Pesticides

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Abstract

Common pesticides such as DDT, microbial pesticides, oils, soaps, sulfur, pyrethrin, and synthetic pesticides are described. Included under the heading of pesticides are herbicides, insecticides, and others. In spite of all the control efforts, pests annually destroy about 35% of all crops produced worldwide. Even after harvesting, insects, microorganisms, rodents, and birds inflict additional 10 to 20 percent loss, making the total destruction to about 40 or 50%. Researchers aim to reduce this loss by improving pest control. Pest control techniques that use physical methods and biological mechanisms are mentioned. All modern farming operations involve chemical pesticides. Environment concerns induced alternative forms of pest control, like crop rotation and control via organisms that damage or kill pests while leaving crops unharmed. Scientists genetically engineer crops to enhance resistantance to troublesome pests. A discussion on their proper use and misuse follows. Misuse could be very dangerous to human beings and the environment.

***Keywords**: DDT, global distillation, insecticides, microbial pesticides, pesticides, pyrethrin, rodenticides, Silent Spring, soaps, sulfur, synthetic pesticides.*

1. Introduction

Pests are undesired living organisms that damage crops, humans or animals. Insects, mice, unwanted plants such as weed or microorganisms such as bacteria and viruses are some examples. Any substance or mixtures developed for preventing, destroying, repelling or mitigating any pest are pesticides.

Many people, including householders and industrialists, use thousands of peticides. Although some pesticides are harmful to environment and users, they are beneficial in many ways. Pesticides enable people to take care of their lands and crops, and prevent vectors from spreading disease.

Reduction to acceptable levels of insect pests, plant pathogens, and weed populations is the objective of a wide range of environmental interventions. These are pest controls. Specific control techniques include chemical, physical, and biological mechanisms. Pests destroy about 35 percent of all crops worldwide annually in spite of all the control efforts. Even after harvesting, insects, microorganisms, rodents, and birds inflict a further 10 to 20 percent loss, making the total destruction to about 40 or 50 percent. Researchers seek to reduce this loss by improving pest control. (Debach and Rosen 1998).

It is hoped that integrated pest management (IPM) using alternative tools together with pesticides, will reduce reliance on conventional pesticides. An assessment (US OTA 2005) examines biologically based tools that influence effective IPM. Technologies like enhanced biological pest control by natural predators and parasites; including commercial microbial formulations are mentioned.

2. Common Pesticides

DDT, Microbial Pesticides, Oils, Soaps, Sulfur, Pyrethrin, and Synthetic Pesticides, are examples of some common pesticides (Pimentel 1990; Pimentel and Lehman 1993).

2.1 DDT (Wikipedia 2010)

Dichlorodiphenyltrichloroethane, DDT whose chemical structure is shown in Fig. 1, is a colorless chemical pesticide used to eradicate disease-carrying and crop-eating insects. First isolated in Germany in 1874, Swiss Nobel Prize-winning chemist Paul Müller recognized it as a potent nerve poison on insects, only in 1939.

DDT is an organochlorine structurally similar to methoxychlor, acaricide and dicofol insecticides. It is highly hydrophobic, colorless, crystalline and almost odorless. It is only very slightly soluble in polar solvents like water, but soluble in non-polar solvents like organic solvents, fats and oils. DDT is produced synthetically by reacting chloral (CCl_3CHO) with chlorobenzene (C_6H_5Cl) in the presence of sulfuric acid catalyst. DDT has been marketed under the following trade names Anofex, Cezarex, Chlorophenothane, Clofenotane, Dicophane, Dinocide, Gesarol, Guesapon, Guesarol, Gyron, Ixodex, Neocid, Neocidol, and Zerdane (WHO 1979).

Several closely related compounds are present in a mixture of commercial DDT. The *p,p'* isomer, shown in Fig. 1, is the major component (77%). The *o,p'* isomer, shown in Fig. 2, is also present (15%). Dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD) consists of the balance; and are the major metabolites and DDT environment breakdown products. "Total DDT" often means the sum of all DDT related compounds (*p,p*-DDT, *o,p*-DDT, DDE, and DDD) (WHO 1979).

DDT was used heavily during World War II for preinvasion spraying. DDT was disseminated in great quantities thereafter throughout the world to combat yellow fever, typhus, elephantiasis, and other insect-vectored diseases. In India, DDT reduced malaria from 75 million cases to fewer than 5 million cases in a decade. Crops and livestock sprayed with DDT sometimes doubled their yields. Extensive spraying via aircraft, called crop dusting, is shown in Figs. 3 and 4.

However, American marine biologist Rachel Carson's *Silent Spring* (Carson 1962) sounded an alarm. He believed that DDT, by entering the food chain and eventually concentrating in higher animals, caused reproductive dysfunctions, such as thin eggshells in some birds (Holm *et al.* 2006).

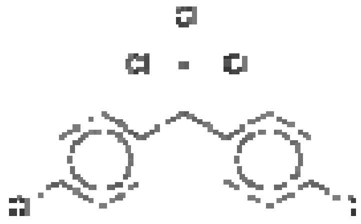

Fig. 1. *p, p'* - DDT.

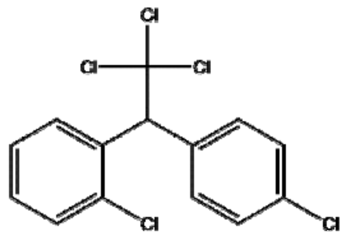

Fig. 2. *o, p'* - DDT.

Fig. 3. Crop dusting.

Fig. 4. Multiple crop dusting.

Moreover, some insect pests gradually developed DDT-resistant strains. These populations grew unchecked while natural predators, such as wasps, were eradicated by spraying. In 1972, DDT was banned in the USA except for use in extreme health emergencies. Many other nations have also banned it or placed it under strict control.

Most developed countries banned agricultural use of DDT in the 1970s and 1980s. Hungary was the first to ban it in 1968, followed by Norway and Sweden in 1970, and the USA in 1972. UK did not ban it until 1984. The use of DDT in vector control is still allowed. However, less persistent alternative insecticides have mostly replaced it.

DDT is a persistent organic pollutant and is extremely hydrophobic. Soils absorb it strongly. Its soil halflife can vary between 22 days to 30 years, depending on environmental conditions. Runoff, volatilization, photolysis and aerobic and anaerobic biodegradation are some loss paths. In aquatic ecosystems, organisms and soil absorb it quickly or it evaporates fast. Only minimal DDT is left in the water.

Marine algae (seaweeds) are effective bioremediation agents and can reduce the DDT contaminated soil toxicity by up to 80% in six weeks (Kantachote *et al.* 2004).

In 2004, The Stockholm Convention outlawed several persistent organic pollutants, including DDT, which was restricted to vector control. More than 160 countries ratified the convention. Most environmental groups endorsed it. The use of DDT in public health was exempted until alternatives are developed. This was in recognition that a total ban of DDT in many malaria-prone countries is unfeasible now. There are few affordable or effective alternatives. However, agricultural use of DDT, continues in India North Korea, and possibly elsewhere. 4-5,000 tons of DDT are used annually for vector control.

The Secretariat of the Stockholm Convention (van den Berg 2008) describes the current global status of DDT in a report. Rise of DDT levels in vegetables and fruits above the MPL (maximum permissible levels) is currently observed in India (Bhosale 2009).

In addition to insects, DDT is toxic to a wide range of animals. Aquatic life, including crayfish, daphnids, sea shrimp and many species of fish are susceptible. It is less toxic to mammals but cats are very susceptible, DDT together with its breakdown products migrates from the world's warmer regions to the Arctic: *global distillation* via the *grasshopper effect*. They accumulate in the region's food web (Environment Canada 1998).

A recent publication discusses human health consequences of DDT usage (Eskenazi *et al.* 2009). DDT is an endocrine disruptor and is suspected to be carcinogenic.

Genotoxicity and endocrine disruption are potential mechanisms of DDT on humans. DDT induced genotoxicity may be direct (Cohn *et al.* 2007) or may induce enzymes that produce other genotoxic intermediates and DNA adducts (Cohn *et al.* 2007).

2.2 Microbial Insecticides (Weinzierl 1996)

Microscopic living organisms, such as viruses, bacteria, fungi, protozoa, or nematodes form common microbial insecticides. They are "unconventional" insecticides but conventional ways, such as sprays, dusts, or granules can be used. Being essentially nontoxic, they do not threaten wildlife, humans, and other organisms unrelated to the target insect. In fact, application on harvest ready fruit or vegetable is possible. "Biologically based technologies have penetrated most major applications of pest control and are the methods of choice for such widespread pests" (US OTA 2005).

Most microbial insecticides are toxic to a single species or group of insects, so you can often target a pest without the risk of killing beneficial insects in the process. In addition, most microbial insecticides can be used in conjunction with conventional insecticides.

Sometimes, the microorganisms in the products become established in an insect population. This provides control for several weeks or seasons.

Heat, drying out, or exposure to sunlight tends to reduce the effectiveness of many microbial insecticides types. Proper timing and application are especially important in such cases (Weinzierl 1996).

Bt (Bacillus thuringiensis) is the most popular microbial pathogen. It paralyzes and destroys the stomach cells of insects that consume it. Once a Bt-coated leaf is eaten, insects stop feeding, and die within several days. Because Bt must be ingested to be effective, it is more selective than sprays that simply kill on contact - and thus is less likely to perturb the insect balance. The type of Bt most commonly sold kills many leaf-eating caterpillars, including precursors of butterflies. There are special strains of Bt aimed at specific pests. For example, Bt tenebrionis is effective against Colorado potato beetle larvae (Schultz 1994).

Viruses also have to be eaten by the insect. Viruses often cause outbreaks of natural diseases. The development of virus-based insecticides has been limited, unlike bacterial insecticides. Some important pests targeted by viral insectides include the gypsy moth, pine sawflies, and the codling moth.

Like viruses, fungi create natural epidemics. This often kills a high percentage of the insect population. Of the few fungal insecticides available in the United States, is the Bio-Path cockroach control chamber where a fungus is the active ingredient.

A wide range of insects is infected by protozoan pathogens. Most have chronic, debilitating effects on pests. Some can kill insects rapidly. Usually protozoan infections shorten an insect’s life span, which result in less feeding, with consequent reduction in the number of offspring.

Nematodes are multicellular roundworms and are technically not microbial agents. However, their size being nearly microscopic, they are used like true microbial insecticides. More than four hundred insect species, including numerous beetles, fly larvae, and caterpillars are affected by nematodes, as evidenced by laboratory or field applications (Weinzierl 1996).

2.3 Oils (Yardener 2009a)

Oils serve several purposes and come in two weights. The heavier traditional heavy horticultural spray oils have a viscosity of 100 to 200, and are called heavy horticultural oil, volk oil or dormant oil. Indiscriminate use on plant foliage can clog the pores of leaves and buds. This cuts off respiration and kills the plant.

It is used as a preventive spray on fruit trees in early spring or late winter (before foliage appears) to kill certain disease spores as well as eggs and dormant stages of some pests. It cannot be used after leaves emerge, since it will scald foliage. Some manufacturers combine heavy horticultural oil with lime sulfur, and market it as "dormant spray".

The lighter oil, also called summer oil is a very effective insect control. It can be used on foliage without harming trees even in summer. This "superior" horticultural spray oil is lighter and less viscous (60 to 70) than heavy oil and thus evaporates much more quickly.

Unlike heavy horticultural oil, it generally does not scald foliage. It can sometimes interfere with transpiration. It is advisable to spray just one branch and watch it for signs of wilting before treating the entire plant. Summer oil smothers both soft-bodied and hard-bodied insects when applied directly to them. It can also prevent rust and mildew spores from taking hold.

