Chemistry and the Environment

KEY QUESTION(S): How does a mass spectrometer work? How can chemical runoff from agriculture be detected? How can chemical runoff from agriculture reduced?

SCIENCE SUBJECT: Environmental Science

GRADE AND ABILITY LEVEL: 9-12, Honors and Advanced Placement

SCIENCE CONCEPTS: Molecular mass, herbicide usage.

OVERALL TIME ESTIMATE: Two 50 minutes class periods, or one 50 minute class period with part one assigned as homework.

LEARNING STYLES: Visual and auditory.

VOCABULARY:

Agricultural runoff – Water from rainfall or irrigation that does not enter the soil but goes into waterways. This runoff often contains extra nutrients from fertilizer along with pesticides.

Bellweather species – An organism that is affected by environmental change before other organisms.

Herbicide – Chemical used to kill plants.

Molecular mass – The mass of a molecule determined by the atomic mass units for each of its atoms.

Quadrupole mass spectrometer – Instrument that separates molecules based on atomic mass by ionizing the molecule.

LESSON SUMMARY: The lesson will introduce how a quadrupole mass spectrometer works by running samples to determine the source of agricultural runoff.
STUDENT LEARNING OBJECTIVES WITH NEXT GENERATION SUNSHINE
STATE STANDARDS:

1. Describe how a quadrupole mass spectrometer works.
2. Determine the molecular mass of a molecule.
3. Use experimental data to make a conclusion.
4. List methods of reducing agricultural runoff.

SC.912.L.17.13 Discuss the need for adequate monitoring of environmental parameters when making policy decisions.

SC.912.L.17.15 Discuss the effects of technology on environmental quality.

SC.912.L.17.17 Assess the effectiveness of innovative methods of protecting the environment.

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

MATERIALS:

ESSENTIAL:

• Quadrupole mass spectrometer, one per class.
• Samples of glyphosate (2), atrazine (1) and 2-4-dichlorophenoxyacetic acid (1), per class.
• Lab worksheets, one per student.
• Computer access if completing part one in class.

SUPPLEMENTAL:

• