Insecticides

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Objectives

1. Relate four major events in the history of Pest Control
2. Describe the major types of insecticides and give an example of each
3. Describe in detail how organophosphates and carbamates interfere with the normal functioning of the nervous system.
4. Describe how toxicity of insecticides is measured
5. Discuss the advantages and disadvantages of insecticides

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Introduction

The word **insecticide** refers directly to those chemicals that kill insects. The term **pesticide** is a broader term meaning a killer of pests in general (fungicides, herbicides, miticides, rodenticides, avicides, insecticides, etc.). An insecticide is a pesticide. These two terms will be used interchangeably throughout this unit.

Foam treatment for drywood termites in a door. termite frass in foam.

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Brief History of Pest Control

Pest control has long and interesting history that appears to have begun around 2500 BC when the Sumerians began using sulfurs as an insecticide. Around the time of Christ, the Chinese and Egyptians were using herbs and oils to control insect pests. By 300 B.C., the Chinese started to monitor the emergence of pests and regulate when they planted their crops to avoid certain pests. Between 1100-1600 AD, the Chinese started using soaps, tobacco and arsenic to control pests; these are techniques that again are used today.

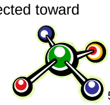
As people began coming to the New World to settle and international trade increased, it became apparent that foreign insect pests were being introduced. In the 1800's, countries started regulating and quarantining goods to inspect for pests before the goods could be unloaded and sold. In 1899, the world had its first major biological control success. The cottony cushion scale insect almost destroyed the citrus industry in California during the late 1800's. Albert Kebele was sent to Australia where the scale had originated to find its natural predator. There, he found Vidalia beetles feeding on it, brought back a population and released the beetles in California. Within a few years it had reduced the scale population to non-economic levels.

Brief History of Pest Control Continued

The development of synthetic (or man-made) insecticides 1939 began what can be called the "Insecticide Era". The importance of this event was quickly manifest with the outbreak of WWII. Stop and think for a moment what connection may exist between WWII and insecticides.

Hint: it has nothing to do with using chemicals to poison people.

Up until WWII insect born diseases such as epidemic typhus and malaria, which can run rampant during warfare, generally took more lives than enemy fire. However, because of the development and use of DDT (65,000 tons were used worldwide during one year), death due to insect born diseases was greatly reduced. DDT effectively controlled both the lice that spread typhus and the mosquitoes that spread malaria. Because of the tremendous success of DDT, people around the world and particularly here in the United States began to assume that insecticides could cure all our insect problems and eliminate any pest we desired. All research being done on biological control and other ways to control pests was stopped and all resources and energy was directed toward developing new and better insecticides.



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History Continued

This euphoric attitude towards insecticides soon came crashing down in 1962 with the publication of Rachel Carson's book, *Silent Spring.* This book brought to attention the real dangers and negative consequences of insecticides. The title "Silent Spring" refers to a time when no more birds, or anything else, would be chirping in the spring, because everything in the environment could be destroyed if we were not careful. Responding to this environmental awareness, government regulation on pesticide use increased and public perception of insecticides began to change.

During this time, it was found that DDT was not a "miracle" chemical. It did not easily break down in the environment and was being passed up the food chain from insects to fish that ate them, to birds of prey that ate the fish. The accumulation of DDT caused the bird of prey to lay eggs with shells so thin that they would easily break. About the same time, it was becoming apparent that insects were becoming resistant to DDT, reducing its effectiveness. Eventually it was banned in the U.S.

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History Continued

Since 1962, the focus has been on **Pest Management** rather than on pest elimination. Rather than thinking in terms of "Let's sterilize the field and kill all the insects," the goal was now to *manage* the pests to prevent their numbers from reaching the EIL. If you notice from the Pest Management industry, exterminators are now known as PMPs or pest management professionals.

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Chemical Control

Chemical controls of insect pests are sometimes necessary. Insects compete with us for food, water and shelter and some may transmit disease. Chemistry has advanced so that we can now carefully choose what type of chemical control measures will help us to control the insect pest and still have minor impact on the environment. There are different chemistries that impact insects in different ways. These are called "modes of action".

Modes of entry
- Contact
- Ingestion
- Systemic
- Inhalent

Modes of action
- Ach.E. Inhibition
- Nerve poison
- Hormone disruptor

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Insecticide Labels

We will now examine insecticides in some detail by first examining the label that by law is placed on every insecticide container. When looking at an insecticide label it will have three names for the chemical listed: the common name, the trade name and the chemical name. The **common name** is very specific name given to the active ingredient of a chemical. It is similar to the scientific name of an insect. Even if more than one company produces an insecticide, they each need to use the same common name.

