agreement between state and federal laboratories.

These laboratories receive samples collected at the market place and conduct tests to determine whether the ingredient statements are accurate, whether there is adulteration of the product due to improper formulation, and to assure that the directions for use, if followed, will result in control of the pests. A product is considered misbranded if its label carries any false or misleading statement, if directions for use are not adequate for the protection of the public, if it does not carry the necessary warning statements, if the statements are not sufficiently clear to be “read and understood by an ordinary individual under customary conditions of purchase and use,” or, if it implies endorsement by the USDA. There are, of course, several other ways in which a product could be considered misbranded, but there is not time to discuss all of them here.

FFD and C Act:

Like the PRD, the FDA has regional laboratories where commodities in interstate commerce are examined for compliance with the residue laws. Inspectors range through the country collecting samples for inspection and analysis. When products are found which carry residues above the tolerances, action is taken to remove them from the market.

In this connection we should note that contamination of food by pesticide residues is only one form of adulteration of food which must be watched by FDA inspectors. Putrefication, contamination by insects or insect parts, contamination by rodent excreta, and pollution by other means is also monitored. During a period when the FDA was publishing data on its seizures of foods for various purposes, this writer noted that, tonnage-wise, less than 10% of the seizures were for illegal pesticide residues and the vast majority of these were for the mixing of treated seed grains with feed grains.

According to the Market Basket Surveys which were begun in 1963, the American consumer is being exposed to pesticide residues at only a fraction of the level which is legally permissible. In fact, these surveys showed that many of the tolerances which has been granted were more liberal than required, resulting in a decision by the FDA to lower certain
tolerances still further. Table 2 shows some results from the Market Basket Survey in 1967.

Table 2. Some results of the Market Basket Survey in Los Angeles, 1967

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Residue</th>
<th>Tol.</th>
<th>Residue</th>
<th>Tol.</th>
<th>Residue</th>
<th>Tol.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Products</td>
<td>Meat</td>
<td>Leafy Vegs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDT</td>
<td>0.036</td>
<td>1.25</td>
<td>0.086</td>
<td>7.0</td>
<td>0.015</td>
<td>7.0</td>
</tr>
<tr>
<td>DDE</td>
<td>0.222</td>
<td>-</td>
<td>0.163</td>
<td>-</td>
<td>0.005</td>
<td>-</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>0.018</td>
<td>-</td>
<td>0.016</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hep. Epox</td>
<td>0.005</td>
<td>0</td>
<td>0.008</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BHC</td>
<td>0.005</td>
<td>-</td>
<td>0.016</td>
<td>-</td>
<td>0.003</td>
<td>10.0</td>
</tr>
</tbody>
</table>

ENVIRONMENTAL PROTECTION AGENCY

As of the first of this year the agencies of HEW and USDA which, for many years, have been administering the FIF and R Act and the FFD and C Act were taken over by a new agency, the EPA (7). This agency starts with a budget of 1-1/2 billion dollars and a staff of 6,000. The organization is divided into five programs: water quality, air pollution control, pesticides, radiation, and solid wastes. Each is headed by a Commissioner who reports to the EPA administrator. There will also be 10 regional offices reporting to the administrator.

The Pesticide Commission will be responsible for setting tolerance levels, registration of pesticides, monitoring residue levels in food and other portions of the environment, review of pesticide formulations for efficacy and hazard, and regulation of sale or use. They will also be responsible for research on the effect of pesticides on human health, on non-target organisms, and on the environment.

Proposed new legislation:

It is also being proposed that the FIF and R Act be repealed and replaced with a new law (8). One of the major changes under this law will be the classification of pesticides into three categories, those for general use, those for restricted use, and those for use by prescription only. Those designated for restricted use would be applied only by licensed operators and those designated for prescription would require approval by a licensed consultant. It is contemplated that it will take four years for full
implementation of these classification and licensing procedures.

Under this bill, EPA would consider both short-term and long-term effects of pesticides on man, plants, animals, and the rest of the environment in determining if the chemicals are injurious. Also studied would be the pesticide’s persistence, degradation, and potential for movement and accumulation in the environment.

EPA would also set standards for the amounts of particular pesticides and their residues permissible in fish, shellfish, wildlife, air, water, and other parts of the environment. Tolerance levels for residues of pesticides on food, tobacco, and in domestic water supplies would be established.