2.4 Botanical Insecticides (Weinzierl 1996)

Botanical insecticides are often called “botanicals.” They are naturally occurring insecticides derived from plants. They are readily degraded by sunlight, air, and moisture. They are breaken down into less toxic or nontoxic compounds. Hence, they pose less risk to nontarget organisms. Precise application timing is required. If additional damage is observed, frequent applications may be needed.

Most botanicals do not damage plants, as they are moderate in mammal toxicity, but exceptions exist. For example, nicotine preparations can cause death.

The root of tropical legumes is a source for rotenone, which is specifically effective against leaf-feeding beetles and certain caterpillar pests. Rotenone is as toxic as the common synthetic insecticides carbaryl and diazinon. Longer than other botanical insecticides, rotenone persists for a few days on treated foliage.

In jungles, rain forests, and other wilderness areas around the world, researchers have found plants whose natural toxins will kill pests. One of the most effective of these is pyrethrin, derived from a daisy-flowered plant, Tanacetum cinerariifolium (formerly Chrysanthemum cinerariifolium). It is used on animals to control fleas, flies, and mosquitoes. Some indoor household sprays, aerosols, and “bombs” contain pyrethrin.

Pyrethrin kills many soft-bodied and some hard-bodied insects, have a low level of toxicity, and dissipate rapidly. It kills beneficial insects as well as pests. Some pyrethrin-based products are combined with other more toxic pesticides. For example, pyrethrins are combined with rotenone and ryania or copper for general use in gardens. Thus reading labels closely is advisable.

2.5 Insecticidal Soaps (Weinzierl 1996)

Insecticidal soaps are soaps that have been formulated specifically for their ability to control insects. As with botanicals, they are readily degraded by sunlight, air, and moisture; and are low to moderate in toxicity to mammals, but there are exceptions.

Soaps are especially effective in killing soft-bodied insects, such as aphids, thrips, scales, whiteflies, leafhopper nymphs, and mites. When the spray hits them, it penetrates their bodies and causes cell membranes to burst. Soaps are effective only by direct contact with sprays before they dry up. Soaps are particularly useful for protecting ornamental plants and houseplants. Nevertheless, it must be noted that soaps can be toxic to some plants.

Unfortunately, soaps kill not only pests but beneficial insects as well - including bees. However, the application of soap spray may be timed to minimize hazard to bees. Bees typically return to their hives in late afternoons, so spraying may be done in early evenings so that by morning the soap will have dissipated. Spraying shall be limited only to those plants exhibiting symptoms.

Some soap is effective in killing weeds. Those marketed as weed killers have a higher proportion of soap to water than those sold to kill insects. Preparations of soap sprays using soft water are more effective than those using hard water: soft water produces a sudsier spray that has better accessibility to all plant surfaces.

2.6 Sulfur

Sulfur has been known and used as a pesticide since very early times, and has been registered for pesticidal use in the United States since the 1920s (US EPA 1991). It was first used around 1880 (Thomson 1993). Currently, sulfur is registered in the USA by EPA for use as an insecticide, fungicide, and rodenticide on several hundred food and feed crop, ornamental, turf and residential sites. It is also used as a fertilizer or soil amendment for reclaiming alkaline soils. Sulfur is applied in dust, granular or liquid form, and is an active ingredient in nearly 300 registered pesticide products (US EPA 1991).

In the finely ground mineral it is effective on a variety of flowers, fruits, and vegetables in preventing powdery mildew, rust, and black spot. It can also control mites and several insect pests. It is toxic to a few plants, including cucumber, raspberry, and apricot, so checking the label carefully to make sure it is safe for the intended target is essential. Unlike lime sulfur, elemental sulfur cannot be used in conjunction with oils: the combination will kill plants. A one-month wait before applying sulfur to any plant that has been treated with an oil spray is mandatory. It must be kept in mind that sulfur is sometimes combined with other pesticides, many of which have higher toxicity levels. The signal word will give you a clue; sulfur rates "caution," but combination products of higher toxicity will be labeled "warning." Lime sulfur (calcium polysulfide) is effective against the diseases and pests noted above for elemental sulfur. It can be purchased separately or in combination with horticultural oil (as dormant spray). It is caustic and the law requires protective clothing, goggles, and a breathing mask.

2.7 Synthetic Pesticides (Yardener 2009b).

Synthetic pesticides, of which DDT is well-known and most controversial, are the last resort solution, to be used only after all other, less toxic approaches to coping with a particular pest, disease, or weed have been exhausted. Despite their higher toxicity, such products sometimes offer the best—or only way to save a precious plant from insect attack or halt a rampant disease or weed infestation.

2.8 Synthetic Insecticides

Synthetic chemicals created from other chemicals are used to manufacture synthetic insecticides, a class of synthetic pesticides. They normally represent improved copies of a basic natural insecticide. A popular type of synthetic insecticides is called "pyrethroids". They are chemically similar to natural pyrethrum, derived from chrysanthemum flowers, but are modified to improve persistence and insecticidal activity. Pyrethroids act on contact with the stomach and are very broad-spectrum. They are more effective than natural pyrethrins and have less mammal toxicity. Permethrin, resmethrin, and deltamethrin are some well-known pyrethroids.

Normally synthetic insecticides kill pests on contact or through direct ingestion. Acephate, however, is a systemic pesticide. When applied to a plant, it is absorbed by the foliage or roots, and any pest that ingest the plant's juices or chew its leaves is killed. Systemic insecticides must never be applied to edible crops.

3. Use of Pesticides

Most farmers use agricultural pesticides, inclusive of herbicides, insecticides, rodenticides, fungicides, and others.

Chemical pesticides are used in nearly all modern farming operations. However, increasing concern over the harmful effects that pesticides may have on the environment has induced resort to alternative pest controls

For example, farmers use crop rotation to prevent pests that feed on a certain crop from becoming entrenched and infesting the field. In addition, certain pests are controlled by introducing an organism that damage or kill the pests, but leave the crops unharmed (Debach and Rosen 1991). Finally, scientists genetically engineer crops to be more resistant to troublesome pests (Winston 1997)

Before the pesticide product is used, the pest must be identified first. Then it should be handled with an experienced person who knows how to use it safely. The labels on the product tell the type of pest it controls, and indicate the treatment location (where it is to be used i.e., outdoor, indoor, etc.)

The following guidelines must be followed when using pesticides:

- Carefully read all label instructions and precautions before using pesticides.Do not drink, eat or smoke while applying.
- Persons and pets should vacate the area during treatment. Remove aquaria.

After handling of pesticides, persons should wash their hands thoroughly. The surface should not be touched until it has dried completely. Empty pesticides containers are wrapped and disposed in household garbage. Unused and partially used pesticides products should be disposed of at provincially or municipally designated household hazardous waste disposal sites.

4. Misuse of Pesticides (Dinham 1973)

If pesticides were misused, it could be very dangerous to human beings and the enviroment. Pesticides could be misused in numerous ways, as follows:

- Failing to follow the label or permit instructions. This would lead to applying the wrong pesticides on a pest and this might lead to another effect.
- Using pesticides in a way that is likely to injure people or damage property.
- Harming a non-target plant or animal.
- Using an unregistered pesticide or possessing one. This product might be illegal and harmful to the environment.
- Disposing of a pesticide or its container illegally, e.g., pouring pesticide waste down a drain.
- Spraying pesticides from an aircraft without a relevant EPA license.
- Spraying pesticide from an aircraft, within 150 meters of a residence, school or other public place (excluding roads,

traveling stock reserves and State Rail land) without the written consent of the occupier.

5. Dangers (Dinham 1973)

All pesticides must be biologically active, or toxic, to be effective against the pests they are intended to control. Because pesticides are toxic, they are also potentially hazardous to humans and animals. It is important for those who use pesticides to know the relative toxicity and the potential health effects of the products they handle.

Toxicity is a measure of the capacity of a pesticide to cause injury; it is a property of the chemical itself. Pesticide toxicity is determined by testing animals (usually rats, mice, rabbits, and dogs) with different dosages of the active ingredient and to each of its formulated products.