Look at insecticide label 1 on the attachment link above. Look under the heading "ACTIVE INGREDIENT." It lists the chemical as Imidacloprid, which is the common name. Next to the Imidacloprid name is the long complicated **chemical name**, "1-[6-chloro-3-pyridinyl)methyl]-*N*-nitro-2-imidazolidinimine." This name describes the chemical compound structure. The **trade name** on this label is "Merit 0.5 G." A trade name is the commercial name given by the company producing the insecticide. The same insecticide can have different trade names depending on who makes it or the market it is being sold in. A company can use different trade names for a product with the same common name. For example, Bayer, who makes "Merit 0.5G", also sells Imidacloprid as "Premise" and "Admire." Premise is used in the pest control industry, Admire is used on row crops while Merit is used on turfgrass pests.

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Label Activity

Take a look at label 2 on the attachment link above.

What is the common name for this pesticide?
What is the trade name?
What is the chemical name?

It is important to understand the difference between common, trade and chemical name because the U.S. Department of Agriculture calls insecticides by their common names when recommending pesticides to the public. Thus, they avoid the confusion that could occur if trade names were used and any bias towards a particular company can be avoided. However, the media (newspapers or news channels) might call the pesticide by either the common or trade name. You do not need to record your answers in your journal, but you do need to be familiar with insecticide labels.

Note: The label is the law!

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Insecticide Toxicity

Many insecticides are toxic to humans and other mammals. So, before an insecticide can be sold, an estimation of how toxic it will be to humans must be determined and be included on the label. This estimate is figured out by testing the insecticide on laboratory rats and rabbits. **Toxicity** is defined as the dose that will kill 50 percent of the test animals it was administered to. The dose is expressed as milligrams of insecticide per kilogram of lab animal body weight. It is referred to as the **LD_{50}**. 'L' stands for "lethal," 'D' stands for "dose" and '50' refers to the 50% killed by the insecticide. An oral and a dermal dose is determined, meaning how much of the insecticide must be ingested to kill 50% and how much of it just has to land on the skin to kill 50% of the test population.

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Pesticide Classification

Insecticides are ranked according to their LD_{50} number. The lower the LD_{50}, the greater the toxicity. Pesticide law in the U.S. requires that labels be placed on all products, and must include words like "**Danger-Poison**," "**Warning**," and, "**Caution**" along with the LD_{50} for oral and dermal toxicity. **Danger-Poison** is the highest classification an insecticide can receive. This classification has an oral LD_{50} of 50 mg/kg or lower. This works out to be approximately a teaspoon of the insecticide. When you convert this dose to ounces per 100 pounds it is .08 ounces per 100 pounds. This means that it takes only about a teaspoon of the insecticide to be taken orally that will kill 50 percent of those who are 100 pounds. For instance, if a 100-pound person accidentally ingested a teaspoon of the insecticide he would have a fifty percent chance of dying unless he received medical attention. Insecticides that fall under this highly toxic category are: parathion and aldicarb.

Note: In this example, the amount of insecticide refers to the active ingredient, not the formulated amount.

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Pesticide Classification Continued

Those insecticides classified in the "**Warning**" category have an oral LD_{50} between 50-500 mg/kg--which is approximately one teaspoon to two tablespoons of insecticide. Rotenone, nicotine and diazinon fit in this category. (*Note: Diazinon was removed from the market in 2004).* There are two categories that require the "**Caution**" word put on the label. The first category is the slightly toxic category and the second is the low toxicity category. The slightly toxic category has higher LD_{50}s than those insecticides labeled "Warning." These have an oral LD_{50} between 500-5,000 mg/kg which is approximately one ounce to one pint. Malathion and carbaryl are slightly toxic insecticides. Low toxicity insecticides have the highest LD_{50}s of all, higher than 5,000 mg/kg. Permethrin fits in this category.

