PESTICIDE APPLICATOR CERTIFICATION TRAINING

Category 7c Manual
Food Processing Pest Control

VIRGINIA COOPERATIVE EXTENSION SERVICE
EXTENSION DIVISION
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
INDUSTRIAL, INSTITUTIONAL, STRUCTURAL,
AND HEALTH RELATED PEST CONTROL

Category 7c: Food Processing

A Training Program for the Certification
of Pesticide Applicators

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INTRODUCTION

This training is intended to provide information that you may need to comply with EPA's Standards for Certification. It will help you prepare for the Certification examination prepared and administered by the Virginia Department of Agriculture and Consumer Services.

The emphasis of these standards and this training is on the principles of applying pesticides safely for man and the environment. It is not intended to provide you with all the knowledge needed. Additional information in the form of publications, short courses, field days, and professional meetings can be obtained from the local Cooperative Extension Service Office in your area.
PESTS ASSOCIATED WITH FOOD MANUFACTURING PLANTS

The certified applicator responsible for pest control in a food manufacturing plant should know the pests that are likely to be found in his operation, their habits and life cycles, the reasons they are there, the damage they do, and the effective, legal ways to control them. He should also be alert for the unusual pests that can occur occasionally. Information from local experts, such as state extension agents, who can advise him on the identification and control of the unusual pests is usually available.

A variety of pests are associated with food manufacturing plants in the United States. The type of pests most likely to occur will depend on both the geographic location of the food manufacturing plant and the type of food being processed.

These pests may be able to damage, destroy, or contaminate. They must be controlled to protect the quality of the product. The presence or evidence of pests may result in the seizure of food products or other actions by federal or state agencies. The pests included for discussion here are birds, weeds, rodents, and insects.

Pest Birds and Their Control

There are many species of bird in the United States, but only three are normally considered pests around food manufacturing plants. All three cause problems in cities. All three survive well in close association with man. They are objectionable primarily because their droppings can be a serious food contaminant. They may also spread diseases. Their droppings deface buildings and their nests plug gutters and cause roofs to leak. Their noise and odor are offensive to many people. They sometimes also carry mites which can bite man.

**English Sparrows (House Sparrow)**

Grayish. 3-4 inches long. The male has a prominent black throat. Small black conical beak. Voice is a non-musical chirp. Creamy white egg.
Eat small grains. Nest is loosely woven grasses, paper, and string. Prefer openings or hollows for nesting and will use any sort of nesting box, cavity, or opening in buildings.

Gregarious - nesting, roosting, and feeding together in large flocks. Produce several broods each year using the same nesting areas over and over.

**Pigeons**

6-10 inches long, varied colors. Fan-shaped tail during take off and landing. Head bobs when walking. Beak pointed down when walking. Voice is long, soft coo-oo-oo. White eggs.

Feed on grain including large kernels such as corn. May feed on spilled grain along railroads.

Prefer to live and roost on roofs and high ledges.

Nest on ledges is not woven, made with twigs and often soiled with excrement.

**Starlings**

Body and wings gold-flecked, iridescent blue-black summer plumage, winter plumage with buffy white spots. Have large spear-like bills that are yellow or olive. Compact with short round bodies, 4-7 inches long.

In flight, they can be recognized by their short square tails and their short triangular wings. Bluish green eggs.
Traps can be built from plans obtained from the U. S. Department of Interior (Wildlife Leaflets 206 and 213 for pigeons) or they can be purchased. Several different types of trap can be used. They include funnel traps and bob-type traps for pigeons; rat traps, sieve-type traps, funnel traps; nest box traps and center drop traps for smaller birds such as the English sparrow. Prebaiting for several days prior to trapping increases trap effectiveness. Traps should be supplied with plenty of food and water. One or two decoy birds may help. Trapped birds must be removed daily.

Shooting may be hazardous in some locations and may not be allowed by some local ordinances. It is a very effective means of killing scattered individuals or small flocks. It is best carried out by no more than a few individuals with low powered guns and who understand what they are doing. Where permissible, shooting with a 22 calibre #12 birdshot is effective.

Chemical control with avicides or other pesticides in certain situations may be the only means of effective control. Pesticides may not be used in a manner inconsistent with the label. Decisions as to the need, type of toxicant used and manner in which it is used should be made by professionals. Information on current registered uses of specific compounds is available from the manufacturer or retailer. Sources of up-to-date pesticide recommendations include: industry representatives; the Cooperative Extension Service; local health, environmental, and agricultural departments; and technical experts in universities and state and federal agencies.

Poisons may be prohibited or may be too risky to use because of the dangers to humans, pets, or desirable birds. Poison sprays on roosts may be effective but dangerous: label directions must be followed precisely.
Toxicant baits, when eaten by pigeons, starlings, or sparrows, produce distress reactions in some birds. This frightens the rest of the flock away from the area.

Anesthetic baits produce narcosis, during which the birds may be caught. They are very expensive.

Prebaiting is necessary when chemical baits are used, just as when trapping is to be done.

Chemical baits are most effective when used against small flocks and when conditions can be carefully controlled.

Associated Problems

Dry, dusty droppings may contain fungus spores which can cause human diseases. Workers cleaning such areas, or involved in hand-capture of birds, should wear approved respirators.

A worker should not smoke, eat, or drink anything until after his dusty clothes are removed and he washes thoroughly.

Ectoparasites such as mites, made homeless when pigeons are removed, may migrate into areas where humans work and live. This can be prevented by spraying or dusting nesting or roosting areas as part of the control operations. Any good acaricide can be used if the label directions are followed.

Rodents and Their Control

Domestic rodents constitute a major food industry pest problem. There are three major domestic rodents in the United States, the house mouse, Mus Musculus; the Norway (brown or sewer) rat, Rattus norvegicus; and the roof (black or ship) rat, Rattus rattus. Rats eat almost everything men or livestock use as food. They contaminate much more than they eat, with the result that contaminated food products must be destroyed. Damaged packages must be repaired or replaced. Before you can control rodents, it is important you identify the correct species and know its behavior patterns.
## CHARACTERISTICS OF DOMESTIC RODENTS

<table>
<thead>
<tr>
<th></th>
<th>Norway Rat</th>
<th>Roof Rat</th>
<th>House Mouse</th>
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<tbody>
<tr>
<td><strong>Weight</strong></td>
<td>10 - 17 oz.</td>
<td>8 - 12 oz.</td>
<td>1/2 - 3/4 oz.</td>
</tr>
<tr>
<td><strong>Total length</strong></td>
<td>12-3/4 - 18 in.</td>
<td>13-3/4 - 17-3/4 in.</td>
<td>6 - 7-1/2 in.</td>
</tr>
<tr>
<td><strong>Head and body</strong></td>
<td>Blunt muzzle; heavy thick body. 7 - 10 in.</td>
<td>Pointed muzzle, slender body. 6 1/2 - 8 in.</td>
<td>Small 2-1/2 - 3-1/2 in.</td>
</tr>
<tr>
<td><strong>Tail</strong></td>
<td>Shorter than head plus body, carried with much less movement, comparatively, than roof rat. Lighter-colored on underside. 6 - 8-1/2 in.</td>
<td>Longer than head plus body generally moving whip-like, uniform coloring top and bottom at all ages and for all subspecies. 7-1/2 - 10 in.</td>
<td>Equal to or a little longer than body plus head. 3 - 4 in.</td>
</tr>
<tr>
<td><strong>Ears</strong></td>
<td>Small, close set, appear half buried in fur.</td>
<td>Large, prominent, stand well out from fur.</td>
<td>Prominent; large for size of animal.</td>
</tr>
<tr>
<td><strong>Fur</strong></td>
<td>Coarse, generally red-brown to gray-brown.</td>
<td>Black to slate gray; tawny above, gray-white below; or, tawny above, white to lemon belly.</td>
<td>Silky, dusky gray</td>
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FIELD IDENTIFICATION OF DOMESTIC RODENTS

ROOF RAT  
**Rattus rattus**

LONGER THAN HEAD + BODY

TAIL

BODY

EAR

EYE

NOSE

HEAVY THICK

LIGHT SLENDER

LARGE

POINTED

NORWAY RAT  
**Rattus norvegicus**

SHORTER THAN HEAD + BODY

Senses, Agility, and Reactions of Rodents

**Touch**

Well developed in highly sensitive whiskers (vibrissae) and certain guard (tactile) hairs. Rats and mice prefer to run along walls or between things where they can keep their whiskers in contact with side surfaces.

**Vision**

Not too well developed. Apparently they are color blind, so any distinctive coloring of poison baits does not reduce their acceptance to rats and mice.

**Smell**

Keen. Rodents apparently like the odors of most foods eaten by man. They are accustomed to the smell of man, so his odor on baits and traps does not repel them.
Taste
Not as sensitive as in man. Rats and mice associate sickness caused by poison bait with the bait and not the poison. They prefer fresh food to decayed food.

Hearing
A keen sense of hearing. They can locate the source of a noise within 6 inches. Unusual noises cause rodents to attempt to escape.

Balance
Excellent. A falling rodent always lands on its feet. The roof rat even maintains its balance well while walking on suspended wires.

Reaction to Strange Objects
Rats may avoid a new sound or a strange object in their environment for three or more days, particularly if their associates are alarmed by it. Other objects are readily accepted by them (examples: food, garbage). As rodent population pressures build, the rats frequently exhibit "chain-fright reaction" to disturbances. Mice are more likely to explore new objects, and to be caught in newly set traps.
Climbing

Roof rats and house mice are good climbers, and the Norway rat can climb quite well when necessary.

Jumping and Reaching

Rats can jump nearly 2 feet vertically, 3 feet with a running start; they can jump 4 feet horizontally, and 8 feet from an elevation that is 15 feet above the finish point. Rats can reach upward about 18 inches.

Swimming

Rodents are good swimmers. They are able to swim up through floor drains and toilet-bowl traps.

Recognizing Rat and Mouse Signs

Rats and mice are habitually nocturnal and secretive and are rarely seen during the day except when infestations are heavy. Therefore, it is necessary to interpret signs of their activities properly in order to plan control work. These signs are found in secluded places, such as along walls, under piles of rubbish, and behind or under boxes, boards, and thick vegetation. From the rodent signs, one can tell the species present and whether a rodent infestation is current or old, heavy or light.

Droppings

Fresh droppings of feces are usually moist, soft, shiny, and dark, but in a few days they become dry and hard. Old droppings are dull and grayish and crumble when pressed with a stick.

Runways

Rats habitually use the same runways between food, water, and harborage. Because of the keenly developed sense of touch in their vibrissae (whiskers) and in specialized hairs along the body, rats prefer continual body contact with at least one vertical surface, such as a fence or wall. Rats also follow "odor trails." Outdoors, their runways are narrow pathways of beaten earth swept clear of debris. Indoors, greasy runways are found along walls, steps, and rafters. Undisturbed cobwebs and dust in a runway indicate that it is not in use.
Rubmarks

Along regularly traveled runways, a dark, greasy mark forms from contact by the rodent's body. Fresh marks are soft and will smear if rubbed. As the grease ages, it dries and gathers dust and will flake off when scratched with a fingernail. The rubmarks of the Norway rat are most commonly found along runways near ground or floor level, while those made by the roof rat are most commonly seen overhead as swing marks beneath beams or rafters at the point where they connect to the walls. Mice do not leave detectable rubmarks except when the infestation is heavy.

Burrows

The Norway rat prefers burrows for nesting and harborage; the roof rat burrows only occasionally. Burrows are found in earth banks, along walls, under rubbish or concrete slabs, and in similar places. If a burrow is in
use, its entrance will be free of cobwebs and dust. Fresh rubmarks on hard-packed soil at the opening indicate a well established and presently used burrow. The presence of fresh fragments of food or freshly dug earth at the burrow entrances also indicates current use by rats.

Gnawings

The incisor teeth of rats grow 4 to 5 inches a year, so these rodents must do some gnawing each day in order to keep their teeth short enough to use. Rats also gnaw to gain entrance and to obtain food. When gnawings in wood are fresh, they are light colored and show distinct teeth marks. Small chips of wood or other materials indicate recent gnawing. With age, wood gnawings become dark and smooth from weathering and from frequent contact with the rodent's body.

Tracks

Fresh tracks are sharp and distinct, whereas old tracks are covered with dust and are, therefore, less distinct. The tracks of the 5-toed rear paws are more commonly observed than are those of the 4-toed front paws, but both may be present. Smooth tracking patches of any dust material, such as flour or talc, placed along runways are of value in checking for rodent activity. To see tracks in the dust, the inspector should hold a flashlight at an angle that causes the tracks to cast distinct shadows. Tail marks, too, are often visible in dust or tracking patches.

Urine

Dried rodent urine will fluoresce bluish white to yellowish white. Commercial black lights are often used to detect the rodent urine. Fluorescence caused by the use of black light does not guaranteed that the substance is rodent urine; numerous items will fluoresce when under a black light, including bleaches found in many detergents and lubricating oils. For positive identification, one uses a Brom Thymol Blue Urease Test. Place the suspected material on Brom Thymol Blue Urease test paper. Moisten with water, cover with a cover glass. If a bluish spot appears after three to five minutes, it is rodent urine.
Rodent Control Procedures*

Complete control of rats and mice is essential to every food and feed processing plant and storage facility and must be accomplished to satisfy legal requirements, prevent losses, and to meet individual company operating standards. While the degree of emphasis on any single phase of rodent control varies with the building structure, location, and species of rodent involved, an effective control program must start by building rodents out.

Exclude rodents from plants and warehouses by having every possible opening in outer walls, at floor/wall junctions, and at all exterior doors tight enough to prevent rodent entry, and by installing guards across runways to prevent entry at loading doors. There should be no openings larger than 1/4 inch.

Some materials that can be used for rat proofing are:
- Galvanized Sheet Metal 26 gauge or heavier
- Galvanized or rustproof expanded metal 28 gauge or heavier - mesh opening no larger than 1/4 inch
- Perforated metal 24 gauge or heavier - perforations no larger than 1/4 inch
- Iron grills As heavy as above materials, slots no larger than 1/4 inch
- Galvanized or rustproof hardware cloth 19 gauge or heavier, opening no larger than 1/4 inch
- Cement mortar 1:3 mixture or richer; concrete should be 1:2:4 mixture or richer

Good housekeeping and proper storage practices discourage rodents by eliminating their food and harborages. It is important to maintain a clearance of 18 inches between pallets of merchandise and the wall. This clearance allows room behind the stock for proper cleaning and pest control. A stock rotation system, utilizing the first in - first out method, is a necessity in all sound warehousing programs.

Now, after taking every practical measure to build rodents out, and to eliminate their food and harborages, we can supplement these preventive controls with baiting and trapping. In most cases, only those rodenticides falling within the anticoagulant group are being used in specific areas of

*Condensed from AQM Series #11 and Modified
food processing facilities. These are available in several forms such as granular, cereal-based bait, paraffinized bait pellets and bait blocks being carried from the bait stations to other plant areas, these materials should be limited to exterior use only. It is not advisable to use canary seed bait inside food plants because of its similarity in appearance to caraway seeds. Thus, anticoagulant baits, to be used inside non-food areas in food plants, should be limited to granular or cereal based materials.

Unless there is a possibility of rat entry into a plant, liquid baits would be ineffective, since the water requirements for mice are slight and they can live for many months on a grain diet obtaining sufficient moisture from their food. The toxic ingredient in all of these baits is one of the several anticoagulants so named because they inhibit the normal coagulation of blood. The use of colored dyes for rodent baits helps prevent accidental human consumption through mistaken identity. Those cereal baits, dyed with alkali-fast green, appear to have the greatest rodent acceptance.

Proper placement of bait stations is very important. It is necessary to place bait stations around the exterior boundaries of our plants because the purpose in exterior perimeter baiting is to attract and eliminate rodents in the area before they can invade the building. On the outside, bait stations should be positioned approximately every 50-100 feet around the perimeter of the building, which has been cleared of all vegetative matter and trash. Also the perimeter of the property line should be included in the baiting program. Again, the bait stations should be positioned approximately every 50 - 100 feet around the perimeter.

Bait stations being used around the exterior of the building should be large enough to accommodate more than one rat at a time. Each station should have at least two openings
approximately 2-1/2 inches in diameter. The bait stations for exterior use may be constructed of metal or wood which will protect the bait from the weather and from disturbance by nontarget animals and children.

If bait stations are used inside plants, they need to be limited to non-food storage areas.

Two inexpensive types of station, which can be used in non-food storage areas are the water resilient cardboard and formed plastic. Bait stations should be placed against walls and the adjacent areas kept clean.

When handling any baits, do not smoke, eat, drink, or put your hands near your mouth. After handling baits, wash your hands, using soap and water. As a safety factor, it is suggested that only ready-mixed baits be used.

All rodenticides received and used must be properly labeled. Labels contain the directions for safe use, caution statement, and first aid and medical instructions. It is important that you read the label, understand label instructions, and that you follow label instructions during use. All bait stations, and bait handling containers must also be properly labeled.