Hazard is the potential for injury, or the degree of danger involved in pesticide use. Hazard depends on toxicity and exposure. Careful handling of the pesticide and using personal protective clothing and equipment can minimize or eliminate exposure. This consequently reduces the risk or hazard.

Pesticides have many entry routes, which may be classified into three major entry ports. The first is the mouth – entry by swallowing or eating. The second is the nose - entry by breathing mist, dust, fumes or smoke. The third is the skin - entry by dermal contact (absorption through the skin).

Reactions and symptoms of pesticide poisoning may appear within minutes of exposure or may take hours or days. Induction time is dependent on factors such as; type, strength, toxicity level, amount received, exposure time, entry route, etc. In excessive amounts, any pesticide can be poisonous or toxic; and result in injuries to humans and animals. Pesticides can also cause skin or eye damage (topical effects) and can induce allergic responses.

The symptoms of pesticide poisoning can range from a mild skin irritation to coma or even death. It is important that pesticide users and handlers learn to recognize the common signs and symptoms of pesticide poisoning.

The effects, or symptoms, of pesticide poisoning can be topical or systemic. Topical effects generally appear at the contact site. Topical effects can be due to the chemical irritant properties in a pesticide formulation (an active or inert ingredient), or an allergic response. The most common topical effect associated with pesticide exposure is dermatitis, or inflammation of the skin. Symptoms of an allergic reaction range from reddening and itching of the eyes and skin to respiratory discomfort often like asthmatics.

Systemic effects are quite different, occurring away from the original contact point (because pesticide absorption and distribution by the body). Systemic effects include nausea, vomiting, fatigue, headache, and intestinal disorders.

Different classes of chemicals cause different types of symptoms. Individual sensitivity varies. A dose that causes severe illness in some people may appear harmless to others. Early symptom recognition and rapid appropriate response is required.

However, it must be remembered that common illnesses like flu, heat exhaustion or heat stroke, pneumonia, asthma, respiratory and intestinal infections, and even a hangover can create similar symptoms. Some individuals are allergic to pesticides or the ingredients.

6. Conclusion

Pesticides are chemical poisons, designed to kill plants and animals such as insects (insecticides), weeds (herbicides), rodents (rodenticides), and mold or fungus (fungicides). They include active ingredients (those intended to kill the target) and inert ingredients, which are often “not inert” at all.

Pesticides can be absorbed through the skin, swallowed or inhaled. Pesticides often stray from their point of application to settle on neighbors' properties, clotheslines, pools, toys and furniture. Children and pets often track pesticide residues into the house. Studies show that only 5% of pesticides reach target weeds. The rest runs off into water or dissipates in the air. Drift from landscaping can range from 12 feet to 14.5 miles. More effects that are serious appear to be produced by direct inhalation of pesticide sprays than by absorption or ingestion of toxins.

Bacterial Pesticides, Oils, Soaps, Sulfur, Pyrethrin, Synthetic Pesticides are some common pesticides that are featured here. There are many advantages for using pesticides, but the misuse of pesticides can harm people and animals. Nowadays, scientists are searching new pesticides to help farmers to produce good quality food. Pesticides can also have good and bad bacterias that can help flowers blossom. Moreover, they can also help fruits to grow faster.

Pesticides not only help farmers but they also help households in many ways. For example, because of pesticides people can live hygienicly without the disturbance of insects such as termites, cockcroaches and mice. Lastly, pesticides can help people in good ways and the misuse of these can lead to many unwanted consequences. Intelligent, safe usage is advocated.

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8. References

Bhosale, J. 2009. Pesticide level in veggies, fruits rises. The Economic Times, 10 June 2009. Available: http://economictimes.indiatimes.com/Markets/Pesticide-level-in-veggies-fruits-rises/articleshow/4637527.cms.

Carson, R. 1962. Silent spring. (Houghton Mifflin, Boston, MA, USA [2002. Anniversary Edition, Mariner Books, New York, NY, USA].

Cohn, B.A.; Wolff, M.S.; Cirillo, P.M.; and Sholtz, R.I. 2007. DDT and breast cancer in young women: New data on the significance of age at exposure. Environmental Health Perspectives 115(10): 1406-14.