Toxicity category	Oral/dermal LD_{50} (mg/kg body weight)	Signal Words (required on label)	Insecticide examples
Highly toxic	<50 oral and/or <200 dermal	Danger-Poison	Parathion, nicotine,
Moderately toxic	50-500 oral and/or 200-2000 dermal	Warning	Rotenone, diazinon
Slightly toxic	500-5000 oral and/or 2000-20000 dermal	Caution	Malathion, carbaryl
Low toxicity	>5000 oral and/or >20,000 dermal	Caution	Permethrin

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Learning Game Placeholder

Learning Game: Sequence

Title: Toxicity Quiz

Quiz Answer

This table ranks the compounds with their corresponding oral LD_{50}s.
(Remember, the higher the LD_{50}, the less toxic it is.)

Compound	Oral LD_{50} (mg/kg)
Nicotine	10
Strychnine	30
Caffeine	250
Carbaryl	700
Aspirin	1100-1500
Malathion	1375
Table Salt	3750

It probably did not alarm you that Strychnine was near the top of the list, but were you surprised to find out that caffeine and nicotine are more toxic than the two insecticides listed?

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Types of Insecticides

Insecticides are classified as **inorganics**, **botanicals**, **synthetic organics**, **insect growth regulators (IGR's)**, and **microbials**.

Inorganics are usually obtained by mining and do not contain organic compounds (those that contain carbon) in them. **Botanicals** are obtained from flowers and **synthetic organics** are man-made. **Insect growth regulators** often kill insects by affecting insect growth and **microbials** include a fungus, a bacteria or a virus applied to plants to kill insects. We will discuss each type of insecticide and give examples of each.

Inorganics
There are four inorganic insecticides we will cover: **arsenic, soap, boric acid**, and **diatomaceous earth**.

Most of you are familiar with **arsenic**. It's a poison that has been around a long time and was used to kill chewing pests on plants. However, arsenic is toxic to humans so now it is not used very much as an insecticide.

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Inorganics

Soap insecticides are obtained from the same kind of fatty acid soaps we use to wash with. They are commonly sprayed on plant eating insects and need to contact the insects while the soap is still wet in order to be effective. Soaps probably kill insects by affecting the nervous system (paralysis) and also by disrupting the waterproof waxy layer on the outside of the insect. This means that the animal will eventually lose all its internal moisture and die from dehydration.

Boric acid, the third inorganic, can be purchased at any discount or home improvement store. It's a powder that is often placed in cabinets to kill roaches. Its mode of action is to abrade the outer waxy layer and cause death from dehydration.

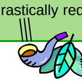
Finally, **diatomaceous earth** is a commonly used product amongst those who are organic gardeners. This pesticide comes from minerals that are mined from the soil, where dead diatoms from old lake or ocean beds have accumulated. A diatom is a type of algae that can live inside a hardened silicate skeleton. The silicon is very abrasive and breaks down the waxy layer just as boric acid and soaps do. It can kill a lot of different pests, but it has to be applied under fairly specific conditions. It works great in dry conditions and is commonly used in stored product situations like stored pastas and grains.

Botanicals

Botanicals
Botanical insecticides include: **pyrethrum, nicotine, rotenones**, and **neem extracts**.

Pyrethrum has been used for a long time and is obtained from a type of flower similar to the common chrysanthemum. It has some neat properties because it knocks insects down extremely quickly. If you spray pyrethrum in the air at a fly, the fly will drop to the ground in a split second. It is not very toxic to other animals or humans. For these reasons it is commonly used for pests of household pets. However, the effects of this pesticide are short-lived, and it degrades very rapidly--within hours or minutes. Often it will just stun the insect and not kill it. When pyrethrum is mixed with other synergistic compounds, it becomes much more lethal than when it is used alone.

Nicotine is derived from the tobacco plant and has been used at least since the 1700's. It kills insects by interfering with the insects' nervous system, but it was found that nicotine is also highly toxic to mammals. So much so that crops cannot be harvested for 7 days after it is applied. This knowledge has drastically reduced its use.



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Botanicals and Synthetic Organics

Rotenone is obtained from tropical plants and was first used by native peoples to poison fish. Today it is still used in this way (when a fisheries project wants to sanitize a body of water from undesirable fish), but it is also used as a spray or dust for chewing insects in garden and fruit crops.

Neem oil is extracted from the seeds of neem trees found in tropical areas. It is getting a lot of attention because it breaks down quickly once in the environment (unlike DDT) and is safe for mammals. In fact, neem oil is used as an anti-inflammatory agent and to fight ulcers in humans. As an insecticide, neem is marketed under the trade name Azatin®. Take a look next time you visit a health food store and you will see a variety of neem products including everything from toothpaste to shampoo.

