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Pesticides, People, and the Environment: A Complex Relationship

Roxanne Greitz Miller
Chapman University, rgmiller@chapman.edu

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Pesticides, people, and the environment: A complex relationship

If you were to ask your students what they do when they find ants or other insects in their homes, their most common response would probably be, "Get the bug spray!" Because students are not only being exposed to pesticides but are also developing patterns of behavior likely to continue throughout their lives, discussions about pesticides, the controversies surrounding their use, and pesticide safety are important in the middle grades.

Pesticide primer

A *pesticide* is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. The term *pesticide* is not interchangeable with *insecticide*, which refers only to chemicals that act on insects. Pesticides include herbicides, fungicides, rodenticides, algicides, and cleaning chemicals or disinfectants designed to kill microorganisms such as bacteria, viruses, and prions.

Many household products are considered pesticides, including

- insect sprays and baits;
- insect repellents for personal use;
- rat and other rodent poisons;
- flea and tick sprays, collars, and powders;
- kitchen, laundry, and bath disinfectants and sanitizers;
- products that kill mold and mildew;
- lawn and garden products that kill weeds or undesirable growth; and
- some swimming pool chemicals.

Pest control devices that trap, destroy, or repel any pest without the use of chemicals as listed above, such as black light traps or sonic devices, are not considered pesticides. Additionally, biological organisms that may be used to control pests, such as ladybugs, birds, or phorid flies, are generally not considered pesticides and are not regulated by the Environmental Protection Agency.

Why do we use pesticides?

Modern pesticide use has both a commercial and personal causation. Commercially, farmers use pesticides to provide consumers with a plentiful food supply, and one that is generally considered in "perfect" condition (e.g., fruit that is free of blemishes, marks, fungi, mold, or insects). Individuals and government health agencies generally use pesticides either to protect human or animal health (e.g., controlling mosquitoes or other biting insects that may spread disease such as West Nile virus or malaria). Individuals may also use pesticides to control nuisances such as nonbiting insects in their home, or for cosmetic reasons, to control weeds or other unwanted pests (such as cinch bugs that destroy grasses) in their lawns and gardens.

The evolution of pesticides

It's important to understand why pesticides were invented, and why they became so important by the mid-20th century. Prior to the 1930s, farmers traditionally planted a variety of different crops on their farms (such as one field of wheat, one of corn, and one of oats). Today, however, farmers try to maximize their efficiency and revenue by specializing in one crop, such as corn. As a result, insects with a taste for corn are treated to entire regions covered by the crop.

Prior to 1940, a number of basic chemical compounds such as sulfur, arsenic, and copper were used as pesticides with limited success despite their high toxicity. DDT (dichlorodiphenyltrichloroethane)—the pesticide invented in 1939 by Swiss chemist Paul Müller to combat the Colorado potato beetle ravaging potato crops in the United States and Europe—was the first carbon-based chemical insecticide and was highly effective on a number of insect species. DDT profoundly changed the lives of farmers and individual people worldwide, and is credited with saving millions of human lives by killing typhus-carrying lice and malaria-carrying mosquitoes. The pesticide was so effective that it earned Müller a Nobel Prize. The mid-century modernization of farming occurring after World War II and the concurrent efforts to develop more organic pesticides worked hand-in-hand to increase crop yield and provide a wide variety of produce on-demand at a reasonable cost for consumers in industrialized countries.

DDT's honeymoon period—a term that could be applied to all pesticide use—continued until the publication of *Silent Spring* by Rachel Carson in 1962. Its revelations about DDT's effects on wildlife prompted further testing and investigation, which led to a U.S. ban on DDT for agricultural use in 1972.

Roxanne Greitz Miller (rgmiller@chapman.edu) *is assistant professor of secondary and science education at Chapman University in Orange, California, and a former middle school and senior high school science teacher in the public schools of Florida.*

How pesticides work

Pesticides work physically, chemically, or biologically to interfere with pest organisms' metabolism or normal behavior. Most pesticides are lethal to target pests, either immediately upon exposure or within a short period of time thereafter.

Some pesticides, however, are not lethal to the target pest. These include

- repellents or attractants (such as personal insect repellents),
- sterilizing agents or growth regulators (which interfere with the reproductive ability of a pest),
- some defoliants (those that cause leaf drop without killing the plant), and
- some products that enhance the action of another pesticide without being particularly toxic themselves.