**Literature Cited**


**Regulations for the enforcement of the FFD and C Act**: Code of Federal Regulations (CFR) Title 21, Chap. I, part 120-120.1018 (raw agricultural commodities); Section 121.1-121.102 (processed foods); (OSU Library Call No.—K C56, 1949, V7).


STATE LAWS RELATED TO PESTICIDE USAGE IN OREGON

Oregon has two laws which govern the sale, use, and application of pesticides in the state: The Oregon Pesticide Application Act, ORS Chapter 573 and The Pesticide Registration Law, ORS Chapter 634.

Chapter 573
This law regulates the application of pesticides in the state. It provides for the licensing of persons who own or operate a business of applying pesticides upon the land or property of another, of persons who are employed by an owner of an application business and actually apply pesticides, and persons who are employees of governmental agencies and apply pesticides upon the land or property under control of the agency.

The Pesticide Application Law requires that persons who do the actual application work or supervise applicators must pass a written examination or otherwise demonstrate satisfactory training in and knowledge of pesticides.

Four types of licenses issued.
1. OPERATOR: For the person who owns or operates a pesticide application business.
2. APPLICATOR: For the person who is employed by an Operator and who actually operates or supervises the operation of equipment used to apply pesticides.
3. TRAINEE: for the person who is employed by an Operator and is working or going through a training program to qualify as an Applicator.
4. SPECIAL APPLICATOR: for the person employed by a governmental agency and applies or supervises the application of pesticides.
Licenses issued in four classifications
1. Herbicide.
2. Insecticide-Fungicide.
4. Fumigation.

Additional Provisions
Pesticide Operators, or owners of an application business, must supply evidence of a public liability policy or a surety deposit to the Department. The policy or surety deposit must be not less than $25,000 for bodily injury and $25,000 for property damage. A deductible clause may be included in the public liability insurance policy in an amount not to exceed $1,000. Operators must also maintain records of their application work showing the owner and location of property or crops treated, date of application, name of applicator, trade name, strength and concentration of pesticide applied, and equipment used.

Chapter 634
This law provides for the annual registration with the Department of all brands and formulations of pesticides manufactured, delivered, distributed, sold or offered for sale in the state. It gives the labeling requirements for each package or container of pesticides and provides for the collection of samples and the analysis of the samples by the Department.

The law provides for the issuance of experimental permits for pesticides which are still in the development or experimental stage. It also provides that the Department through the public hearing process may establish, maintain, and modify a listing of pesticides which are highly toxic to man and may prescribe conditions under which these pesticides shall be handled. The Department has done this and at the present time thirty-nine pesticides are on the highly toxic list and are restricted to use by licensed commercial applicators only. Pesticides on the highly toxic list may not, under any circumstances, be registered for sale or distribution for home and garden use.

DDT Regulations
Last year the Department, under provisions of Chapter 634, held public hearings relative to the use of DDT in the state. Hearings were held in three locations. Out of the testimony presented at the hearings and after considerable deliberation, the Department promulgated a regulation which lists eight crops or uses for DDT that are considered
essential in Oregon. The regulation restricts DDT from home, garden, and shade tree use and from use in the aquatic environment, but it does provide for emergency use to control outbreaks of serious pests in agricultural, horticultural or forest areas and for control of pests having public health significance.

Committee on Synthetic Chemicals in the Environment.

Chapter 634, as amended by the 1969 Oregon Legislature, provided for the establishment of a twelve-member committee on Synthetic Chemicals in the Environment. The Committee as now formed has representation from several agencies and industries in the state, including the State Forestry Department, State Board of Health, Environmental Sciences Center, and several others, which are concerned with and most knowledgeable in the problems relating to pesticides. The Committee serves to advise the Department and, upon request, may advise other agencies or governmental bodies on matters relating to pesticides, their use and regulation of disposal sites, disposal of containers, and disposal of residues from the manufacture of pesticides.

The Committee has met on a fairly regular schedule since its formation and has explored many areas relative to pesticides and their use in Oregon. It has submitted several recommendations to the Department. The Committee undoubtedly will have considerable influence in the coming months on the scope and direction of the pesticide program in Oregon.
PUBLIC RELATIONS AND HERBICIDES

One of the great dilemmas of an Information and Education man is that land managers always wait to throw oil on troubled waters until after a little turbulence has become a storm. As in the Boy Scouts, U. S. Coast Guard, and other such fine organizations, preparedness is essential. You should be prepared for the oftentimes bumpy road ahead. This preparation may not smooth out the bumps, but at least you will have something to hang on to when they come.

