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LESSON:

Is Organic Food Worth the Extra Cost?

Summary: Students calculate the amount of pesticide residue in selected foods for two pesticides and determine if these levels are safe. Then they read an article about a research study looking for metabolites of these pesticides in children. Finally, they use this information to determine if organic food is worth the extra cost.

***EHP* Article:** "OP Pesticides in Children's Bodies: The Effects of a Conventional versus Organic Diet"
EHP Student Edition, May 2006, p. A112
http://www.ehponline.org/docs/2006/114-2/ss.html

Objectives: By the end of this lesson, students should be able to

1. calculate the dose of a pesticide using food intake levels and pesticide residue concentrations;
2. evaluate the safety of food pesticide residue levels using the oral reference dose; and
3. compare the costs and benefits of organic food versus conventional food.

Class Time: 45 minutes

Grade Level: 10–12

Subjects Addressed: Environmental Sciences, Biology, Health

Prepping the Lesson (15 minutes)

INSTRUCTIONS:

1. Download the entire May 2006 *EHP Student Edition* at http://www.ehponline.org/science-ed/, or download just "OP Pesticides in Children's Bodies: The Effects of a Conventional versus Organic Diet" at http://www.ehponline.org/docs/2006/114-2/ss.html.
2. Review the Student Instructions and Background Information.
3. Read the article "OP Pesticides in Children's Bodies: The Effects of a Conventional versus Organic Diet."
4. Make copies of the article and Student Instructions, as necessary.

MATERIALS (per student):

- 1 copy of *EHP Student Edition*, May 2006, or 1 copy of the article "OP Pesticides in Children's Bodies: The Effects of a Conventional versus Organic Diet"
- 1 copy of the Student Instructions
- Calculator

VOCABULARY:

- chlorpyrifos
- dose
- malathion
- metabolites
- micrograms
- nanograms
- oral reference dose
- organophosphates
- tolerances

BACKGROUND INFORMATION:

To protect the food supply, the U.S. Environmental Protection Agency (EPA) sets "tolerances," or safe levels of pesticide residues in foods. Tolerances are based on a risk assessment process that estimates the possible harm pesticides might cause to those who are exposed. The tolerances are typically based on oral reference doses, an estimate of daily oral exposure to the human population that will not result in any harmful effects.

The U.S. Food and Drug Administration (FDA) routinely tests foods for pesticide residues to ensure that pesticide residue levels are below the tolerances. The FDA also uses food consumption data generated by the U.S. Department of Agriculture to look at how much food is eaten that may contain pesticides and evaluate the risk. One of the interesting ongoing food safety studies the FDA conducts is the Total Diet Study. The FDA buys foods from throughout country four times a year, prepares the foods for consumption, and determines the concentration of numerous contaminants and nutrients in the prepared foods.

The "Analytical Results" of the FDA Total Diet Study are posted online at http://www.cfsan.fda.gov/~comm/tds-res.html. The results since 1991 are presented in two ways, as "Data Summaries" and as "Individual Results." The results only include values for each pesticide where a residue was found. Levels of 0.0 are not included, except in cases where the laboratory indicated the presence of a trace level but did not enter a value. For example, if the FDA tested white bread four times in 2001 for malathion and only found malathion once, it would report only the value for the one result. To take into the account the times no pesticides were found, the data presented in this lesson use the average of the four quarterly results for 2001 for the pesticides malathion and chlorpyrifos found in selected foods and add the value of 0.0 for each quarter that no pesticide residue was found (U.S. FDA 2001). Average serving sizes listed in the lessons were obtained from various sources on the Internet and by looking at actual food packages.

Oral Reference Doses. The EPA maintains a database called the Integrated Risk Information System (IRIS) describing the oral reference dose values and how these values were determine for numerous chemicals and pesticides found in our environment. The oral reference doses for malathion and chlorpyrifos provided in this lesson were obtained from this IRIS database (National Library of Medicine 2005). Oral reference doses are given in milligrams per kilogram per day (mg/kg/day). Since the effects of any chemical on a person is affected by body size, the safe dose in mg/day for a person can be determined by multiplying the reference dose by the body size in kg.