Store unused rodenticides in a locked area with access restricted to authorized personnel. The locations of all bait stations should be noted so that inspections can be made rapidly and the bait that has been consumed can be quickly replaced. At each inspection, smooth the surface of the granular baits so that new signs of feeding will show readily. Also, examine bait blocks for signs of rodent gnawing. Replace moldy, wet, caked, or insect infested baits with fresh ones.

Records should be maintained indicating where baits have been disturbed, dead rodents found, droppings or tracks observed, or where rodents have been caught in traps.

Some rats prefer burrows for nesting and harboring. Burrows are found in earthbanks, in grassy areas, around weeds, under trash, around concrete slabs and railroad tracks, and in similar secluded places.

There are several ways to control burrowing rats. One method is to place a small amount of bait in wax paper or a plastic bag and place the bag inside
each burrow. Burrows can also be fumigated with Calcium Cyanide, in a dust form. Calcium Cyanide, in contact with moist soil or air, releases hydrocyanic acid gas which kills rats quickly by preventing oxygen exchange between the body tissues and the blood. Hydrocyanic acid gas has a characteristic odor of peach blossoms and bitter almonds. The dust is normally applied to the burrows with a foot pump duster. The hose nozzle is inserted into the burrow and dirt is then packed around the hose to prevent the escape of gas. If gas is observed escaping from other holes, these should be sealed with dirt or the rats might escape.

All individuals applying cyanide, or assisting with the fumigation, must wear respiratory protection. An air-purifying respirator, with the appropriate canister for hydrocyanic acid gas should be worn when fumigating with Calcium Cyanide. Proper cyanide storage is important. Cyanides must not contact acids, or be exposed to the air, because this will release the gas. Store cyanides in a cool, dry, locked area with the other pesticides.

Reliance entirely upon bait stations and fumigants for rodent control will not produce the desired results. It is necessary to kill rodents quickly upon entry into a building and, therefore, trapping must be used. The most popular, least expensive, and probably the most effective trap is the wooden 4-way snap trap. An enlarged trigger can be fitted onto the wooden trap by inserting a piece of cardboard on the tripping device. This provides a treadle, covering nearly half the trap, which is easily sprung by a rodent traveling from any angle. Different size traps are used to catch mice and rats. To be effective, traps must be placed along walls or other runways with the trigger end abutted to the passage. An ample number of traps should be placed in each area requiring preventive control.

Be sure that the trap is properly set and in place.

Overhead beams, trusses, and ceiling wall junctions should not be overlooked as potential runways. Traps should be set across any obvious runways in overhead areas. On vertical structures, traps can be glued or otherwise fastened across runways.

When a rodent is suspected of being in a particular area, whether inside or out, lightly smooth a dusty material, such as talcum powder, around the
suspected area. If rodents are present, you can observe their tracks in the dust. Then cover all possible avenues of escape with traps. Traps can be placed either unbaited or baited. When baiting traps, a variety of baits can be used, such as gum drops, peanut butter, bacon, or a piece of hotdog or cheese. The proper method of applying bait to traps is to place a small amount on the trigger. Too much bait could prevent the trigger from activating properly, plus it looks messy.

Where a variety of food is plentiful, it is often just as effective to use traps without bait on them. The key is to place the trap properly so it is tripped by the rodent as it travels the wall/floor functions. All traps should be checked at least 3 times a week to be sure they are properly set and that dead rodents have been removed.

In order to indicate locations where traps are to be placed, a marking can be painted above the trap.

The automatic Ketch-All trap is especially good in wet areas and where other mouse traps are frequently tripped accidentally. A Ketch-All is a spring powered box-type trap capable of catching up to 10 or more mice in one setting. These traps must be properly positioned against the wall. The easiest method of disposing of mice caught in a Ketch--All trap is to dunk the entire trap into a bucket of water to drown the mice. The mice can then be disposed of in a covered waste container.

Remember the three fundamentals for effective rodent control:
-- build them out by proofing
-- good housekeeping and proper storage
-- trapping and baiting
SYMPTOMS AND EMERGENCY TREATMENT FOR ACUTE POISONING BY RODENTICIDES

Coumarins
  Indandiones
  Diphacinone (Diphacin)
  Fumarin
  Pival (Pivalyn)
  PMP (Valone)
  Warfarin

After repeated ingestion for several days: bleeding from nose, gums, and into conjunctiva, urine, and stool.

Possible pallor and petechial rash.

Late - massive ecchymoses or hematoma of skin, joints, brain hemorrhage.

Shock and death.

Fluoroacetate

Causes central nervous system stimulation (convulsions) and cardiac arrhythmias.

1. Lavage stomach with tap water. Catharsis 30 gm. sodium sulfate in 250 cc tap water.

2. Vitamin K (mephyton or menadione preparation) by mouth, intramuscularly, or intravenously. Vitamin C may be a useful adjunct.

3. Transfuse with fresh blood if bleeding is severe or until anemia is corrected.

4. Iron (ferrous sulfate) by mouth for correction of secondary anemia, 0.3 gm. t.i.d.

Specific treatment includes Monacetin (glycerol monoacetate) intramuscularly, 0.5 mg per kg every half hour for 12 hours. Vary injection sites.

*Check labels before using
Insect Pests

There are a variety of insect pests associated with food materials and food-processing operations. These include cockroaches, house flies, fruit flies, flour moths, and grain and flour beetles. Although there are no insect pests unique to particular food processing plants, some of the common pests may be more numerous or more difficult to control in certain operations. I will discuss several persistent, year-round pests, and some temporary or seasonal pests.

Cockroaches

The most common and most important pests of food-processing plants are cockroaches. Most common because they occur around the world, in every plant, in every food industry; most important because they can and do carry and spread numerous disease organisms. Cockroaches are known to carry four strains of poliomyelitis, more than 40 different pathogenic bacteria, and the eggs of several pathogenic worms (Roth and Willis, 1957, 1960). It has been estimated that a single cockroach can carry a total of 13,470 bacteria.

Female cockroaches do not lay eggs singly, one at a time; they produce small egg cases that contain from 6 to 33 eggs, and this egg case is deposited in a hiding place. Young cockroaches begin feeding soon after they hatch from the egg case. They feed on the same material as the adults, and look like adults except for size and absence of wings. After shedding their skin several times to grow larger, they become winged adults. Adult cockroaches live for a few months to over a year, depending on the species. They mate several times and the females generally produce one egg case per month.

The mouthparts of cockroaches are the biting-and-chewing type. These insects can and will feed on a variety of foods, but they prefer starchy and sugary material. They will sip milk, nibble at cheese, meats, pastry, flour, meal, grease, chocolate, and other foods. They can feed just as freely on book binding, shoe lining, dead insects, other cockroaches, and human waste. They usually feed at night when they are not likely to be disturbed by human activities.
German Cockroach -- This is probably the most common and widespread cockroach in food processing plants -- around the world. It is a small insect, about 3/4" long, and is yellowish brown with two dark-brown stripes behind the head. Both male and female have well-developed wings.

The female carries the egg case protruding from the tip of the abdomen until hatching time. The adult female may live for about 9 months and produce about 140 young. The egg cases are hidden in areas with abundant food, water, and hiding places.

In food-processing plants, German cockroaches will infest the main food-preparation (ground level), and storage areas, as well as offices, clothing lockers, and restrooms. They are not usually found in storage areas below ground level.

American Cockroach -- This is the largest cockroach in the U.S., adults may reach a length of 2". The color of the adult cockroaches is brown, the young are pale brown.

The female American cockroach hides her egg cases as soon as they are produced. The adult female may live for 12 to 18 months and lay as many as 33 egg cases, which would mean about 430 young.

American cockroaches usually inhabit basements, storage rooms, garbage areas, and sewers. These places are slightly cooler than the habitats of the German cockroach, and the cracks and crevices to hide in are larger.

In food-processing plants the American cockroach usually infests large storage areas (below ground level), loading docks, and basements.
**Oriental Cockroach** -- This pest is about 1” long, dark brown to black in color, and the wings are very short in the male and absent in the female. The young are pale brown in color.

The female hides the egg case soon after it is formed. Each female can produce an egg case per month for the 5-6 months of her life. This would mean each female could produce about 80 young.

The preferred habitat of the oriental cockroach is similar to that of the American cockroach. They usually inhabit areas below ground level, such as basements, storage areas, sewers, etc. In food-processing plants they are common in below-ground storage areas.

**Cockroach Control** -- Cockroaches are a year-round pest in all food-processing plants. Therefore, control of these pests has to be a year-round project, and it has to be in the form of sanitation and the use of chemicals.

The first step and most important aspect of control is sanitation. Recognizing that cockroaches require food, water, and a hiding place, and moving against these areas with an ongoing sanitation program is the foundation of cockroach control. Chemical control has to follow sanitation; it cannot be used alone or in place of it.

Most supervisors and managers in the food processing industry understand their role in controlling cockroaches through sanitation, and most work hard in this regard. But few recognize their role in the use of chemicals to control cockroaches. Most food-processing plants depend totally on professional pest control operations for the chemical control of pests. Separating the two arms of control - sanitation and chemical - is not the best way to control pests. I will discuss this in more detail later.

**Flies**

The most common of the seasonal pests of food-processing plants are flies. There are a variety of flies associated with these plants, but the most common are the house fly and the fruit fly.

**House Fly** -- This insect is found all over the world. It is a pest to all segments of the community -- from households to industry. Like cockroaches,
house flies can and do spread pathogenic organisms to man and his food. It has been estimated that a single fly can carry 3,680,000 bacteria. The pathogenic organisms are collected on the feet and mouthparts when the fly visits garbage, some of the organisms are taken into the gut. The organisms are deposited when the fly crawls on human food or deposited in the fly excrement.

The house fly passes through three stages on its way to becoming an adult. Under warm summer temperatures, the egg requires 8-12 hours to hatch. The maggot that hatches from the egg begins feeding and gnawing. The maggot stage lasts about 5 days. When full-grown, the maggot changes to the pupa stage. This is a resting stage, and it lasts about 4 days. The adult fly comes out of the small seed-like pupa stage - and the cycle starts all over.

The maggot stage in the fly's life does most of the feeding, the adult simply takes in a little fluid for quick energy. The adults may be attracted to rotting garbage by the smell and also by a desire to lay eggs. They are attracted to window screens and picnics for the same reason -- the smell of food. The danger comes when flies move from garbage or manure to man's food without washing their feet!

House flies are more abundant in the late summer and fall because the population has been building rapidly during the warm summer months. The adults enter buildings in a search for food and shelter from the cool nights. Once inside they seldom leave.

House fly Control -- Since house flies are probably breeding away from the plant site, and flying to the site, there is little hope of controlling the size of the fly population outside the plant. Control must be aimed at 1) preventing entrance to the plant; and 2) reducing the number inside the plant.

Most food-processing plants use wind screens and appropriate doors. These are excellent mechanical controls for flies, if they are strong enough. The stronger the better.

Control inside the plant can be achieved with electric fly traps. These work by attracting the adult flies to a special blue light and killing them with an electrical grid. These traps should be run day and night, and the catch basin should be cleaned out every day.
Chemical control -- aerosol sprays or fogs -- are usually not effective in fly control. The results are temporary at best, and the use of the chemical is restricted in food handling establishments. The best control for house flies is exclusion.

**Fruit flies** -- These tiny flies are also seasonal pests, being most abundant in the late summer and fall. The adults are small (about $1/10''$ long) flies, with light brown bodies and red eyes. The adults are attracted to fruit, especially rotting fruit. Since they are not attracted to sewage or animal waste, the food-damaging bacteria they carry is probably limited.

The life cycle and feeding habits of fruit flies is similar to that of house flies. In the late summer there is an abundance of rotting plants and fruit, this allows the fruit fly population to increase rapidly. The adult flies live about a month.

**Fruit fly control** -- Complete control of these pests -- like most insect pests -- is nearly impossible. Wind screens and electric traps may be somewhat effective. Removal of all attractive material (rotting fruit, fermenting foods) will help.

**Flour Moths**

The flour moths are among the most common insect pest of grain products. They are called flour moths because they prefer milled cereal products such as flour, breakfast foods, and meal; they seldom attack sound kernels of grain.

Flour moths and other insect pests of grain products are present throughout the manufacturing and distribution scheme. These pests can be found at the mill, in warehouses, in delivery trucks, and at their final destination. Therefore, these insects are likely to be a constant problem and will need constant attention.

Female moths lay eggs singly or in small groups, not in egg cases like cockroaches. Caterpillars hatch from the eggs and feed on the foodstuff. The caterpillars grow large and shed their skin several times before they are fully grown. The caterpillar spins a silken cocoon and transforms into a pupa, from which the adult develops and later emerges. Males and females live for a short time, the females die soon after the eggs are laid.
The infestation and damage to the flour is done by the caterpillar stage. Adult moths do not feed and return to the flour only to lay eggs.

**Indian Meal Moth** -- This rather distinguished moth has a wing expanse of about three-fourths of an inch. The adult moth is easily distinguished from other grain pests by the color bands on the large, front wings. The outer two-thirds of the wings are reddish brown, the region behind the head is gray.

Female moths can lay from 100 to 300 eggs, singly or in groups, on food material. The eggs hatch in about three days. The caterpillars feed upon grain products, dried fruits, nuts, dry pet food, and a wide variety of foodstuffs.

When full grown the Indian Meal Moth caterpillar is about half an inch long and is grayish white, sometimes varying to greenish and pinkish colors. The caterpillar spins a web as it becomes fully grown and leaves a silken thread behind wherever it crawls. This webbing is often dense enough to attract attention when sacks of flour or meal have become heavily infested.

During warm weather, the Indian Meal Moth may pass through the egg, larval, and pupal stages in 6-8 weeks.

**Mediterranean Flour Moth** -- This small moth has a wingspread of about 1 inch. Its large front wings are gray with wavy black markings.

The female moth lays small white eggs in accumulations of flour and meal. The caterpillars feed on flour and meal. The full-grown caterpillar spins a silken cocoon, in which it transforms into a reddish-brown pupa.

During warm weather, the Mediterranean flour moth requires 8-9 weeks to pass through the egg, larval, and pupal stages.
Grain and Flour Beetles

There are a great number of beetles that infest stores of flour and grain. Listing them all or providing life history data is not practical. Three of the most common species are presented here; the other species have similar habits and life histories.

Grain and flour beetles are often present throughout the manufacturing and distribution process. Like flour moths they can be a pest at the mill and in the food processing operation, and require constant attention.

Female beetles lay eggs singly on the flour or grain. The larva or "grub" that hatches from the egg will feed on the foodstuff. The grub stage may last 14-16 months. The full grown grub builds a cocoon out of scraps of the food material and transforms to a pupa. Male and female beetles often live for several months to a year.

The infestation and damage to the flour is done by the adult and grub stage. Adults and grubs have well-developed chewing mouthparts.

Sawtoothed Grain Beetle -- This small, brown beetle is probably the most common of the cosmopolitan grain pests. It is a slender, brown beetle about one-tenth of an inch long, and with six sawtooth projections on each side of the thorax.

Adult beetles live 6-10 months, but some may live as long as 3 years. The female lays 43-285 eggs loosely in the flour or meal. The eggs hatch in about 4 days and the grub begins feeding. The adult and grub stages feed on all food of plant origin, especially grain products such as flours, meals, breakfast foods, nut meats, candies, and dried fruits.

After about 2 weeks (in warm weather) the grubs become full grown and construct a cocoon out of fragments of foodstuffs. Within these cells, the grub changes to the pupal stage then to the adult. In summer, the development period from egg to adult is about 4 weeks.
Red Flour Beetle and Confused Flour Beetle -- These small, shiny, reddish-brown beetles are about one-seventh of an inch long. They are distributed over the world and are very abundant in the U.S. They are general feeders on grain products, and are the most abundant and injurious insect pests of flour mills in the U.S.

The average life of the adults is about 1 year. The female lays an average of 450 eggs loosely in flour or food material in which the adults live. The eggs hatch in 5-12 days and small worm-like grubs emerge. The grub stage feeds on flour or other food material made from grain.

When fully grown, the larvae transform into pupae -- they do not construct a cocoon. Shortly afterwards they transform to adults. In summer, the period from egg to adult is about 6 weeks. The life cycle is prolonged by cold weather, as is true of all grain pests.

Weevils

The word "weevil" is usually used incorrectly in speaking of insects that infest flour. The term "flour weevil" usually refers to a sawtoothed grain beetle or a red flour beetle. Technically, a weevil is a beetle that has modified mouthparts which form a long snout or beak at the front of its head. The most common weevils in food processing operations are the granary weevil and the rice weevil.
Weevils do not infest milled (= flour) products. The presence of these beetles indicates there is whole grain being stored.

**Cigarette Beetle**

The cigarette beetle is one of the most common household insect pests in Virginia. As its name implies, the cigarette beetle is a pest of dried tobacco either in the stored, bundled form or in cigars, cigarettes, and chewing tobacco. But they can (and do!) feed on a variety of stored products including, grain, cereal products, ginger, raisins, dates, pepper, dried fish, drugs, and seeds. This feeding habit often makes them difficult to control.