As you well know, much of the reaction to the use of chemicals is based on emotion and hysteria. A couple of years ago we received some letters from people who said they enjoyed an outing to the same area each year, and had always previously enjoyed the bird sounds, and had seen an occasional deer. After our spray job, they hadn’t heard a peep or chirp, or seen a deer. Even though we wrote a lengthy letter to each of these people explaining our program in detail, I doubt that we were very convincing because when many people’s minds are made up, they don’t want to be confused with facts. I think the Globe, Arizona incident that Logan Norris spoke of is a classic example.

As has often been said, “The best defense is a good offense.” I think the most important thing about a public relations or I&E plan is that we should be honest with the public. We MUST tell them what we are doing, and how we are going about it. If we try to sweep our programs under the rug so they can’t be seen, we will surely trip over the hump. If you try to hide what some people might consider dirty laundry you may end up being scouring, agitated, and hung out to dry. People, especially our critical younger generation, are right up to the eyebrows with government propaganda. The “credibility gap” is a fairly new term in our language, but everyone knows what it means. People are too sophisticated now to be hoodwinked by doubletalk. Even more important is that people are now interested in the environment. A few years ago most people couldn’t even spell “ecological environmentalist,” but now most people consider themselves to be one.
So above all, be honest with the public—its their land, and they have a right to know what's going on.

For any project an operational plan is necessary, and this should include a public relations or information and education plan, too. A good plan is predicated on solid facts. Nothing is more aggravating to someone than not to be given a straight answer, whether by intention, or by lack of adequate homework. Whoever is the most knowledgeable on the staff should be given the task of pulling enough facts together to answer most of the questions that people will logically ask. A well prepared document should answer 95% of the questions people would ask. The scope of the project, type and amount of application, safeguards, and other pertinent data must be included. This could be put into the form of a printed fact sheet for public distribution.

One of the first steps in laying the groundwork for a spray job is to talk to local landowners adjacent to the areas where you will be operating. The extent of the program and the safeguards to be taken should be discussed. This does not necessarily mean that all local landowners are going to buy what we are doing, but at least they will be informed about it. Also, the various cooperating agencies should be given the opportunity to review the contract for any suggestions or criticisms they may have. This group would include game and fisheries people, sanitarians, and water users.

Make sure that the key people within the local communities know what is happening early in the game, and before the spray program becomes public information, because they can do much to spike rumors and alleviate the fears of the uninformed. This group should include those people to whom the citizens look for leadership. If your Forest or District has an advisory council, be sure that these people are well informed at the earliest possible date. This may be done by letter, personal contact, or whatever method is best for you.

The very thought of the next step will bring cold chills to the backs of many a forester, but it is a necessary fact of life. The mass media i.e., newspapers, radio stations, and T.V. should be told of the project, preferably by sending them a prepared news release. If it is typed and ready to go, the chance of being misquoted is reduced. Also, be sure there is enough information in it. In basic journalism we refer to the "5 w's and the h" of news. This is who, what, where, why, when, and how. Don't worry too much about format, because if the story is too bad, a rewrite man will make it more palatable. Most little weeklies are short staffed, and don't have the manpower to assemble a total chaos into something sensible, so at least try to be coherent, and not verbose. On our Forest we send out a news release about 2 weeks prior to the spray job, and then the
District Rangers supplement as needed for their local papers. Above all, be sure to stress the safety aspects of the operation.

Once the spray operation has started, don’t be afraid to take people out on the ground to show them what’s happening. This may require taking a man away from his regular work to act as a guide and spokesman, but it will pay off if you do. People very quickly become suspicious when we appear to not have time or act like we don’t really want to show them what’s happening. There may be groups in your area that will want a show-me trip since nothing takes the place of being on the ground for first hand observation. Last year we sponsored a field trip, not during the spray operation, but afterward, for the Governor’s Committee on Synthetic Chemicals in the Environment, and found it to be a rewarding exchange of ideas and information.

When people come into the office and want to know what the spray program is, give them adequate information and time to review materials, and then be available to answer questions.

During the operation, you may want to encourage the local press to send a reporter-cameraman to do a story. A large feature is a good way to let the general public know about our work. Now, what do we do with a reporter who has, as his calling, the need to stir up controversy. As in all fields, ethics is something that exists in varying degrees from person to person. Unfortunately, there are journalists around who print half-truths, double entendres, innuendos, insinuations, and leave omissions of facts from their stories. Sometimes it helps to try to get them to come out for a field trip. If this does nothing more than to get them to stop writing about your project, you will have spent your time well. On the other hand, there is such a situation as a lost cause, so bear in mind that you can’t win ‘em all.

Try to have a competent cameraman on hand during the flights so that you can have both 35mm slides and black and white film documentation. This will make the next public presentation a lot easier, because you’ll have slides with which to illustrate. The black and white pictures are necessary in case you ever want to print a brochure or leaflet. If you don’t have proper camera equipment or anyone who knows how to use it, it might be worth the cost to hire a freelancer to do it once, so you will have the photos available when you need them.

Education is also an internal matter. Some of our most severe critics work for us. These are well meaning employees who don’t understand the big picture but are ready at the drop of a hat to expound on land management. Be sure that the guy on the ground is properly tuned in, especially if he is likely to have any public contact. After all, you know as
well as I, that anyone, no matter how little paid, who works for an organization is to the public as much an authority to speak for the organization as is the Chief.

If you follow these suggestions for an approach to your public relations plan no one can guarantee success. A few well organized and vociferous members of the minority can stir up a hornets nest in spite of your best efforts to head it off. But, if you do your homework by preparing a plan, being armed with facts, letting the public know what’s happening, and keeping your own people informed, you are at least reducing the odds of trouble. The best you can hope for is no misunderstanding by the public and no negative public opinion, but at least if you get it, you may be able to help neutralize or nullify it.
It's a pleasure for me to participate in your program today to discuss “The Grants Pass Story.” It’s the story about a public relations problem we encountered during our herbicide program last spring.

The Forest, situated in the southwest corner of the State where brush competition is severe, is one of the heaviest users of herbicides of all of the 19 Forests in the Pacific Northwest Region. As an example, during 1970 the Siskiyou treated approximately 8,700 acres out of a total of 23,000 acres treated in the Region. This is about 37 percent of the Region’s total.

The two herbicides we have been using almost exclusively are 2,4-D and 2,4,5-T. About 80 percent of our applications have utilized 2,4-D and 20 percent, 2,4,5-T.

As I talk to you about the public relations problem we encountered last spring I don’t want to infer in any way that we handled it in the best possible or the most effective way. All I want to do is let you know what happened to us and how we responded.

On March 18 we issued a relatively innocent new release announcing our program for the spring. This release included information about the number of acres in the program, the reason why we were spraying, and the chemicals that would be used.

The first hint we had that our brush control program would meet with opposition came shortly after this release. We received a call from a representative of the Josephine County Humane Society strenuously objecting to our program. We were urged to suspend the program because, according to the caller, it would cause immeasurable suffering to wildlife.

We attempted to explain that scientists had studied the effects of 2,4-D and 2,4,5-T on the environment. They had found that with the controls that were used, and with the small amounts applied, there was no evidence that these herbicides were harmful. We were unable, however, to change his position.

Shortly after our news release, the first of a series of six paid advertisements appeared in the Grants Pass Daily Courier. It covered an
entire half-page and some of the comments made in the fine print included:

“We ask citizens to note the decline in bird song since the advent of the chlorinated hydrocarbon poisons used locally for killing brush, insects, termites, etc.

“Josephine County Humane Society believes that the Forest Service brush spraying...causes immeasurable suffering to many forms of wildlife.

“Forest Service officials repeatedly deny that chemical defoliants are harmful to wildlife. Josephine County Humane Society knows this claim to be false and ridiculous. A surveyor commented: ‘If you don’t think they die, look in the brush after the helicopter dumps the stuff. Count the squirrels and quail with their toes turned up’.”

“Do you give tacit approval to the Forest Service to inflict suffering on wildlife by hiding your feelings and not speaking out? For God’s sake, let your feelings out!”

This paid advertisement then continued by urging citizens to call the Forest Supervisor, Secretary of Agriculture, or the White House.

As our brush control program got under way there was also a series of paid announcements read over the air by the two radio stations in Grants Pass. One of the local stations read their message, 38 separate times. We don’t know how many paid spots the other station devoted to these messages, but it was probably about the same.

As a result of the announcement in the newspaper urging people to contact the Forest Supervisor, we received approximately 70 phone calls. The majority of those calling merely wanted to find out more about the spraying. Our Forest Silviculturist, Ralph Jaszkowski, handled most of these inquiries and the callers appeared to be satisfied that the program was worthwhile and that there was very little chance that it would have adverse effects on the environment.

A number of the callers did not want to talk to anyone but merely stated they were opposed to the program. About 5 of the 70 called to support the program even though there had been no request for support.

In addition, 6 telegrams and 2 letters were sent to either the White House or the Secretary of Agriculture.

Fairly early in the campaign the spokesman for the opponents to our program phoned and requested a small supply of the herbicide mixture
that was being used on the Forest. He informed us that he wanted to conduct an experiment by putting it on a hive of bees to see what would happen. We told him that we would not provide the material as we felt it would be almost impossible to apply it in the same amount and under conditions that were identical to our field applications. We offered the caller an opportunity to place a hive of bees in one of the units that was to be sprayed, but he seemed to think we might ask the helicopter pilot to skip that particular location.

Pickets showed up in front of our office in Grants Pass as our program got under way. There were normally 2 or 3 of them but as many as 6 or 7 for short periods of an hour or so. They were orderly and did not attempt to interfere with the public who visited the office nor with the conduct of our business.

Picketing lasted for approximately a month, but toward the end there was usually just one man engaged in this activity.


Having been deluged by material from the opposition that condemned our brush control program — the Forest Service launched a public information program designed to tell the story as we knew it. Briefly, it consisted of newspaper articles, interviews on both radio stations, and an interview on one of the southwestern Oregon television stations. In both the newspaper articles and the interviews we tried to point out the importance of the program to forest management, the tremendous difference in cost between the use of herbicides and any other method of controlling brush, and Research's findings relative to the effect of herbicides, as applied to forest land, on the environment.

All of the news media were exceptionally cooperative in this endeavor and no commentator or reporter attempted to slant the information in any way.

We were also thinking about conducting a public meeting in Grants Pass on the use of herbicides. However, on April 15 the Secretary of Agriculture announced a ban on interstate shipment of 2,4,5-T for certain uses. Its use on range and forest lands was not banned but interstate shipment for use around homes, water supplies, food crops, and recreation areas was restricted.

Because the fate of 2,4,5-T was somewhat uncertain and because we did not know how much interest there might be in a public meeting, we decided against it.

The notice of this ban, however, did prompt another paid newspaper advertisement opposing spraying on the forest. This was actually a
About this time we received a call from the Chairman of the organization publishing this ad, the Citizens Opposed to Pollution of our Forests. He was the same individual who contacted us as President of the Josephine County Humane Society, and who would make future contacts as Chairman of still another organization, the Citizens Opposed to Poisoning and Pollution of Josephine County. He asked if we intended to continue using 2,4,5-T on the forest during the remainder of the spring program.

We responded that we were not using any herbicide around any lake, stream, or river, that it was not being used near any recreation area or even close to any well-traveled forest road and that we planned to complete the spring program. He replied that he considered the entire National Forest a recreation area as implied in this particular advertisement.

During this conversation he announced that a logger had found three dead deer in the vicinity of some of the units that had been sprayed during the spring. We asked for the name of the logger and pointed out that both the Forest Service and the Oregon State Game Commission would appreciate it very much if the logger would show us the deer so that we could have them analyzed to determine the cause of death. We were unable to get the logger's name.

We were quite sincere in this request because if there is any evidence that indicates that the small concentrations of chemicals used in our program are harmful to wildlife in any way, I am sure the Forest Service would re-evaluate its herbicide program immediately.

We completed the spring program and in September conducted a show-me trip for interested parties from the Grants Pass area. We invited those individuals who were the most vocal opponents to the program, as well as County Commissioners, the Forest Advisory Council, a representative from Oregon State Game Commission, student and teacher representatives from CLAW (Clean Air and Water) which is an organization in Grants Pass High School concerned with the environment, and the press. It was an excellent opportunity to get interested parties out on the ground and show them exactly what we were doing and why we were doing it.

Our invitation to the trip prompted another paid advertisement in the local newspaper. Let me comment briefly on the fine print which contained the following statement:

“A tour of seedling areas won’t give you a picture of the disaster caused by herbicides in spring. Spray turns thousands of acres into brown, eerie desolation.”