The method of application for pesticides is based upon both the nature of the pesticide and the type of environment in which the pesticide is being used. Common application methods include spraying, fumigating, and baiting. Many pesticides are *contact* pesticides, requiring absorption by the target pest to be effective.

Other pesticides are *systemic* in action. Systemic pesticides can be moved (translocated) from the site of application to another site within the organism they effect. For example, some insecticides are absorbed by foliage and translocated throughout the plant, where they kill chewing or sucking insects, and some nematicides are applied to the leaves of plants and are transferred to the roots to kill worms or caterpillars that are attacking the plant there. Similarly, blood anticoagulant rodenticides take effect once they have been transferred from the digestive system to the bloodstream of rats or mice.

Pesticide problems

Studies show that pesticides can have significant effects on nontarget organisms. The studies include organisms exposed (1) through normal daily activities (such as farm workers and persons living in farming communities), (2) unintentionally (such as animals that ingest pesticides/residues, or people who ingest pesticide residues in food or water), and (3) during scientific studies where animals and humans are intentionally exposed to pesticides and their responses monitored.

In humans, pesticides can enter the body through the lungs, digestive system, or skin. Depending on the pesticide, health effects can be immediate or they can occur after years of low-level exposure. The immediate health effects on people who are accidentally overexposed to pesticides may include skin and eye irritation, headaches, dizziness, blurred vision, nausea and vomiting, tiredness, changes in heart rate, muscle weakness or cramps, respiratory paralysis, mental confusion, and convulsions. Chronic low-level pesticide exposure can lead to cancer, nervous system disorders, liver and kidney damage, respiratory problems, and reproductive problems. Often pesticide-caused health problems do not become evident until years later, when it may be difficult to link to a specific chemical. Pesticides can also affect reproduction by causing miscarriage, stillbirth, birth defects, or acting as a mutagen.

Direct, unintentional contact with pesticides may also injure wildlife, livestock, pets, and nontarget plants. For example, herbicide drift from an intentional spraying can damage sensitive nearby plants, including crops, forests, or ornamental plantings. Pets, livestock, or people who are exposed to freshly sprayed fields (including residential lawns or sports fields) may develop acute reactions similar to those of humans listed previously, and possibly long-term effects with repeated exposure. Pesticide runoff or pesticide contamination in water environments may harm fish and other aquatic animals and plants in ponds, streams, and lakes. There are a number of examples of the negative effects of pesticide contamination available in print, media, and on the internet; the most famous of these explore DDT contamination and its environmental effects on egg-laying animal species whose shells are thinned due to exposure.

The movement of pesticide chemicals through the food chain is not widely understood by the general public; people often wonder how a pesticide applied to a plant can be found in high levels in an upper-level consumer that does not consume that plant as a food source. The answer lies in the processes of *bioaccumulation*, *bioconcentration*, and *biomagnification*.

Bioaccumulation refers to the buildup of a chemical compound in an organism as a result of uptake exceeding metabolization or elimination. Simply put, when an organism takes in a chemical faster than it is broken down, bioaccumulation occurs.

Bioconcentration is the specific bioaccumulation process in which the concentration of a chemical foreign to an organism becomes higher than the concentration in its environment. For fish and other aquatic animals, bioconcentration after uptake through the gills (or sometimes the skin) is usually the most significant bioaccumulation process.

Biomagnification describes a process that results in the accumulation of a chemical in an organism at levels higher than are found in its food. It occurs when a chemical becomes more and more concentrated as it moves up through a food chain. If each step in a food chain results in increased bioaccumulation, biomagnification can occur in an animal at the top of the food chain through its regular diet.

Biomagnification is illustrated by a study of DDT that showed where soil levels were 10 parts per million (ppm), DDT reached a concentration of 141 ppm in earthworms and 444 ppm in robins. Through biomagnification, the concentration of a chemical in the animal at the top of the food chain may be high enough to cause death or adverse effects on behavior, reproduction, or disease resistance and thus endanger that species, even when levels in the water, air, or soil are low. Fortunately, however, bioaccumulation does not always result in biomagnification.