Organophosphate Pesticides. The lesson uses two very common organophosphate pesticides, malathion and chlorpyrifos, as the example pesticides. Organophosphate pesticides account for about HALF of all insecticides used in the United States. Each year, 60 million pounds are used on 60 million acres of crops, and another 17 million pounds are used for other purposes, especially on lawns. Malathion is used widely in producing many agricultural crops, such as rice and wheat. Chlorpyrifos is used in agricultural settings on more than 40 different crops, such as strawberries, apples, grapes, onions, peppers, broccoli, corn, tomatoes, beans, peas, wheat, peanuts, sugarcane, and bananas.

Organophosphates are a leading cause of pesticide poisoning and death. Symptoms of acute poisoning from exposure to large amounts may develop during or after exposure, within minutes to hours. Some of the early symptoms include headache, nausea, dizziness, sweating, and excessive salivation. Later, more severe symptoms include muscle contractions and weakness, abdominal cramps, vomiting, and diarrhea. If exposure is very severe, coma and death can occur. It is still not clear, however, what the toxic effects of more frequent exposures to smaller doses might be, especially in children. Most worrisome about these "chronic" exposures is the effect they may have on the brain.

Organophosphate pesticides impact the nervous system by interfering with the body's ability to transmit electrical signals across the neurons and control muscle movement. Neurons use neurotransmitters to relay messages to other neurons or to other tissues of the body, such as muscles, parts of the digestive system, and blood vessels. It's easy to remember how neurotransmitters work by thinking of a telephone call: you (the "neuron") make a call, it travels through a telephone wire (the "synapse," or the space between the neuron and the target cell), your friend's telephone rings (the "receptor" is activated), and your friend picks up the phone (the "target cell" responds)!

Acetylcholine (ACh) is one of the many neurotransmitters in the nervous system. By acting on different target cells, ACh can make your pupils constrict, your blood vessels dilate, your glands sweat, and your mouth salivate. ACh also has many effects in the brain, and helps your brain tell your muscles to move. Once ACh is released from the neurons, an enzyme called ACh-esterase (ACh-E) breaks it down so that the target tissue (muscle, sweat gland, pupil, blood vessel, neuron) doesn't keep receiving the message over and over again (in effect, this enzyme hangs up the telephone call). There are many chemicals that can prevent ACh-E from working properly, which means that the ACh that *should* have been broken down doesn't get broken down, and the excess ACh keeps delivering the message over and over again (as if you *had* to keep calling your friend over and over, and your friend *had* to answer each time you called).

Organophosphates are one kind of a chemical that prevents ACh-E from doing its job of getting rid of excess ACh. There are many kinds of organophosphates, including many commonly used pesticides (such as malathion, chlorpyrifos, diazinon, and methyl-parathion). Several kinds of nerve gas (such as sarin and VX) are also organophosphates. These chemicals can poison the body by keeping too much ACh in the synapse. If you kept calling your friend over and over again, your friend would probably just get annoyed. However, when there's too much "message" in the body (in this case, ACh), you will see signs of toxicity. Too much ACh will cause the eyes to produce tears, the mouth to salivate, the digestive system to cramp and possibly vomit, and the muscles to have violent contractions; these muscle contractions may eventually cause muscle weakness and possibly death from respiratory failure. In the brain, too much ACh may cause seizures, coma, or even death.

Food Safety. The *EHP Student Edition* article raises the question of whether organic foods are worth the extra cost. The article indicates that consumption of organic food reduces exposure to pesticides. It does not address the questions of whether eating organic food is necessary for improved health and whether eating conventional foods is unsafe. Science indicates that foods are generally safe based on current risk estimates. However, there are still many unanswered questions about the risks of pesticides, especially the risk of repeated exposure to low doses of pesticides and the cumulative effects of ingesting multiple pesticides at the same time.