It also challenged cutting practices on the Forest in that it quoted a college student as saying:
"Why not log the country selectively, take some, leave some—Leave some trees to seed and propagate? Who likes to look at bald mountains?"

"Clear cutting is cheaper," a male student explained. "It hurts them to log selectively, hurts profits. It eats them to mark off trees for cutting and leave trees for reforesting. Planting seedlings is a cop-out, a crutch for spoilers," he charged.

The show-me trip was, in my opinion, most informative. It gave the opposition, as well as others, an opportunity to comment on what they saw and to ask questions about anything they did not understand.

A scientist from the Pacific Northwest Forest and Range Experiment Station was present and he did an excellent job of responding to questions about the effects of herbicides on the environment. The trip received very good coverage from both TV channels at Medford as well as from the newspaper in Gold Beach. The Gold Beach paper strongly endorsed the Forest's brush control program in an illustrated, full-page report of the tour which gave exceptionally strong support to our program.

Since a number of people on the western side of the Forest had also expressed an interest in our herbicide program, we conducted a similar show-me trip for them last month.

So much for the "Grants Pass Story."

In summary I would like to state that as a realist I expect that opposition to the use of herbicides will continue to crop up. However, being somewhat of an idealist I also hope that any future restrictions on the use of herbicides will be based on scientific study and evaluation rather than on emotion.
CONTRACTING

Introduction

A contract is a legal document or instrument which contains points of agreement between two or more parties relating to definite responsibilities, specifications, and liabilities to the end that given objectives of service, sale, or supply are performed or delivered within a given time span.

This discussion is specifically limited to pesticide application contracts. A pesticide application contract is a service agreement to establish the basis for an efficient economical operation according to the preceding definition with particular respect for:
1. Personal safety of project personnel.
2. Effective control of target species.
3. Satisfactory environmental protection.
4. Confinement of operation to target areas.

The full scope of contracting involves PLANNING, PREPARATION, and ADMINISTRATION. This discussion will develop the practical elements related to each of these phases.

Planning – As in any other work, success is usually in direct proportion to the amount, quality, and timeliness of the planning. The contract document should contain the full and complete points of agreement. As such, it must clearly reflect careful thinking and a top level of professional expertise. Basic elements of planning for contracted pesticide application may be listed and briefly discussed as follows.
1. Clearly identify target species such as particular herbs or insects.
2. Clearly stipulate the method of application such as aerial, fixed-wing or helicopter, mobile tanker, hand carried, etc.
3. Research prior work which has been done in the general area or similar areas. Particular attention should be given to chemicals used, rates of application, and operational control. It is also important to review the record of results which are available. Special study should be made of any available records of water monitoring or adverse effect upon non-target species.
4. **Identify the target area.** As a minimum, the target area should be clearly shown on maps of suitable scale to be satisfactory for field work as well as for permanent records. One inch equals one mile is a satisfactory scale. Aerial photos are also useful in identifying target areas, especially when aerial application of pesticides is planned. Ground application, as for roadside brush control, should be shown by miles, identifiable intersections, or suitable map features and legend.

5. **Identify critical areas and uses.** Critical areas are municipal supply watersheds, fish hatchery water supply watersheds, orchards, dwellings, private property, etc. All of these need to be identified, located, and delineated on operation maps or photos to serve as a base for pre-operational contacts with respective owners, boards or management agencies. Many times a use permit or agreement will supply a clue to the extent of the possible impact, such as a case where area involved is a municipal water supply watershed.

6. **Identify specific measures for environmental protection.** These may include leaving untreated streamside strips, scheduling treatment before emergence of desirable browse species, or agreement with water users for alternate supply during contract period and a specific post spray period. Invert emulsions and special spray nozzles and booms offer additional accuracy of application, but these special systems also appear to decrease the amount of chemical getting to the target species with a corresponding reduction in control.

7. **Plan preferred chemical application with best practical alternative.** This involves a thorough knowledge of all current applicable chemical characteristics and limitations. It also involves timely contacts with the appropriate State office on Environmental Quality or Federal Bureau Coordinator of Pesticide Use. Some agencies have coordinating committees.

8. **Obtain approval for proposed practice.** If the chemical and formulation which is preferred and proven is not available, there probably is an acceptable substitute. However, even the use of substitute chemicals must be approved and approval may require more time than available. Therefore, approval for substitute chemicals should be requested along with those of first preference.