Children and pesticide exposure

Because children are in a rapid stage of physical growth and development, they have the potential to suffer greater consequences than adults from exposure to any type of chemicals suspected or known to have detrimental effects on humans. Additionally, children consume more food in relation to their body mass than adults, which potentially increases the level of exposure to pesticide residues that may be found in food. Lastly, because childrens' typical diets include a disproportionate amount of single foods (such as apple products), if a child is ingesting a food that has pesticide residue, he or she may be consuming a much higher percentage of pesticide residue than an adult with a more varied diet.

Lifestyle issues also contribute to increasing children's exposure. Children are more likely to spend time playing in areas that may be sprayed with pesticides, such as grassy sports fields or on the floor. Outside play in areas where biting insects are prevalent may prompt use of insect repellents or insecticides on children or in their yards. Children's fears of insects may increase their likelihood, or their parents', of reaching for an insecticide rather than employing alternative, less toxic methods to remove unwanted insects from their surroundings. Because of this increased risk among children, there are many laws and policies that aim to reduce juvenile exposure to pesticides in places frequented by children, such as playgrounds, schools, and day-care centers.

Change, change, change

Over the past 30 years, pesticide use could be characterized by

- a decrease in the amounts of pesticides used agriculturally (farmers use about one-third less chemicals today than they did in 1983);
- an increase in the availability and awareness of biologically-based alternatives;
- the development of integrated pest management (IPM), in which a variety of methods are employed to control pests and the least-toxic methods are used first and their results evaluated before escalating to more toxic alternatives; and
- an increase in the public's awareness of the potential effects of pesticide use on all species in the environment.

However, despite an increase in public awareness of the risks to animals and people, there has also been an increase in the use of pesticides for cosmetic reasons (such as keeping a lawn weed-free) and convenience (avoiding nuisance insects such as ants). As teachers, we should make students aware of the environmental impact of pesticides used in and around the house so they can make informed decisions about their use.

We should also explain how they can reduce their exposure to pesticides. Students should be encouraged to

- thoroughly wash all fruits and vegetables,
- buy organic produce and/or meats certified to be free from pesticide exposure,
- grow their own vegetables,
- peel vegetables or remove the outer layer of leaves,
- cook vegetables, rather than eat them raw all of the time,
- trim visible fat from meats, as many pesticide chemical residues are fat-soluble,
- cook meat and chicken thoroughly,
- consume a variety of foods (including meat alternatives like legumes, tofu, nuts, and eggs),
- avoid playing in areas that have been recently sprayed or cleaned with compounds considered to be pesticides,
- wear long-sleeved or body-covering lightweight clothing rather than using insect repellants, and
- employ the safest and least toxic methods for pest removal (such as trapping insects, manually removing them from plants, or physically pulling weeds) before escalating to more toxic pesticides.

The delicate balance

The risk versus return of using pesticides to control agricultural pests is viewed by many to be low enough to continue their use if responsible practices designed to minimize exposure to nontarget organisms are employed. Persons who maintain this belief generally cite the demand for food supplies that are plentiful and reasonably priced as their primary motivations for use.

The U.S. ban on DDT provides a workable and understandable case of both sides of pesticide arguments to explore with students. As previously mentioned, DDT was invented for use as an agricultural pesticide. However, the 1972 ban was prompted by the subsequent effects of DDT on many species of wildlife, and the presumption based on animal test results (which are now heavily debated and widely rejected by some scientists) that humans would run a considerable health risk from DDT exposure.

What the U.S. ban did not consider was the potential effect on malaria-related illnesses and deaths, which had been practically eradicated in areas in which DDT was popularly used. While originally created for agricultural use, its effectiveness on a wide variety of insect species made DDT the pesticide of choice for combating diseases spread by biting insects. Since the ban on DDT, a rise in malaria deaths has been noted in many developing countries, even in those where DDT use is still permitted. Some scientists contend that the U.S. ban has led to decreased availability of DDT for the developing world, where approximately 300 million people contract malaria each year, with at least 1–2 million deaths. Alternative pesticides that we use in the United States (such as malathion) are not only less effective than small amounts of DDT, but also are much more costly to purchase and need to be applied more frequently, say DDT proponents. Supporters maintain that there are no results from studies of human exposure to DDT that indicate strong causal links between DDT exposure and human health risks. They also argue that the use of low levels of DDT should be permitted given the potential risks of malaria and other debilitating mosquito-spread illnesses such as yellow fever and Dengue fever.