The adult beetles are oval, about 1/10 of an inch long, and are covered with small hairs which give them a silky, yellowish-brown color. The female produces about 100 eggs, and they are deposited on or near the available food supply. The wormlike larvae are slightly smaller than the adult beetles. They are creamy white except for the yellow head and brown mouthparts. They become full-grown in about 40 days. The entire life cycle can be completed in 45-50 days, and there may be 3-6 generations a year.

**Carpet or Hide Beetles (Dermestidae)**

The larval stages of these beetles feed upon, damage, or destroy a large variety of leather goods, hair, fur, dried animal remains, and stored products of many kinds, especially foods of high protein and fat content.

With dermestids, as with many other beetles, the greatest damage is done by the larval stages, and it is in this stage they are most frequently encountered.
Silverfish

Silverfish are often found in food processing operations, but are not a serious or potentially harmful pest. These insects prefer vegetable matter with a high carbohydrate and protein content. However, indoors they will feed on almost anything. A partial list includes dried beef, flour, starch, paper, gum, glue, cotton, linen, rayon, silk, sugar, molds and breakfast cereals. They can go for up to 1 year without food, so sanitation alone will not eliminate an infestation, although it may prevent new ones from starting.

Adult silverfish lay eggs in small groups containing a few to 50 eggs. The eggs are very small and deposited in cracks and crevices. A female normally lays less than 100 eggs during her lifespan of 2 to 8 years. Under ideal conditions, the eggs hatch in 2 weeks, but may take up to 2 months to hatch.

The young nymphs are very much like the adults except for size. Several years are required before they are sexually mature, and they must mate after each molt if viable eggs are to be produced. Populations do not build up rapidly because of their slow development rate and the small number of eggs laid. A large infestation usually means the house has been infested for some time.

Casual Invaders

There are several different insects and other arthropods that occasionally invade food processing operations. They represent no threat or potential infestation, but may cause concern.
Ground beetles -- These blackish-brown beetles are common in late summer and fall. The adults are good fliers, and will come to lights at night. The larval stages live outdoors.

Sowbugs -- These small relatives of the crawfish are usually found in dark, moist environments. They feed on vegetation, and will not infest buildings unless there is a moisture problem.

Centipedes -- These fast moving, predacious animals are usually not seen in numbers. They feed on insects and spiders inside and out of buildings. Control is rarely recommended for these animals.
Ants -- Only a few ants build their nest inside buildings. Most have their nest outside in the soil and invade buildings looking for food. Control must be directed at the point of entry, outside the building.

Crickets -- These insects are most common in late summer and fall. At this time the population is composed of adults. They are good fliers (and hoppers), and are attracted to lights at night, and will seek a warm location on cool fall nights.

Insect Larvae

In some instances the immature stage, not the adult, is all that is found in infested material. Identification of the insect pest from just the larval or pupal stage is difficult, and subject to mistakes. The following figures may help in making the task easier and more accurate.

Carpet or Hide Beetles
Weevils

Sawtoothed Grain Beetle

Confused Flour Beetle
Flour Moths
INSECT CONTROL - METHODS AND APPLICATION

Good sanitation practices and compliance with good industry practices is fundamental to sanitary, pest-free operation. These practices include the absence of attractants, breeding places, entryways, and hiding places to supplement pesticide program. Entry of insect pests can be reduced through the use of self-closing doors, screens, and traps, especially light traps for flying insects.

Insecticides

Before undertaking insect control with an insecticide near food processing, it is essential to recognize that EPA established on August 3, 1973, some definitions to assist in the regulation and control of insecticides in food handling establishments. The definitions they use are as follows:

1. **Food** is defined by Section 201 (f) of the Federal Food, Drug, and Cosmetic Act to mean (1) articles used for food or drink for man and animals (2) chewing gum and (3) articles used for components of any such article.

2. A **Food Handling Establishment** is an area or place other than a private residence in which food is held, processed, prepared, and/or served.
   a. **Non-Food Areas** of food handling establishments include garbage rooms, lavatories, floor drains (to sewers), entrances and vestibules, offices, locker rooms, machine rooms, boiler rooms, garages, mop closets, and storage areas (after packing, canning, or bottling)
   b. **Food Areas** of food handling establishments include areas of receiving, serving, storage (dry, cold, frozen, raw), packaging (canning, bottling, wrapping, boxing), preparing (cleaning, slicing, cooking, grinding), edible waste storage, and closed processing systems (mills, dairies, edible oils, syrups).

3. **Non-Residual Insecticides** are those products applied to obtain insecticidal effects only during the time of treatment and are applied either as space treatments or contact treatments.
a. **Space Treatment** is the dispersal of insecticides into the air by foggers, misters, and aerosol devices for control of flying insects and exposed crawling insects.

b. **Contact Treatment** is the application of a wet spray for immediate effect.

4. **Residual Insecticides** are those products applied to obtain insecticidal effects lasting several hours or longer and are applied as general, spot, or crack or crevice treatment.

   a. **General Treatment** is application to broad expanses of surface such as walls, floors, and ceilings, or as outside treatment.

   b. **Spot Treatment** is application to limited areas on which insects are likely to occur, but which will not be in contact with food or utensils and will not ordinarily be in contact with workers. These areas may be floors, walls, and bases or outsides of equipment. For this purpose, a "spot" will not exceed 2 square feet.

   c. **Crack and Crevice Treatment** is application of small amounts of insecticides into cracks and crevices in which insects hide or through which they may enter the building. Such openings commonly occur in expansion joints, between different elements of construction, and between equipment and floors. These openings may lead to voids such as hollow walls, equipment legs and bases, conduits, motor housings, and electrical junctions or switch boxes.

   The EPA also authorized certain residual insecticides, if used with proper care, in food handling establishments for careful Crack and Crevice treatment in food areas in addition to authorized label uses.

**APPLICATION EQUIPMENT**

Insecticides are applied by many different methods which are discussed briefly in your core manual. Two of the more widely used methods -- the compressed air tank sprayer and ULV -- are discussed in more detail here.
Compressed Air Sprayer*

The one gallon stainless steel compressed air sprayer is a basic tool for insect control in a food processing plant. It is useful for residual and contact spraying in the receiving and shipping areas, and, with the proper nozzle tip extension, can be used for crack and crevice treatment in the food processing and packaging areas.

Even though it is solidly made with quality materials, a good sprayer needs regular maintenance. Hoses age and get cut and abraded. Then they may burst and needlessly expose the operator or contaminate food. Pump leathers wear or dry out so that pumping is difficult. The check valve in the bottom of the pump may become faulty or dirty so that the pump barrel fills with spray and the next downstroke causes spray material to squirt out the top of the pump, either exposing the operator or contaminating the surroundings. Shutoff valves that do not close tightly also cause needless and sometimes expensive contamination. These small sprayers are very easily and economically maintained. Replacement parts are not expensive and spare parts should be kept on hand so the equipment is always in first class condition. Probably the most important part of maintenance is keeping the sprayer tank clean. Don't forget to clean the outside of the tank also. A sprayer that is clean is not so likely to contaminate a food preparation area if it is temporarily left in the room, and a clean exterior does not expose the operator.

*Adapted with modifications from "Care and Maintenance of the One Gallon Stainless Steel Sprayer" by William L. Brehm. Pest Control Magazine, May 1968.
Ultra-low Volume Applicators

Ultra-low volume (ULV), although new to the structural pest control industry, has been a technique used for insect control in agriculture, forestry, and public health programs for some time -- particularly in aerial application. As used in these industries, ULV is the application of a pesticide that is almost pure toxicant by spraying it in extremely small amounts (1/2 gal. or less per acre) over a large area. ULV in the pest control industry is a technique using high concentrations at reduced rates of application, and more closely resembles "concentrate sprays" as used in agriculture.

In either case, however, distribution and effectiveness are dependent upon the production of very small or "fine" drops in much larger numbers than with conventional methods of application. These very fine drops, however, are more subject to drift and tend to deflect around target insects instead of hitting or impinging upon them.

Effectiveness of spray droplets is dependent on their size, their ability to penetrate or to reach the target area, and their ability to impinge upon or hit the insect. Research indicates that droplets in the 5-15 micron range (most conventional spray droplets are in the range of 100 to 400 microns) are more efficient for controlling cockroaches and other structural pests.

Spray droplet size is affected by the pressure or flow rate, the size of the outlet orifice, and the viscosity and physical characteristics of the spray mixture. The higher the air pressure or flow rate, or the smaller the orifice outlet, the smaller the droplets produced. Viscosity affects flow rates and evaporation rates - higher viscosities generally reducing both rate of flow and evaporation.

