Spex Speaker

Issue 1 • Spring 2016

Speaking Spectroscopy Since 1954

Evolution of Pesticides

Human history is a tale of mankind trying to control their environment. One of the earliest attempts to master the environment was the control of food which led to the agricultural revolution. The rise of the agricultural controls increased the threat of the loss of livestock, harvests and livelihood through predation, pests and disease.

From ancient primitive methods, to more complex applications of farming techniques and tools, early pest controls evolved over the centuries at a slow pace. The Renaissance and following centuries saw the dawn of the age of scientific pursuits, which would eventually grow into all of our modern scientific disciplines.

In this issue of SpexSpeaker, we look at the history and development of pest controls and pesticides from the earliest recorded uses of pesticides to the dawn of the industrial and chemical revolution. This issue will also follow the changes over the past 80 years of our modern age of chemical pesticides which was jump started with a bang after World War II and continues to evolve into new and complex forms of pest controls from organic farming to genetically modified organisms.

History of Pest Control

Many people believe that pesticides and pest controls are a modern invention, in part due to the rise of chemistry in modern life. However, before the first farmer ever thought to plant the first seed, a battle had been raging for centuries between humans and pests. Visit our 'History of Pest Control' articles and then take a look at our 'History of Pest Control' timeline.

To Be Or Not To Be ... Organic

The phrase 'Organically Grown' can carry a lot of importance to modern consumers who actively pursue healthy food options. The organic seal can mean increased profits for farms and growers. The question remains in many people's mind — Exactly what does it mean to be called Organic? Take our Organically Grown quiz! Visit http://spexcsp.polldaddy.com/s/organicfood

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Modern pest management and control is an increasingly diverse science with thousands of different management strategies Synthetic chemical pesticides, which appeared in our arsenal around World War II, are a relatively new development in an epic battle against pests and parasites. Prior to the development of synthetic pesticides, there was a perpetual and slow battle of simple tools and natural chemicals against the incessant onslaught of pests.

As long as there have been producer/consumer, predator/prey or parasite/host relationships, there have been attempts at pest control. The need to control pests is not only a human pursuit; many animal and insect groups have pest control behaviors or mechanisms to reduce the effect of parasitism. Bird species have been observed to crush ants on the surface of their feathers to discourage other pests. Higher order animals, such as bears and primates, create pest deterrents from natural products such as roots and plants which then are applied to their coats.

Pest control needs increased as humanoids began gathering food stuffs and branched into agriculture. Attempts at pest control developed into management strategies. Pest control strategies are generally grouped into three basic categories: Biological controls, Mechanical or Physical controls and Chemical controls.

Biological pest control is a method of pest management which uses other living organisms to control the population of the predator or parasite. There is often an exploitation of an existing predator-prey, parasite-host or pathogenic relationship, which is then implemented and managed by humans.

There are three types of biological control strategies: Importation, Augmentation and Conservation.

Importation involves introducing either a native or non-native predator to an environment which previously did not contain that predator. In some cases, nonnative species of predators are used due to their predation on similar or related species. An example of this type of importation occurred when the Chinese wasp was imported into North America to control the borer beetle population.

Traditionally, biological controls had the benefit of being relatively inexpensive to implement, but carried the danger of adding an uncontrolled and invasive predator into an environment. Modern biological controls attempt to limit the environmental impact of the release to just the targeted prey species.

The importation of predators is most successful in the control of invasive or nonnative introduced species of parasites or pests.

Augmentation pest control involves increasing the population of a natural native predator population to control the prey species. An example of commonly used augmentation pest management with a native species is when gardeners purchase ladybugs, or other native predators, for release in their gardens. Even the domestication of dogs and cats can be considered, in terms of pest management, as an early implementation of biological controls to reduce pests and discourage other predators.

Spex Speaker

Issue 1 • Spring 2016

Speaking Spectroscopy Since 1954

Conservation pest control implements the advancement and propagation of the native predator species by increasing habitat or optimizing conditions for population growth of those predators, over the prey species. An example of one such management strategy is planting varieties of plants which encourage or host the predators.