Synthetic organics

The synthetic organic insecticides are some of the most common insecticides used today, especially over the last 30 years. They include the **organochlorines, organophosphates, carbamates, pyrethroids,** and **chloronicotinyls**.

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Synthetic Organics

The **organochlorines** include pesticides such as Chlordane, Lindane, and DDT. All these products are not available today because they do not break down in the environment very easily. Usually there is a problem with biological amplification. Chlordane was used up until a few years ago because it can last longer than 20 years in the soil. This is why it was used for termite control around the perimeter of buildings and homes.

Jane Medley, University of Florida

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Synthetic Organics

Organophosphates took the place of the organochlorines when they were taken off the shelf. These include malathion, diazinon, and Dursban®. Dursban® was used up until 2004 in the place of chloridane for termite control. Because of environmental concerns, diazinon and Dursban were removed from the market. These organophosphates range from very dangerous products to ones that are safer to use like Malathion or Lindane. Some of these products, like lindane, are considered safe enough that they are prescribed by physicians to control lice or to use as a flea dip on pets. Research is continuously being done on these chemistries and Lindane has been recently implicated in neural damage from repeated exposure and the frequencies of doctor prescriptions is falling.

One of the oldest and effective **carbamates** is carbaryl which is marked as Sevin®. This class of insecticides is generally safer to use than the organophosphates. Their drawback is that they are toxic to beneficial insects, particularly hymenopterans and other organisms like earthworms.

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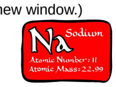
How Organophosphates and Carbamates Work

Both the organophosphates, carbamates, and nicotine kill insects by affecting their nervous system. Consequently, these pesticides affect our nervous system, too and thus are toxic to humans. When a nerve impulse travels down a nerve and reaches the end of the nerve, a chemical called acetylcholine (Ach) is released. Ach will bind to the next neuron causing channels to open. As the channels open, sodium ions rush into the nerve cell stimulating it to fire and the original impulse is continued.

After the sodium rushes into the cell, Ach is released and is broken down by an enzyme called Ach esterase. Carbamates and organophosphates will bind to this enzyme and keep it from breaking down Ach. If it is not broken down, Ach will bind to another channel and cause the nerve to fire again and again. When many nerves are affected, this continuous firing will eventually kill the organism, whether it is an insect, human or other mammal. Nicotine mimics Ach and binds to the sodium channel. However, Ach esterase cannot break down nicotine and the neuron keeps firing just like in carbamate and organophosphate use. We will follow this process over the next few slides. (The animation will appear in a new window.)



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Synthetic Organics - Continued

Pyrethroids are a synthetic version of another chemical we discussed previously.

Which pesticide name does pyrethroid sound like?

The answer is <u>pyrethrum</u>. The suffix "-oid" means "derived from or like." Pyrethroid is a synthetic copy of pyrethrum, but the molecule has been changed so it has better quality. Pyrethroids kill more effectively and last longer so they do not breakdown in the environment as quickly as pyrethrum. Pyrethrum is generally too expensive to spray on an entire field, but pyrethroids are cheap enough that they can be used in large quantities. Common pyrethroids are the pyrethrins which are up and coming products because they are safe for animals and effectively kill insects.

The final synthetic organic pesticide we will discuss are the **Chloronicotinyls**. Just as pyrethrins are similar to pyrethrum, chloronicotinyl compounds are derived from nicotine. Presently there's only one product amongst this class, but it's a very important one. It is Imidacloprid, which was discussed previously when we looked at insecticide labels. This insecticide is extremely popular in its market because insects have not developed a resistance to it, yet. Unlike nicotine, Imidacloprid is relatively non-toxic to mammals and is selective for pest insects.

Insect Growth Regulators (IGR's)

Insect Growth Regulators
IGR's are relatively new chemicals that show a lot of promise. The neatest thing about them is that they are specific to insects. Remember the juvenile hormone mimics you learned about it in unit 4? Juvenile hormone mimics keep insects molting and molting and never allow the insect to become an adult. That is an insect growth regulator. Another kind of IGR is the chitin synthesis inhibitor. When the insect molts, it is not able to form a proper exoskeleton. This is extremely safe because humans do not make chitin or juvenile hormone.