References:

U.S. FDA. 2001. Total Diet Study—Analytical Results: Pesticides and Industrial Chemicals. Data files MB 01-4, MB 01-3, MB 01-2, MB 01-1. Available: http://www.cfsan.fda.gov/~comm/tds-res.html.

National Library of Medicine. 2005. Oral Reference Dose Summary—Integrated Risk Information System (IRIS). Available: http://toxnet.nlm.nih.gov.

RESOURCES:

Environmental Health Perspectives, Environews by Topic page, http://ehp.niehs.nih.gov. Choose Neurology, Pesticides/Pest Management

Agency for Toxic Substances and Disease Registry (ASTDR), http:// www.atsdr.cdc.gov

- Public Health Statement for Malathion, http://www.atsdr.cdc.gov/toxprofiles/phs154.html
- Public Health Statement for Chlorpyrifos, http://www.atsdr.cdc.gov/toxprofiles/phs84.html

National Pesticide Information Center (1-800-858-7378), Food and Pesticides, http://npic.orst.edu/gen.htm#pf

Toxicology Data Network (ToxNet), http://toxnet.nlm.nih.gov/. Various databases maintained by the National Library of Medicine containing information about various chemical hazards including pesticides found in our environment; searchable by chemical name

USDA, National Organic Program, http://www.ams.usda.gov/nop/indexIE.htm

U.S. EPA, http://www.epa.gov

- Pesticides and Food: What You and Your Family Need to Know, http://www.epa.gov/pesticides/food/
- Organophosphate Pesticides in Food—A Primer on Reassessment of Residue Limits, http://www.epa.gov/pesticides/op/primer.htm
- Setting Tolerances for Pesticide Residues in Foods, http://www.epa.gov/pesticides/factsheets/stprf.htm
- Malathion Revised Risk Assessment Fact Sheet, http://www.epa.gov/oppsrrd1/op/malathion/fs2005.htm
- Chlorpyrifos Revised Risk Assessment and Risk Mitigation Measures, http://www.epa.gov/oppsrrd1/op/chlorpyrifos/consumerqs.htm

U.S. FDA, Center for Food Safety and Applied Nutrition, Total Diet Study, http://www.cfsan.fda.gov/~comm/tds-toc.html

Implementing the Lesson

INSTRUCTIONS:

1. Give a brief introduction about the use of pesticides and the possibility that they end up in foods we eat using the Background Information as a guide.
2. Give students the Student Instructions and a copy of the article "OP Pesticides in Children's Bodies: The Effects of a Conventional versus Organic Diet." Have students complete the activity as individuals or in groups.
3. Lead a discussion about the risks of pesticide residues in foods, the benefits of eating organic foods, and whether organic foods are worth the extra cost.

NOTES & HELPFUL HINTS:

- The lesson could be expanded by having advanced students look at some of the data on food consumption and pesticide residues available on the FDA Total Diet Study website. Students could look at other pesticide residues found in foods or could just look at the eating habits of people based on food consumption levels.
- Students could conduct additional research on the use of pesticides, organic food production, and organic food labeling.
- Student could keep a food diary for one day, look up the pesticide residues for each of the foods, and then calculate their potential pesticide exposure. Students could discuss variables that may increase or decrease their exposure and dose.

Aligning with Standards

SKILLS USED OR DEVELOPED:

- Communication (note-taking, oral, written)
- Comprehension (listening, reading)
- Computation
- Critical thinking and response
- Experimentation
- Tables and figures (reading)
- Unit conversions

SPECIFIC CONTENT ADDRESSED:

- Pesticide residues in foods
- Food safety
- Organic foods
- Environmental health

NATIONAL SCIENCE EDUCATION STANDARDS MET:

Science Content Standards

Unifying Concepts and Processes Standard

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Form and function

Science As Inquiry Standard

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Life Science Standard

- The cell
- The interdependence of organisms
- The behavior of organisms

Science in Personal and Social Perspectives Standard

- Personal and community health
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

History and Nature of Science Standard

- Nature of scientific knowledge

Assessing the Lesson

Step 2: Tables 1 and 2 show some foods that a teenager may eat during a typical day and the food testing results for these foods from the FDA pesticide sampling tests in 2001 for two common pesticides: malathion (Table 1) and chlorpyrifos (Table 2). These pesticides belong to a class of pesticides called "organophosphates." Organophosphates interfere with the body's ability to transmit electrical signals and control muscle movement.

Complete the tables by calculating the pesticide dose (the amount that would be ingested) for each food eaten in one portion size (typical serving size) and then for all the foods combined.

The calculation for cheese pizza is given as an example. Pay attention to how the units are cancelled to leave you with the unit you want, which is nanograms.

170 ~~grams~~ x 1.0 nanogram/~~gram~~ = 170 nanograms

Table1: Selected Foods Sampled in the 2001 FDA Total Diet Study that Contained Malathion

Food	Typical serving size (grams)	Malathion concentration levels (nanograms/gram)	Dose using typical serving size (nanograms)
Cheese and pepperoni pizza, take-out	1 slice (170)	1.0	170
White bread	1 slice (40)	27.5	1,100
Quarter-pound cheeseburger on bun, fast-food	1 sandwich (250)	4.5	1,125
Chicken potpie, frozen, heated	1 pie (200)	5.2	1,040
Chocolate chip cookies, commercial	1 cookie (15)	15.5	232
Sugar cookies, commercial	1 cookie (15)	6.8	102
Bagel, plain	1 bagel (100)	4.8	480
English muffin, plain, toasted	1 muffin (50)	7.0	350
		Total	4,599

Table 2: Selected Foods Sampled in the 2001 FDA Total Diet Study that Contained Chlorpyrifos

Food	Typical serving size (grams)	Chlorpyrifos concentration levels (nanograms/gram)	Dose using typical serving size (nanograms)
Cheese and pepperoni pizza, take-out	1 slice (170)	0.08	14
Taco/tostada, carry-out	1 taco (100)	0.62	62
Peanut butter, smooth	2 tablespoons (32)	0.95	30
Chicken potpie, frozen, heated	1 pie (200)	0.40	80
Chocolate chip cookies, commercial	1 cookie (15)	0.22	3
Sugar cookies, commercial	1 cookie (15)	0.08	1
Granola cereal	1 cup (30)	0.22	7
Apple, raw	1 apple (200)	6.00	1,200
		Total	1,397

Step 3: The oral reference dose (safe level of ingestion) is 0.02 milligrams/kilogram/day (mg/kg/day) for malathion and 0.003 mg/kg/day for chlorpyrifos. An average adult male weights 70 kg, so a safe level of exposure per day for this person would be as follows:

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0.02 mg/kg/day x 70 kg = 1.4 mg/day for malathion

0.003 mg/kg/day x 70 kg = 0.21 mg/day for chlorpyrifos

a. Determine your weight in kilograms (1 pound = 0.4536 kg). Show your work including units and unit cancellations.

Answers will vary. Students should show their units for their calculations. For a 120-lb person, the answer would be: 0.4536 kg/1 ~~lb~~ x 120 ~~lb~~ = 54.4 kg

b. Calculate your safe level of exposure per day in mg/day for malathion and chlorpyrifos using your own weight in kilograms.

Answers will vary. For a person weighing 54.4 kg (120 lb), a safe level of exposure would be 1.1 mg/day for malathion and 0.16 mg/day for chlorpyrifos.

c. How much larger are your oral reference dose levels compared to the totals in Table 1 and 2? Show your work including units and unit cancellations. (NOTE: There are 1,000,000 nanograms per 1 milligram).

Answers will vary. The following answers are for a person weighing 54.4 kg (120 lb):

Malathion: (1.1 ~~mg~~ /1 ~~day~~) x (1,000,000 ~~nanograms~~/1 ~~mg~~) x (1 ~~day~~ / 4,599 ~~nanograms~~) = 1.1(1,000,000)/4,599 = 239 times larger

Chlorpyrifos: (0.16 ~~mg~~/ 1 ~~day~~) x (1,000,000 ~~nanograms~~/ 1 ~~mg~~) x (1 ~~day~~/1,397 ~~nanograms~~)

0.16(1,000,000)/1,397 = 115 times greater

Step 4: What is the effect of body size on the safe level of pesticide exposure?