Debach, P.; and Rosen, D. 1991. Biological control by natural enemies. Cambridge University Press, Cambridge, UK.

Debach, P.; and Rosen, D. 1998. Pesticides and pest control. *In*: Academic American Encyclopedia, Grolier, Inc., Danbury, CT, USA.

Dinham, B. 1993. The pesticide hazard: A global health and environmental audit. Zed Books, London, UK.

Environment Canada. 1998. The grasshopper effect and tracking hazardous air pollutants. The Science and the Environment Bulletin, Environment Canada, Gatineau, Quebec, Canada, May/June.

Eskenazi, B.; Chevrier, J.; Rosas, L.G.; Anderson, H.A.; Bornman, M.S.; Bouwman, H.; Chen, A.; Cohn, B.A.; de Jager, C.; Henshel, D.S.; Leipzig, F.; Leipzig, J.S.; Lorenz, E.C.; Snedeker, S.M.; and Stapleton, D. 2009. The Pine River statement: Human health consequences of DDT use. Environmental Health Perspectives 117(9):1,359-67.

Holm, L.; Blomqvist, A.; Brandt, I.; Brunström, B.; Ridderstråle, Y.; and Berg, C. 2006. Embryonic exposure to *o,p'*-DDT causes eggshell thinning and altered shell gland carbonic anhydrase expression in the domestic hen. Environmental Toxicology and Chemistry 25(10): 2,787-93, October.

Kantachote, D.; Naidu, R.; Williams, B.; McClure, N.; Megharaj, M.; and Singleton, I. 2004. Bioremediation of DDT-contaminated soil: enhancement by seaweed addition. Journal of Chemical Technology & Biotechnology 79(6): 632-8, June.

Pimentel, D. 1990. CRC handbook of pest management in agriculture. vol. 1, CRC Press, New Yolrk, NY, USA.

Pimentel, D.; and Lehman, H. (eds.). 1993. The pesticide question: Environment, economics and ethics. Springer, Berlin, Germany.

Schultz, W. (ed.). 1994. Natural insect control. Brooklyn Botanic Garden, Brooklyn, NY, USA.

Thomson, W.T. 1993. Agricultural chemicals. Book II: Herbicides. Thomson Publications, Fresno, CA, USA.

US EPA. 1991. Reregistration eligibility document facts: sulfur. US Environmental Protection Agency, Pesticides and Toxic Substances, Washington, DC, USA, May.

US OTA. 2005. Biologically based technologies for pest control. US Office of Technology Assessment. University Press of the Pacific, Honolulu, Hawaii, USA.

van den Berg, H. 2008. Global status of DDT and its alternatives for use in vector control to prevent disease. Stockholm Convention on Persistent Organic Pollutants, United Nations Environment Programme (UNEP), Stockholm, Sweden, 23 October 2008.

Weinzierl, R.A. 1996. 57 ways to protect your home environment (and yourself), Cooperative Extension Service, University of Illinois at Urbana-Champaign, Urbana, IL, USA.

WHO. 1979. Environmental health criteria 9: DDT and its derivatives. World Health Organization, Geneva, Switzerland. Available: http://www.inchem.org/documents/ehc/ehc/ehc009.htm.

Wikipedia. 2010. DDT. Available: http://en.wikipedia.org/wiki/DDT.

Winston, M.L. 1997. Nature wars: People vs. pests, Havard University Press, Cambridge, MA, USA.

Yardener. 2009a. Horictulture oil. Yardener, San Francisco, CA, USA. Available: http://yardener.com/YardenersToolshedofProducts/PestInsectControlProducts/InsecticidesToKillInsects/TipsonUsingNaturalInsecticides/UsingHorticulturalOil.

Yardener. 2009b. Synthetic insecticides. Yardener, San Francisco, CA, USA. Available: http://yardener.com/YardenersToolshedofProducts/pestinsectControlProducts/InsecticidesToKillInsects/SyntheticInsecticides.