Zoecon Gentrol IGR

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Microbials

Microbials
The microbial insecticides include ***Bacillus thuringiensis*** (Bt), **fungi, viruses** and **nematodes**. Most microbials can be applied much in the same way as chemical insecticides (dusts, sprays, baits, etc.) **Bt** is now a common product especially among organic gardeners to control lepidopteran pests. **Fungal insecticides** have been tried as pesticides since the late 1800's. A professor in our department, Dr. Stimac, is trying to develop a fungus that kills fire ants and can be placed as bait. The idea is that when the ant eats the bait, it picks up the fungus unknowingly and takes it back to the ant nest which will kill the rest of the colony. As the fungus germinates on the ants, it will take over their bodies sapping all their nutrients and eventually killing them. However, using fungus as an insecticide is difficult because it needs humidity and a certain temperature to germinate. Because of this, fungi are not widely used as insecticides.

USDA - Fire ant queen with *Metarhizium anisopliae* fungus

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Microbials Continued

Viruses are produced commercially to control some caterpillars. They are expensive, but are useful where poisonous insecticides cannot be used because of hazards to people or animals. The viruses used only infect arthropods.

Nematodes have been used to kill insects. A nematode is small, microscopic worm that lives in the soil. Some feed on the roots of plants, and some feed on insects. Nematodes are mass-produced and applied as an insecticide. They can be added to water and sprayed on turf. The nematodes enter through an insect's mouth or spiracle and release bacteria into the insect. The bacteria digest the insect's insides and the nematodes feed on this bacteria soup. Once the insect is dead, the nematodes crawl away to find another victim. One of the problems with using nematodes to kill insects is that they require a lot of moisture to survive. If the vacuum packed package of the little guys is left out in the sun, the nematodes will die before they ever get a chance to do their work.

Female nematodes

Nematodes crawling out of a mole cricket they have just killed.

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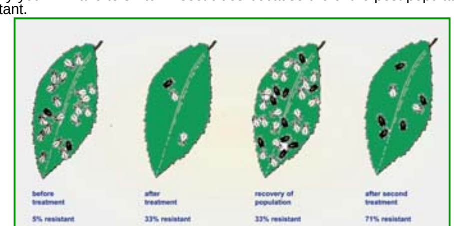
Pesticide Resistance

Unfortunately, insecticides can often create pesticide resistance. This topic has been eluded to, but now we will talk about it in more detail. The leaf is representative of a plant before insecticide treatment. Before treatment, 5% of the insects on the leaf are resistant, or will not be affected by the pesticide. It is common, maybe because of a mutation, that there will be a small number in the pest population that won't be affected by the insecticide. After the leaf is treated, the resistant insects survive along with a few of the non-resistant. The ones left on the leaf reproduce, and the resistant population percentage increases to 33%. You treat again and wipe out most of the non-resistant insects; this will increase your defiant population to 71% of the entire population! Each time you treat, you increase the percentage that are resistant and eventually you will have to switch insecticides because the entire pest population will be resistant.



Modified from Daly *et al*. 1998, p287

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Insecticide disadvantages

Insecticides have important disadvantages that must be addressed. Many of them can injure or kill humans when not applied properly or if an accident occurs. Although sometimes overlooked, wildlife and beneficial insects are also often affected by insecticide use. Insecticides can end up in rivers and streams killing fish and aquatic plants. Some insecticides build up in the soil like chlordane and DDT. As you learned in unit 12, pest resurgence, secondary pest outbreaks and pesticide resistance occurs if insecticides are not managed wisely.

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Insecticide advantages

Even though there are disadvantages, insecticides have a lot of important advantages. For one thing, they act very quickly which is important because a farmer can cure an insect problem before the crop is lost or fire ants can be managed before children are stung . Since there are so many insecticides out there, you can usually find an insecticide that suits your needs. Insecticides are also easy to apply. People with minimal experience or training can use them as long as the label directions are followed. Besides being easy to apply, they are usually relatively inexpensive to use compared with other pest management tactics. Lastly and most importantly, insecticides have saved thousands of lives by keeping down insect populations that spread diseases. Few of us would like to go back to the era when epidemics of typhus, malaria and yellow fever were common. When considering the alternatives, the benefits of insecticide use may outweigh the risks. Also, it is important for everyone to understand insecticide use so that people and the environment are protected.

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Learning Game Placeholder

Learning Game: Choices

Title: Review Quiz

Conclusion

Do you understand pesticide labeling? Do you know some modes of action of certain insecticides? What is tolerance? When can a farmer treat a field? Make sure that you are familiar with these topics and please review your lesson objectives before moving on to unit 14.

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