9. **Advise and consult with interested agencies, individuals, and organizations.** Information and communication relative to project objectives is one of the most important elements of planning. The great majority of people normally demonstrate small concern with environmental situations as long as they are not personally affected. This segment of society deserves, nevertheless, to be fully informed through news media releases, special discussion groups, and individual contacts.
Agencies involved in environmental protection, public health, and wildlife habitat normally offer strong support to careful plans and operations. These groups as well as known opposition should be fully and forthrightly informed well in advance of effective contract dates.

**Preparation** – The key to preparation is organization of material into logical sequence. Usually this develops somewhat as follows, following the general sequence of PLANNING.

1. **Objective** of the project should be stated. That is, mobile power spraying of roadside brush, helicopter spraying for control of grass or noxious weeds. Exact target species should be stated.
2. **Exact location** of project work should be identified. Maps and photos may be designated as part of written contracts by attachment.
3. **Exact formulation** of chemical solution to be used should be stated including the carrier, that is water or diesel.
4. **Specific responsibilities and agreements** of each party should be listed. Mutual responsibilities, if any, should be given.
5. **All means** of project control such as maximum wind speed, humidity, flight control, mixing points and mixing responsibility should be clearly stated.
6. **Identity of all operational officers** for both parties should be determined. This applies in particular to contracting officers, contracting officer representatives and inspectors.
7. **Payment schedules, rates for special services, orders to proceed, suspension notices** are other points of agreement which require separate contractual treatment.
8. **Within the time frame of the contract,** progress must usually proceed at a uniform rate in order to accomplish completion by a given date. Language should be included to permit timely control to result in satisfactory progress.
9. **Default cannot always be avoided.** When a combination of circumstances produces a default situation, it is necessary to protect Government interest by contractual surety. This should usually be a satisfactory bond.
10. **Modification should** be alluded to under a general range of conditions not prejudicial to the interests of the Government. In this regard, provision for extension is usually desirable.
11. **Termination date** is necessary to all contracts. The date should end a reasonable period at which time final acceptance and payment provision will formally terminate the contract.

**ADMINISTRATION** begins with a Pre-Work conference. This is one of the most important contractual relationships between the parties.
Identification of official representatives of both parties and establishing lines of communications are very important functions of this meeting; however, the primary purpose is to review the contract in careful detail. A carefully planned and prepared contract should give little difficulty in administration. For this reason, there is no point in an itemized discussion of the sequence of operation. Some discussion of potential trouble spots, however, may be helpful in expediting project objectives.

*Calibration of Equipment* should be taken care of well in advance of the order to proceed. Tankers and extra equipment, as required, should be checked out for operability in every aspect, including safety.

*Agency crews* (Forest Service, Bureau of Land Management, etc.) should be thoroughly trained in all elements of their work. Provision for overtime pay or substitute arrangements should be approved in advance. These crews and their leaders must give priority to project work even on days of doubtful operation.

*Uniform contract interpretation* should be observed regardless of changes in Agency crews. With this in mind, it is preferable that a single Agency crew work with a given contractor crew for the life of the contract.

*Written records* should be developed and filed in regard to all important phases of the operation. This is particularly true of cases where suspension for whatever reason appears appropriate or where departure from a normal pattern of progress is agreed upon.

*Special pay items* such as aerial reconnaissance should be carefully documented.

*In all cases* where stream contamination is possible, great care must be taken to document precautionary measures, inspection procedures, and monitoring. Much the same action must be observed when treating areas which are adjacent to private property.

*Publicity relative to the project* in operation is not normally a part of the operating program. But, when there is interest or a special reason for publicity, care should be taken to see that the elements of a well-rounded story are provided. Normally, publicity would be the responsibility of the Contracting Officer or Contracting Officer's Representative. There should be no hesitance for any member of a crew or other personnel to refer news media people to the best source of information and authority available to the project.

*Safety is an integral part* of all projects. Special safety training must be given all crew members as part of their training. Safety equipment needed for the work must be kept immediately available with specific crew responsibility clearly defined.
In conclusion, contracting for the use of pesticides has become a highly specialized operation. Great care in detailed planning and training of administrative personnel will pay dividends in safe, effective control of target species without degrading the environment or impact upon private property.
APPENDIX A

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