The safe level of exposure is smaller for smaller body sizes. The smaller the body size, the less pesticide is needed to cause an adverse effect.

Step 5: Answer the following questions.

a. Using the doses you calculated in Step 2 for the foods in Tables 1 and 2 and the results you calculated in Step 3, can you safely eat the foods listed in the two tables? Explain (be sure to discuss amounts of individual pesticides versus the possible presence of multiple pesticides in the food).

The total amount of malathion in the foods in Table 1 is 4,599 nanograms. The total amount of chlorpyrifos in the foods in Table 2 is 1,397 nanograms. The daily oral reference dose for malathion and chlorpyrifos for a 70-kg person is 1.4 and 0.21 mg, respectively. The foods contain pesticides on the order of 100 to 250 times below the safe level of exposure, indicating the foods are safe to eat.

Students may raise the question about eating multiple foods, which would increase your dose, or the possibility of eating multiple pesticides, which could have a cumulative or compounding effect (e.g., the presence of certain chemicals together increases their toxicity). Even so, pesticide residue levels are still likely to be within safe levels. A person may still, however, make a personal decision that they don't want to be exposed to any pesticide in a food product, and only organic foods should be used.

b. How do the foods included in Table 1 and 2 compare to your normal diet? Do the serving sizes really reflect what you eat (e.g., do you eat four cookies instead of one)? How might your "normal" food consumption impact the amount of pesticides you are exposed to?

Most students eat more than what is included in the table and more than one serving size. For example, a sandwich would really include two slices, therefore two servings, of bread. Unless they are consuming a significant amount of organic foods, their pesticide exposure may likely be higher than what they calculated.

Step 7: What does the article tell you about how likely it is that pesticides are being ingested from food products?

Because the article reported that metabolites of malathion and chlorpyrifos were found in children's urine, exposure to these pesticides through the food was most likely occurring.

Step 8: On average, organic foods cost 30 to 50% **more** than conventional foods. Is the purchase of organic foods worth the extra cost? Explain.

Answers will vary. The pesticide levels found in the foods are within levels currently believed to be safe. However, science has not clearly assessed the risks associated with repeated low doses of pesticide exposure and the risks associated with multiple exposures at the same time. Individuals may believe that organic foods are worth the extra cost because eating these foods errs on the side of caution and addresses the current scientific uncertainty.

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Give us your feedback! Send comments about this lesson to ehpscienceed@niehs.nih.gov.

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STUDENT INSTRUCTIONS: Is Organic Food Worth the Extra Cost?

Step 1: Pesticides are any substances or mixtures intended to prevent, destroy, repel, or mitigate pests. Pests can be insects, mice, weeds, fungi, bacteria, or viruses. Pesticides are used during the production and distribution of food products to reduce pest damage. Unfortunately, some pesticides can get left behind on food products. To protect the food supply, the U.S. Environmental Protection Agency (EPA) sets safe levels of pesticide residues in foods called "tolerances." Tolerances are based on a risk assessment process that estimates the possible harm pesticides might cause to those who are exposed. The tolerances are typically based on "oral reference doses," an estimate of daily oral exposure to the human population that will not result in any harmful effects. One limitation of these risk estimates is that they only consider the potential effect of an individual pesticide and not the combined effects of exposure to multiple pesticides.

The U.S. Food and Drug Administration (FDA) routinely tests foods for residues for over 60 types of pesticide to ensure that pesticide residue levels are below the tolerances. Some foods have been shown to contain residues of more than one type of pesticide. The FDA also uses food consumption data generated by the U.S. Department of Agriculture to look at how much food is eaten that may contain pesticides.

Step 2: Tables 1 and 2 show some foods that a teenager may eat during a typical day and the food testing results for these foods from the FDA pesticide sampling tests in 2001 for two common pesticides: malathion (Table 1) and chlorpyrifos (Table 2). These pesticides belong to a class of pesticides called "organophosphates." Organophosphates interfere with the body's ability to transmit electrical signals and control muscle movement.