Penetration of droplets into an area not in direct line with the spray outlet is primarily dependent on droplet size, speed or velocity of the droplets, air currents into which the droplets are introduced, and gravity.

Impingement is affected by the same factors affecting penetration plus the size and shape of the target insect.

*Adapted with modifications from "ULV in Pest Control Operations" by Bennett and MacNeal. Pest Control Magazine, June 1974.
Factors influencing the effectiveness of conventional sprays also affect ULV -- i.e., the insecticide used, concentration and rate of application, thoroughness of application, amount of harborage area (hiding places), and the nature of the surfaces treated.

Since ULV involves the use of higher than normal concentrations and lower than normal rates of application, this information must appear as part of the labeling to avoid misuse of the product. At this time, the number of insecticides registered for ULV use is limited to only a few non-residual insecticides (pyrethrins and resmethrin).

Other disadvantages of ULV in comparison to conventional space sprays are poor residual life, chemical slick if oversprayed, poor results in ventilated areas, necessity of wearing protective equipment, a certain degree of fire and explosion hazard compared to conventional space sprays, and application at a time when the area is unoccupied. If a gasoline powered spray unit is used, the additional disadvantages of carbon monoxide and noise may be factors. Because droplet size is critical, equipment must be maintained and operated at specified pressures of flow rates. At present, there are no practical field methods for determining droplet size quickly.

The advantages of ULV include shorter treatment time and lower fire and explosion hazards than foggers. Other more debatable advantages include deeper penetration, more thorough flushing action, and more effective use of the insecticide.

ULV is presently being used as an additional tool or technique in pest control problems, it is not a panacea. Many applicators are using ULV to supplement residual treatment in cockroach and crawling insect programs. It is being used in food handling areas and restaurants. Favorable results have been obtained for stored product pests in areas such as warehouses, elevators, bakeries, meat plants, mills, etc. by preventing incoming insects from becoming established. It has not been effective with the present registered materials for controlling established infestations, particularly those within packaged food products or protected areas.
To obtain the best results with ULV you should:
-- Keep the equipment in a well maintained condition. The flow rate or pressure must be correct.
-- Keep insecticides and solvents at room temperature. Low temperature increases viscosity, causing larger droplets to be formed which results in poorer control and tendency to create oil slicks on hard finished horizontal surfaces.
-- Direct the application into harborage areas for maximum penetration and greatest contact (impingement) with the pests.
-- Reduce air flow and air currents in treatment area by closing doors and windows to allow droplets to stay in suspension longer.
-- If using gasoline engines:
  the engine should run evenly at the proper speed and it should be kept well tuned.
  turn off smoke alarms
  start engines outside
  keep engine mufflers and exhause pipes away from combustible materials
-- Use only materials registered for use in ULV equipment for structural uses.
-- Follow label directions.
-- Follow safety precautions.
  Wear an approved respirator and goggles
  Remove or cover food
  Cover food-contacting surfaces or clean after treatment
  Extinguish all flames and pilot lights
  Post warning signs on all entrances
  Men should work in pairs and in sight of one another during application if machine is operated indoors
BASICS OF INSECTICIDES, RODENTICIDES, AND AVICIDES

Pesticide applicators conducting health, industrial, and institutional, structural, and health-related pest control should have a basic understanding of the commonly used pesticides. The paragraphs that follow will present information on: 1) chemical structure; 2) common commercial products; 3) toxicology; and 4) frequent symptoms of poisoning.

Insecticides

A large number of the pesticides used today are for the control of insects. Most of the insecticides produced are "contact poisons"; that is, they must actually come in contact with the insect to exert their toxic action. The toxic action most important for insecticides is acute toxicity. Insecticides that kill insects rapidly display the property of chronic toxicity.

Insecticides are often classified into groups according to their chemical structure. The groups of insecticides important to most commercial pesticide applicators include:

1. ORGANOCHLORINE PESTICIDES
2. ORGANOPHOSPHATE PESTICIDES
3. CARBAMATE PESTICIDES
4. PENTACHLOROPHENOL
5. BOTANICAL PESTICIDES
6. BIOLOGICAL PESTICIDES
7. FUMIGANTS

In some cases, the chemical structures of pesticides in the groups will be presented. These structures will help show similarity between different compounds; it is not necessary for the reader to commit them to memory.
ORGANOCHLORINE PESTICIDES

CHEMICAL STRUCTURE

LINDANE

CHLORDANE

DIELDRIN

ENDOSULFAN

HEPTACHLOR

METHOXYCHLOR

COMMON COMMERCIAL PRODUCTS

Highly toxic: endrin (Hexadrin), a stereoisomer of dieldrin.
Moderately toxic: aldrin (Aldrite, Drinox), lindane (Isotox, Gammexane), chlordane (Chlordan).

TOXICOLOGY

In adequate dosage, these chemicals interfere with axonic transmission of nerve impulses and, therefore, disrupt the function of the nervous system, principally that of the brain. This results in behavior changes, sensory and equilibrium disturbances, involuntary muscle activity, and depression of vital centers, particularly that controlling respiration.

SYMPTOMS OF HUMAN POISONING

APPREHENSION, excitability, dizziness, HEADACHE, DISORIENTATION, weakness, PARESTHESIAE, muscle twitching, tremor, tonic and clonic CONVULSIONS (often epileptiform), coma. Soon after ingestion, nausea and vomiting are prominent. When chemicals are absorbed by parenteral routes, apprehension, twitching, tremors, and convulsions may be the first symptoms. Respiratory depression is caused by the pesticide and by the petroleum solvents in which these pesticides are usually dissolved.
REMARKS

Chemically, organochlorine pesticides are very stable compounds. They persist in the environment and are sometimes considered pollutants. Organochlorine compounds have a long residual activity and are broad-spectrum insecticides--they kill many types of insects.
ORGANOPHOSPHATE PESTICIDES

GENERAL CHEMICAL STRUCTURE

\[ \text{C}_2\text{H}_5\text{O or CH}_3\text{O} \stackrel{\text{P}}{\text{S (or O)}} \text{LEAVING GROUP} \]

COMMON COMMERCIAL PRODUCTS

Highly toxic: TEPP, phorate (Thimet), mevinphos (Phosdrin), and ethyl parathion (Parathion, Thiophos).

Moderately toxic: dichlorvos (DDVP, Vapona), chlorpyrifos (Dursban), diazinon (Spectracide), trichlorfon (Dylor, Dipterex, Neguvon), and malathion (Cythion).

TOXICOLOGY

Toxicants of this group phosphorylate almost irreversibly varying amounts of the acetylcholinesterase enzyme of tissues, allowing accumulation of acetylcholine at cholinergic neuro-effector junctions (muscarinic effects), and at skeletal muscle myoneural junctions and in autonomic ganglia (nicotinic effects). Poison also impairs central nervous system function. Toxicants can be absorbed by inhalation, ingestion, and skin penetration.

SYMPTOMS OF HUMAN POISONING

Symptoms of acute poisoning develop during exposure or within 12 hours after contact. HEADACHE, DIZZINESS, EXTREME WEAKNESS, ATAXIA, TINY PUPILS, blurred or dark vision, muscle TWITCHING, TREMOR, sometimes convulsions, mental confusion, incontinence, unconsciousness, NAUSEA, vomiting, abdominal cramps, diarrhea. Tightness of chest, SLOW HEARTBEAT, wheezing, productive cough, sometimes PULMONARY EDEMA (up to 12 hours after poisoning). SWEATING, rhinorrhea, tearing, salivation. Severe poisoning may cause sudden unconsciousness or TOXIC PSYCHOSIS resembling acute alcoholism.
REMARKS

This is a very large group of poisons. A conservative estimate is that at least 100 organic phosphate insecticides have reached the commercial market. Some examples include diazinon, malathion, parathion, and methyl parathion.

The chemicals in this group have several properties which we need to know something about. An important property is that they are easily broken down under alkaline conditions. This means that they are not particularly stable chemicals and are often short-lived as insecticides. They do not persist in the environment and, from a practical point of view, they often have to be applied repeatedly to bring about insect control.

Organic phosphate insecticides have a wide variability in their toxicity to mammals. Malathion, for example, is quite safe for use around mammals while others, such as parathion and methyl parathion, are very toxic to mammals. The organic phosphate chemicals are only slightly soluble in water, but are completely soluble in organic solvents. They are used for a variety of purposes including insecticides, acaracides, plant systemics, and others.

The mode of action of the organic phosphates is fairly well understood. These chemicals act upon the insect's nervous system to cause death.