Mechanical or Physical pest controls are one of the simplest forms of pest control. These include barriers (i.e. fences, traps, crop barriers, tilling); removal of pests (i.e. weeding, hand-removal); and environmental changes (i.e. fire, smoke, temperature control). The earliest methods of pest control, which persist into modern times, started with just the removal of the pests and using simple tools such as fire, smoke, mud, animal fats, and dung as deterrents or barriers to pests.

Chemical pest control methods encompass a large range of strategies from companion planting to chemical sterilization agents. The most common forms of chemical pest controls are pesticides.

Pesticides are chemical or biological agents which deter, discourage, incapacitate, or kill a pest. Early pesticides included the use of botanicals and simple elements or compounds. With scientific and cultural development, more pesticide agents were discovered and utilized. Early Romans discovered that crushed olive pits produced oil called Amurea which could kill pests.

The earliest documented chemical pesticide compounds were elements such as sulfur, heavy metals and salt. The use of elemental compounds for pest control started at the dawn of agriculture and has continued, in some cases, through the present day.

Elemental sulfur is believed to be one of the earliest chemical pesticides. Solutions of lime sulfur were used as dips to destroy lice. Sulfur dioxide was generated by burning elemental sulfur, and was used to inhibit the respiration of insects and other small pests. Acidic solutions of sulfur, applied as a liquid or powder, discouraged the growth of molds. Even today, the use of sulfur as a pesticide continues in modern pest management.

Sodium chloride, or Salt, was a very important commodity throughout history. Its value as a preservative was recognized early on, and it became a traded commodity and currency. Early Romans also discovered that salt could kill their enemies' crops and caused fields to go fallow, making it an early herbicide.

The heavy metal compounds were probably first used due to their high toxicity. Arsenic compounds (particularly Arsenic (III) oxides) were found to be highly toxic to insects, bacteria and fungi. Arsenic (III) oxides combine rapidly with thiols found in biologically important molecules such as cysteine and coenzyme A, and interrupt enzymatic activities including ATP production. Modern use of Arsenic compounds is still found in wood treatment and preservative processes, as well as some arsenate pesticides. Similarly to Arsenic compounds, Mercury compounds (primarily organic mercury compounds) also have a high affinity for thiols and can disrupt biological and enzymatic processes. Lead compounds act as a calcium analog and cause incomplete heme synthesis leading to anemia.

The benefit of these inorganic pesticides, at the time, was that they lasted a long time and were not easily degraded. Unfortunately, they often leached into the ecosystem, wreaking havoc on local wildlife and posing a health threat to its human inhabitants.

Spex Speaker
Issue 1 • Spring 2016
Speaking Spectroscopy Since 1954

During the course of the Middle Ages to the Victorian era, science moved from the realm of religion and magic to practical study. The disciplines of chemistry and biology were embraced, opening up studies into chemical compounds, reactions, and chemical synthesis. Pest control methods benefited from this pursuit of knowledge. Older methods of pest control were still in use (removal, barriers, botanicals, and elemental salts) but the mechanisms behind the efficacy of these methods were being discovered.

The nineteenth century was the dawn of the manufactured chemical pesticides. Chemicals were extracted from their botanical sources and purified in laboratories. By the 1800's, nicotine compounds were purified from tobacco, pyrethrums were extracted from flowers and rotenone isolated from roots. Cyanides were recognized as the toxic compounds in pits of some fruits.

During this time, chemical compounds were blended and produced for the purpose of pest control. In 1814, an inorganic compound of copper (II) acetoarsenite called "Paris Green" was introduced as a pigment. By 1867, Paris Green was widely sold as an insecticide and rodenticide. Paris Green paints were produced up until the 1960's.

Similarly, the Bordeaux Mixture was developed in the late 19th century to fight the Great French Wine Blight. The mixture of copper (II) sulfate and calcium hydroxide was designed to combat fungal and mildew infections in vineyards.