Thus, this classic debate about pesticide use brings to the forefront a host of issues to be considered. Should people have the right to use potentially harmful compounds to assure an adequate and affordable food supply? Should there be a distinction between animal and human life when it comes to technology use? Should one nation's use of a pesticide be allowed if it affects the lives of people in other nations?

Student activities

The most important aspect of pesticide education is to inform students of the potential risks to themselves and to promote students' consideration of the consequences of their actions. A good place to start would be with a simple household hazardous waste survey (see *Science Scope*, April 2004, pp. 48–50, Farenga, Joyce, and Ness). Because the term *pesticide* encompasses many products that you might not normally think of as pesticides (such as bleach), the household hazardous waste survey can raise students' awareness of all of the chemical compounds in their homes that can be considered and used as pesticides. Then, alternatives to the use of more toxic pesticides—such as integrated pest management, biological alternatives, and organic farming—can be explored by student groups or through reports. In addition, students can construct their own action plans for pest management in their homes, which could include simple strategies such as keeping areas dry and food containers closed and using the least toxic pesticides available before considering stronger alternatives.

An interdisciplinary project between science and social studies would be to research some of the major disease outbreaks related to pests, such as plague, yellow fever, malaria, mosquito-borne encephalitis, West Nile virus, Dengue fever, Lyme disease, and lice-borne typhus. They could also research widespread crop failures (such as the Irish potato famine) and discuss how the world was affected by these disasters and how they may have been prevented or controlled if effective chemical agents were available.

Something that my middle level students have enjoyed is mounting public-awareness campaigns in our school. They created their own videos that were shown on the morning announcement broadcasts, wrote articles for the school newspaper, and made posters and presentations to other classes (and even the school administration) on topics we've studied. This could be done with pesticide awareness, and can even be taken to a higher level with the creation of a schoolwide pest management plan or team. Of course, no pest management plan involving students should be implemented without proper supervision and approval by the school's administration.

Finally, an exciting way to explore pesticides is to engage in a scenario or simulation activity. The National Institute of Environmental Health Sciences (NIEHS) has a series of simulations based on the fictional town of Hydroville. The first activity in the series simulates a pesticide spill and asks students to take on the roles of mechanical engineers, analytical chemists, soil scientists, environmental toxicologists, and regulatory compliance experts. They must work together to come up with a plan to remove the spilled liquid, evaluate the health risk to residents, and develop a proposal for complete cleanup of the site. An additional scenario, Spill Sleuths, appeared in *Science Scope's* February 2005 issue and includes mapping activities, town meetings, and other activities specifically for middle level students.

Closing thoughts

No matter the strategies or activities used, any study of pesticides must consider the varied points of view involved, and should encourage students to think before they act. Creating thoughtful, mindful students is essential not only in this arena, but for all complex topics in the science class and beyond.

Online resources (accessed September 1, 2005)

- Pesticides and food: What you and your family need to know—*www.epa.gov/pesticides/food*
- Allergy and Environmental Health Association—*www.aeha.ca/feb-28-05.htm*
- Pesticides backgrounder—*www.lehigh.edu/~kaf3/books/reporting/pesticid.html*
- Wessels living history farm—*www.livinghistoryfarm.org*
- American Council on Science and Health—*www.acsh.org/healthissues/newsID.442/healthissue_detail.asp*
- Natural Resources Defense Council—*www.nrdc.org/health/pesticides/hcarson.asp*
- Malaria Foundation International—*www.malaria.org/smithddt.html*
- NIEHS Pesticide Spill Simulation—*www-apps.niehs.nih.gov/outreach-education/Search/MatlDisplay.cfm?MatlNbr=655&Src=Subj&SrcValue=Science%20education*
- Extension Toxicology Network (EXTOXNET)—*http://extoxnet.orst.edu/tibs/bioaccum.htm*
- Australian Environmental Protection Agency—*www.epa.nsw.gov.au/envirom/pesthwwrk.htm*
- Pesticides in the environment—*http://pested.unl.edu/pat4.htm*
- Pesticide Action Network (Asia/Pacific)—*www.panap.net/faq.cfm?category=Health*