The nervous system works much like an electric light and an on/off switch. When you flip the switch on, the electricity travels rapidly to the light bulb and it lights. Similarly, when an insect is touched or stimulated in some way, the message is received at the receptor and travels along the nerve wires (axon) to the central nervous system (CNS). Before the message reaches the CNS, it must pass over a break in the axon. This break is called a synapse. The message is carried across the synapse by the help of a chemical called acetycholine. This
chemical is produced for a very short time -- just long enough to transfer the message from one side to the other. After this, another chemical is produced to break down acetycholine so the axon is ready for another message. When an organic phosphate insecticide is introduced into this nervous system, the effect is to prevent the production of the chemical that breaks down acetycholine. Under these conditions, the chemical acetycholine accumulates at the synapse. It is toxic to the synapse. The insect nervous system is damaged and is not capable of carrying out its normal function. As a result of this, the insect dies.
CARBAMATE PESTICIDES

GENERAL CHEMICAL STRUCTURE

\[
\begin{align*}
\text{H}_3\text{C} & \text{N} \overset{\text{O}}{\text{C}} \overset{\text{O}}{\text{LEAVING}} \\
\text{H} & \text{II LEAVING} \\
\text{GROU}P
\end{align*}
\]

COMMON COMMERCIAL PRODUCTS

Highly toxic: aldicarb (Temik), carbofuran (Furadan).
Moderately toxic: propoxur (Baygon), carbaryl (Sevin).
Some chemicals of this class are "systemic," i.e., they are taken up by the plant and translocated into foliage and sometimes into the fruit.

TOXICOLOGY

Toxicants of this group cause reversible carbamylation of the acetylcholinesterase enzyme of tissues, allowing accumulation of the acetylcholine at cholinergic neuroeffector junctions (muscarinic effects), and at skeletal muscle myoneural junctions and autonomic ganglia (nicotine effects). Poisons also impair central nervous system function.

A few of the carbamate insecticides are formulated in methyl (wood) alcohol. In cases of ingestion of these formulations, the toxicology of the methanol must be taken fully into consideration: severe gastroenteric irritation, acidosis, and central nervous system injury.

SYMPTOMS OF HUMAN POISONING

Symptoms of acute poisoning develop during exposure or within 12 hours after contact. HEADACHE, DIZZINESS, WEAKNESS, ATAXIA, TINY PUPILS, blurred or "dark" vision, muscle TWITCHING, TREMOR, sometimes convulsions, mental confusion, incontinence, unconsciousness. NAUSEA, vomiting, abdominal cramps, diarrhea.
Tightness in chest, SLOW HEARTBEAT, wheezing, productive cough, occasionally pulmonary edema. Sweating, rhinorrhea, tearing, SALIVATION. Severe poisoning may cause sudden unconsciousness, or a toxic psychosis. RESPIRATION DEPRESSION may result from actions of the toxicant and solvent.
PENTACHLOROPHENOL

CHEMICAL STRUCTURE

![Chemical structure of pentachlorophenol](image)

COMMON COMMERCIAL PRODUCTS

PCP, Dowicide-7 Penchlorol, Pentacon, Penwar, Weedone, Veg-I-Kill, Wood Preserver, Wood Tox 140, Purina Insect Oil Concentrate, Gordon Termi Tox, Usol Cabin Oil, Certified Kiltrol-74 Weed Killer, Ciba-Geigy Ontrack OS 3, 4, or 5, Ortho Triox Liquid Vegetation Killer, Black Leaf Grass, Weed and Vegetation Killer Spray.

Pentachlorophenol has many uses as a weed killer, defoliant, wood preservative, germicide, fungicide, and molluscicide. It is an ingredient of many other formulated mixtures sold for one or more of these purposes.

TOXICOLOGY

Pentachlorophenol irritates the skin, eyes, and upper respiratory mucous membranes. It is efficiently absorbed through the skin, the lungs, and the gastrointestinal lining. It stimulates oxidative metabolism of tissue cells by uncoupling oxidative processes from the normal stepwise phosphorylation reactions. In common with other phenols, it is toxic to the liver, kidney, and central nervous system.

The majority of severe poisonings have occurred in workers exposed when in hot environments.

SYMPTOMS OF HUMAN POISONING

IRRITATION of nose, throat, eyes, and skin is the most common symptom of exposure to PCP. Severe or protracted
exposure may result in a CONTACT DERMATITIS. Intensive occupational exposure has resulted in chloracne.

PROFUSE SWEATING, HEADACHE, WEAKNESS, AND NAUSEA are the most consistent symptoms of systemic poisoning by absorbed PCP. FEVER is usually present but may be minimal or absent.
COMMON COMMERCIAL PRODUCTS

The natural pyrethrins which include Pyrethrins I and II, Cinerins I and II, and Jasminolins I and II.

Synthetic pyrethrin-line (pyrethroid) compounds that duplicate the activity of natural pyrethrin compounds include allethrin, barthrin, cycluscalthrin, dimethrin, furethrin, Neopyrnanin, phytholthrin, resmethrin.

TOXICOLOGY

Pyrethrum and allethrin may be absorbed through the gastrointestinal and respiratory organs. They are not absorbed to a significant degree through the skin; however, allergic reactions may result from dermal exposure.

The nervous systems produced by pyrethrum and allethrin poisoning resemble those of veratrin intoxication, proceeding from excitation to convulsions to tetanic paralysis, except the pyrethrins cause muscular fibrillation as well. Death is due to respiratory failure. If recovery occurs, it is usually complete. Injury to man from pyrethrum has most frequently resulted from the allergenic properties of the material rather than its direct toxicity.
Under practical conditions, pyrethrum and allethrin are probably the least toxic to mammals of all the insecticides currently in use.

**SYMPTOMS OF POISONING**

Pyrethrum toxicity may manifest itself in several forms in man. Contact dermatitis is by far the most common. The usual picture is a mild erythematous, vesicular dermatitis with papules in moist areas, and intense pruritus. A bullous dermatitis may develop. Some individuals show manifestations of pyrethrum sensitivity similar to those seen in pollinosis, including sneezing, serious nasal discharge, and nasal stuffiness.
BIOLOGICAL PESTICIDES

The materials in this group are toxins of bacterial origin, most commonly from *Bacillus thuringiensis*. These materials are probably composed of proteins and must be eaten by the insect. They are often quite specific and work on only one species or one group of insects. Apparently, they have to be eaten in fairly large quantities in order to be effective. Their mode of action seems to be an interference with insect gut membrane. Once this has happened, a variety of secondary effects probably set-in which eventually cause the death of the insect. Use of this kind of an insecticide represents a form of biological control of insects. Because the pathogens or their toxins seem to be specific for insects, they probably do not constitute an environmental pollution hazard.
FUMIGANTS

CHEMICAL STRUCTURES

ALIPHATIC - Carbon tetrachloride, methyl bromide; Chloropicrin (Acquinite, Chlor-O-Pic, Pic-Clor, Picfume, Trichlor); ethylene dichloride (EDC); ethylene dibromide (EDB, Bromofume, Celmide, Dowfume W-85, Kip-Fume, Nephis, Pestmaster EDB-85, Soilbrom).

AROMATIC - Paradichlorobenzene (PDB, Paracide, Paradow)

SULFURYL - Sulfuryl fluoride (Vikane)
TOXICOLOGY

Except for the solid paradichlorobenzene moth chrystals, these chemicals are gases or highly volatile liquids at room temperature. As fumigants, they have a remarkable capacity for penetration. Some, especially the bromine compounds, pass readily through human skin and rubber protective gear, thus complicating the protection of exposed workers. In varying degrees, they irritate the skin, eyes, and respiratory tract. When held on the skin by an occluding cover, such as contaminated gloves, these chemicals not only irritate, but cause acute dermatitis and vesiculation. Repeated contact with the liquid halocarbons defats the skin, leading to chronic dermatitis. All are capable of producing pulmonary edema and/or hemorrhage in persons heavily exposed by inhalation, ingestion, or dermal absorption. Death following exposure to the halocarbon fumigants is usually due either to pulmonary edema or to respiratory depression.

Inhalation of pyrolysis products of these fumigants has caused massive necrosis of respiratory tract linings in exposed firemen.

Toxic action on the central nervous system is generally depressant, causing unconsciousness, seizures, and general muscle weakness, including weakened respiratory effort. The neurotoxic action of methyl bromide apparently include the basal ganglia as well as the cerebrum, causing not only sensory and motor impairments but also behavioral and emotional disturbances. These may or may not progress to epileptiform seizures and coma. In some cases, behavioral and neurologic manifestations have first appeared several hours or even days after exposure, then they have persisted for days to months.