The Victorian era was the time when the traditional methods of pest control were formally investigated and put to the scientific method. All of the chemical compounds that were historically available in their botanical forms (i.e. rotenone in roots and pyrethrums in chrysanthemums) now were purified for commercial and home use. Elemental compounds were blended to create more efficient pesticides. The humble beginnings of simple, natural repellents and physical pest controls grew into chemical and agricultural industries seeking out new and improved methods.

The primitive tools now had scientific reasoning behind their efficacy and identifying chemical formulations, moving them from the realms of natural extracts to synthesized pesticides, signaling the rise of the chemical pesticide revolution.

Knowledge Base

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Speaking Spectroscopy Since 1954

Pest control, which had begun with simple tools and methods, was refined over centuries and completely reborn during World War II. The late 19th and early 20th century world of the first synthetic organic chemicals gave rise to the first modern synthetic pesticides in the form of organochloride compounds.

Many organochloride compounds, such as BHC and DDT, were first synthesized in the 1800's, but their properties as insecticides were not fully discovered and exploited until the late 1930's. BHC (Benzene hexachloride) was first produced by the English scientist, Michael Faraday, in 1825. Its properties as an insecticide were not identified until 1944. DDT (dichlorodiphenyltrichloroethane) was first prepared by Othmar Ziedler, an Austrian chemist, in 1825. The insecticidal properties of DDT were discovered by the Swiss chemist Paul Hermann Müller in 1939. This discovery led to Müller's Nobel Prize in 1948.

This organochloride class of pesticides grew out of those initial discoveries and, through the 1930's-1970's, developed into the range of organochloride pesticides known today. Primarily, there are two groups of organochloride pesticides: chlorinated alicyclic and cyclodiene compounds (Aldrin, Dieldrin, Endrin, Heptachlor, Chlordane, and Endosulfans), and the DDT compounds (DDD, DDE, etc). The chlorinated alicyclics and cyclodienes bind to active sites in nerve processes leading to depression of the central nervous system.

The DDT compounds work on the peripheral nervous system, interrupting the axon's ability to complete repolarization after activation and membrane depolarization.

The discovery of DDT for pesticide use was a huge boon to the war efforts. Prior to the discovery of DDT, pyrethrins were one of the major insecticides in use. However, pyrethrins were extracted from natural sources, primarily from flowers of the genus Chrysanthemum (Pyrethrum), supplies of which were limited and could not meet the demands of wartime needs.

DDT became the insecticide of choice for Allied Forces to control insects that were vectors for typhus, malaria and dengue fever.

At the time, DDT was seen as a broad spectrum insecticide with low toxicity to mammals. It was inexpensive to produce, easy to apply to large areas and was persistent, so that reapplication was generally not needed; DDT is insoluble in water and therefore was not washed away by weather. The compound appeared, at first, to be incredibly effective at eliminating the insect vectors of disease and was hailed as a wonder insecticide.

By 1945, DDT was made available for agricultural applications. By the 1950's the first signs of insect resistance to DDT began to appear. In 1962, Rachel Carson, a marine biologist and conservationist, published *Silent Spring*. Her book highlighted the detrimental effects of pesticides on the environment. The widespread popularity of her book started many grassroots organizations which called for more environmental protections and strict controls on pesticide use.

Part of the call to change was the reduction or removal of DDT, and many other pesticides developed in the 1940's-1960's, from the pest fighting arsenal.

DDT was in widespread use around the world until the 1970's and 1980's. The EPA canceled most uses of DDT by 1972. Many other countries shortly followed suit by removing DDT from most agricultural applications. In 2004, the Stockholm Convention outlawed many persistent organic pollutants (POPs) and restricted the use of DDT to vector control (primarily for malaria). Despite worldwide restrictions and bans on DDT, as of 2008, India and North Korea were still using DDT in agricultural applications. India is the sole country in the world still producing DDT.

Since the start of the production boom in the 1940's to present day, a huge catalog of thousands of insecticides, herbicides, and general pesticides was developed, including organochlorides (DDT, BHC), organophosphates (Parathion, Malathion, Azinophos methyl), phenoxyacetic acids (2,4-D, MCPA, 2,4,5-T), Captan, Carbamates (Aldicarb, Carbofuran, Oxamyl, Methomyl), neonicotinoids (Imidacloprid, Acetamiprid, Clothianidin, Nitenpyram), and Glysophates.

The neonicotinoids are neuro-active insecticides, similar to nicotine compounds, that were developed in the 1980's and 1990's. Of all the neonicotinoids, Imidacloprid has become one of the most abundantly used insecticides in the world. Patented in 1988 and registered with the EPA in 1994 by Bayer Crop Science, Imidacloprid works by disrupting the transmission of nerve impulses in insects by binding to an insect's nicotinic acetylcholine receptors, resulting in paralysis and death of the insect. Imidacloprid is highly toxic to insects and other arthropods, including marine invertebrates. It is considered to be moderately toxic to mammals, if ingested at high dosages.

The acute toxicity and environmental fate of Imidacloprid and other neonicotinoid pesticides have been greatly debated since their adaptation in the 1990's. Many studies question the persistence of neonicotinoids in water supplies and the ecological impacts to other environmentally and economically important arthropods. Studies published within the last two decades have linked bee colony collapse disorders with Imidacloprid and other similar pesticides. The most toxic pesticide in the world today for honey bees (Genus Apis) is also the most commonly used insecticide in the world, Imidacloprid.

If Imidacloprid is the most widely used insecticide in the world, Glyphosate is the most widely used herbicide in the world. Glysophate was developed by a Monsanto chemist, John E. Franz, in 1970. Roundup (as it was trademarked) quickly became one of the most popular herbicides in the world by both agricultural enterprises and home users. The mode of action for Glyphosate is to inhibit a plant enzyme which is part of the synthesis of aromatic amino acids. The inhibition of the amino acid production affects primarily the growing regions of the plants, killing plants in their growth cycle but not in their seed stage.

In 1994, the Roundup Ready Soybean was commercially approved in the United States. This genetically engineered soybean was created to be resistant to glyphosate. These types of crops allowed for the use of glyphosate to control other pest plants without endangering the crop. The list of glyphosate resistant crops has grown since the introduction of the Roundup Ready Soybean to include: corn, canola, alfalfa, cotton, and wheat.

Early genetic manipulation of plants and animals can be seen throughout history as selective breeding and pollination techniques were employed to produce hardier and more disease resistant plants and livestock. The discovery of specific DNA sequences, which could be transferred from one organism to another, has only occurred within the last few decades. In 1983, a tobacco plant resistant to antibiotics became the first transgenic plant. Cotton followed in the 1990's, and then came the 'Round-Up-Ready' Soybean. Genetically modified organisms (GMOs) have become widely used in the United States since their initial introduction in the 1990's. Genetically modified crops are grown by millions of farmers in dozens of countries. The predominant modified crops are soybeans, corn or maize, cotton, and canola.

As of 2010, 93% of soybeans, 78% of cotton, and 70% of corn were herbicide-resistant GMOs. The United States is one of the leading proponents for research into GMOs and surpasses most other countries, growing 59% of the world's GMO crops. The success of GMOs around the world has been mixed. Many European nations have experienced protests over GMOs and their safety. Most of the controversy surrounds the actual process of altering the genetic structure of plants and whether or not those plants should require labeling. The overall, general scientific opinion weighs in favor of the safety of GMO crops.

GMO labeling is required in many countries but not in the United States. Scientists and economists argue that the potential benefits of GMO crop include reduction of the use of pesticides and other hazardous pollutants and the increase in the nutritional value and production of agricultural products. Opponents of GMOs claim that all the latent risks have not been adequately identified, especially the potential long-term impact on human health and the environment.

The issue is not if genetically modified organisms should be used as a pest control strategy. The truth is that genetic modification has become the newest tool in the arsenal of pest management, and it will be up to the future to decide if the history of this pest management strategy goes the same way as heavy metal pesticides and DDT or if it will become the ultimate response to pest control.

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