Complete the tables by calculating the pesticide dose (the amount that would be ingested) for each food eaten in one portion size (typical serving size) and then for all the foods combined.

The calculation for cheese pizza is given as an example. Pay attention to how the units are cancelled to leave you with the unit you want, which is nanograms.

170 ~~grams~~ x 1.0 nanogram/~~gram~~ = 170 nanograms

Table 1: Selected Foods Sampled in the 2001 FDA Total Diet Study that Contained Malathion

Food	Typical serving size (grams)	Malathion concentration levels (nanograms/gram)	Dose using typical serving size (nanograms)
Cheese and pepperoni pizza, take-out	1 slice (170)	1.0	170
White bread	1 slice (40)	27.5	
Quarter-pound cheeseburger on bun, fast-food	1 sandwich (250)	4.5	
Chicken potpie, frozen, heated	1 pie (200)	5.2	
Chocolate chip cookies, commercial	1 cookie (15)	15.5	
Sugar cookies, commercial	1 cookie (15)	6.8	
Bagel, plain	1 bagel (100)	4.8	
English muffin, plain, toasted	1 muffin (50)	7.0	
		Total	

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Table 2: Selected Foods Sampled in the 2001 FDA Total Diet Study that Contained Chlorpyrifos

Food	Typical serving size (grams)	Chlorpyrifos concentration levels (nanograms/gram)	Dose using typical serving size (nanograms)
Cheese and pepperoni pizza, take-out	1 slice (170)	0.08	
Taco/tostada, carry-out	1 taco (100)	0.62	
Peanut butter, smooth	2 tablespoons (32)	0.95	
Chicken potpie, frozen, heated	1 pie (200)	0.40	
Chocolate chip cookies, commercial	1 cookie (15)	0.22	
Sugar cookies, commercial	1 cookie (15)	0.08	
Granola cereal	1 cup (30)	0.22	
Apple, raw	1 apple (200)	6.00	
		Total	

Step 3: The oral reference dose (safe level of ingestion) is 0.02 milligrams/kilogram/day (mg/kg/day) for malathion and 0.003 mg/kg/day for chlorpyrifos. An average adult male weights 70 kg, so a safe level of exposure per day for this person would be as follows:

0.02 mg/kg/day x 70 kg = 1.4 mg/day for malathion

0.003 mg/kg/day x 70 kg = 0.21 mg/day for chlorpyrifos

a. Determine your weight in kilograms (1 pound = 0.4536 kg). Show your work including units and unit cancellations.

b. Calculate your safe level of exposure per day in mg/day for malathion and chlorpyrifos using your own weight in kg.

0.02 mg/kg/day x _____ kg = _____ mg/day for malathion

0.003 mg/kg/day x _____ kg = _____ mg/day for chlorpyrifos

c. How much larger are the oral reference dose levels compared to the totals in Table 1 and 2? Show your work including units and unit cancellations.

Step 4: What is the effect of body size on the safe level of pesticide exposure?

Step 5: Answer the following questions.

a. Using the doses you calculated in Step 2 for the foods in Tables 1 and 2 and the results you calculated in Step 3, can you safely eat the foods listed in the two tables? Explain (be sure to discuss amounts of individual pesticides versus the possible presence of multiple pesticides in the food).

b. How do the foods included in Table 1 and 2 compare to your normal diet? Do the serving sizes really reflect what you eat (e.g., do you eat four cookies instead of one)? How might your "normal" food consumption impact the amount of pesticides you are exposed to?

Step 6: Read the article "OP Pesticides in Children's Bodies: The Effects of a Conventional versus Organic Diet," *EHP Student Edition*, May 2006, p. A112.

Step 7: What does the article tell you about how likely it is that pesticides are being ingested from food products?

Step 8: On average, organic foods cost 30 to 50% **more** than conventional foods. Is the purchase of organic foods worth the extra cost? Explain.