The chlorocarbons, notably chloroform, increase myocardial irritability and impair contractile strength. Large inhalation dosages may cause death by inducing ventricular fibrillation.
In varying degrees, these fumigants damage the liver and kidneys. In laboratory animals, and in autopsy specimens from fatal human cases, this is commonly manifest as fatty degeneration. More severe poisoning causes centrilobular necrosis of the liver and acute tubular necrosis of the kidney. Fatty degeneration of the myocardium and corneal opacities have been observed in dogs following systemic absorption of ethylene dichloride.

Methyl bromide and ethylene dichloride (and possibly other chemicals of this series, by analogy) are alkylating agents in mammalian tissues; they can inhibit multiple enzyme systems, including the sulfhydryl enzymes and hexokinases in multiple tissues. This may be a major mechanism of toxicity of this series of chemicals.

Paradichlorobenzene is substantially less toxic to humans than are the gaseous and liquid fumigants. It has neither the hemolytic nor the cataractogenic properties of naphthalene fumigant, which it has largely displaced. Given at extreme dosage to laboratory animals, it causes liver injury and neurologic disturbances.
RODENTICIDES AND AVICIDES

Rat and bird control are important aspects of industrial, institutional, structural, and health-related pest control. There are a variety of factors that influence the effectiveness of rodenticides and avicides. Such factors include: 1) toxicity; 2) dosage levels; 3) acceptance and reacceptance; and 4) the development of tolerances. Odor and taste must be considered in some instances. Safety precautions are an essential part of any procedure. An understanding of the mode of action will enable you to use rodenticides and avicides more effectively and safely.

RODENTICIDES

Rodenticides are pesticides used to control rodents such as rats, mice, and squirrels. They are normally employed in solid baits, liquid forms, as dusts, or as volatile chemicals used as fumigants. The most effective rodenticides are those with a high toxicity and palatability, and with one or more safety features. Rodenticides used in solid baits or liquid forms can be divided into two groups based on the mode of action: 1) the acute rodenticides; 2) the chronic rodenticides.

The acute rodenticides are those in which a lethal quantity of poison is ingested in a single dose with the food or drink of a rodent. They cause death by heart paralysis, gastrointestinal and liver damage, or by attacking the central nervous system. The target animal must consume a lethal dose before the onset of poisoning symptoms. A sub-lethal dose may produce side effects which will make the rodent "bait shy". Pre-baiting is recommended before applying acute rodenticides so the animal will be conditioned to the bait. The unpoisoned bait is first presented to the rodents until they freely feed regularly and then it is replaced by bait containing the poison.

Chronic rodenticides bring about death of an animal only after the poisoned bait or liquid has been consumed on a number
of occasions. Because the poison is consumed over a period of time, a low dosage is lethal. For example, a brown rat can survive a single 50 MG/KG dose, but succumbs to 5 consecutive doses of 1 MG/KG taken on successive days. The symptoms of poison are so delayed that the animal never learns to associate discomfort with the bait consumption, and continues to feed until a lethal dose has been ingested. The main components possessing chronic poisoning action are the anticoagulants, which interrupt the synthesis of blood-clotting factors so the poisoned animals die from internal bleeding. Chronic rodenticides are relatively nontoxic to domestic animals and man; however, there is no such thing as a "safe rodenticide".

However toxic a chemical poison might be, it will not be lethal unless a rodent, of its own volition, consumes a lethal dose. Additives are sometimes included in the bait to improve performance. Attractants such as flavoring or oils are sometimes added to bait to make it more appealing by enhancing the taste or masking disagreeable odors. Anticoagulants may be made more lethal by adding potentiating agents that accentuate the action of the anticoagulants. Preservatives and binders are used in baits to keep them from deteriorating over time. To guard against accidental consumption of the poisoned bait by nontarget animals, safety additives may be incorporated. Since rodents are unable to vomit, it is often the practice to incorporate an emetic agent in the bait. The emetic agent will induce vomiting and provide a safety factor for the non-target animals.

Secondary poisoning to animals which feed on dead or dying rodents should be anticipated. The danger may be reduced by removing rodent carcasses whenever possible.

Acute or chronic poisons may be used in dust formulations. A poisoned dust is placed in the holes and burrows of rodents where it adheres to their feet and fur and is transferred to
the mouth during normal cleaning and grooming activities. This method requires a high concentration of poison since the animal can only be expected to consume small amounts. The advantage of contact dusts is that rodents do not suspect the source of illness.

In situations where rodents do not respond to poisoned baits or dusts, a fumigation technique can be used. Rodents breathe the volatile substances and gases which cause death.
ANTICOAGULANT RODENTICIDES

STRUCTURES OF PRINCIPAL CLASSES

WARFARIN (COUMARIN-TYPE)  1,3 INDANDIONE TYPE

COMMON COMMERCIAL PRODUCTS

Coumarin type: warfarin (Kypfarin, Warf-42, D-Con, Warficide, Prolin), coumafuryl (Fumarin), Dethmor, Rax.

1,3-indandione type: diphacinone, or diphenadione (Ramik), chlorophacinone (Drat, Caid, Liphadione, Microzul, Ramucide, Rotomet, Raviac, Topitox), pindone (Pivalyn, Pivacin, Tri-ban, Pival), valone, (PMP).

TOXICOLOGY

Gastrointestinal absorption of these toxicants is efficient, beginning within minutes of ingestion and continuing 2-3 days. Apparently, warfarin can be absorbed through the skin, although the circumstances under which this has occurred are extraordinary.

Both types of anticoagulant depress and hepatic synthesis of substances essential to normal blood clotting.

Unlike the coumarin anticoagulants, the indandiones cause symptoms and signs of neurologic and cardiopulmonary injury in laboratory rats; these injuries often lead to death before hemorrhage occurs. These actions may account for the somewhat greater toxicity of this class of anticoagulants.

SYMPTOMS OF POISONING

In most instances of accidental ingestion by man of anticoagulant baits, victims have remained asymptomatic, due to the small dosage taken. Even in cases involving ingestion of sub-
stantial doses, hypoprothrombinemia occurs without symptoms of poisoning. Hemorrhage appears only when extraordinary amounts have been absorbed. In these cases, the anticoagulants were either taken deliberately, were absorbed over long periods out of neglect of elementary hygienic standards, or were injected by starving indigents who used quantities of rodent bait for food.

Victims of large doses exhibit HEMATURIA, NOSEBLEED, HETATOMATA, BLEEDING GUMS, AND MELENA. ABDOMINAL PAIN AND BACK PAIN PROBABLY REFLECT HEMORRHAGE IN THE ABDOMINAL AND RETROPERITONEAL TISSUES.
VACOR AND DLP-787

CHEMICAL STRUCTURE

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\text{H} - \text{H} - \text{O} - \text{H} \\
\text{RH-787} \\
\text{NO}_2
\end{array}
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COMMON COMMERCIAL PRODUCTS

Vacor Rat Killer (2% RH-787 in vehicle resembling corn meal); DLP-787 Bait (2% RH-787 in vehicle resembling corn meal); DLP-787 House Mouse Tracking Powder (10% RH-787 in a light green powder vehicle). Compound RH-787 is the active ingredient of both formulations.

TOXICOLOGY

The exact mechanism of RH-787 toxicity is not known. It has no anticoagulant action, and is, therefore, entirely different from the coumarin or indandione rodenticides.

FREQUENT SYMPTOMS OF POISONING

Human poisonings of a significant nature have occurred only after deliberate ingestions of RH-787. Symptoms vary, depending on dose and individual susceptibility.

Symptoms may not appear until 4-48 hours after ingestion of the formulated rodenticide. EARLY symptoms include NAUSEA, VOMITING, ABDOMINAL CRAMPS, CHILLS, AND MENTAL CONFUSION.
AVICIDES

Avicides are pesticides used to control birds in pest situations. Some common avicides include compound DRC 1339 and avitrol. Most avicides are acute poisons which act on the central nervous system. The reaction time required to kill a bird varies with the type of poison. Strychnine used as an avicide will kill birds shortly after the bait is consumed while the avicide containing the compound DRC 1339 does not kill the birds for several hours, generally after they go to roost. This difference in mode of action is important in reducing the effects of secondary poisoning to animals that consume dead birds. Birds dying at the roost sites can be easily picked up and disposed of.

No avicide has been found that is specific for a given bird; thus, there is always a danger that non-target birds will be affected. A poison such as strychnine is lethal to all animals while DRC 1339 is more lethal to starlings and blackbirds, but will also kill smaller birds. Avitrol is an avicide which is used to control blackbirds. Birds ingesting avitrol react with distress symptoms and calls which frighten away the remainder of its flock from feeding area with a minimum of mortality. The advantage of avitrol is that only few birds need to ingest the bait, thus a relatively small amount of bait needs to be put out.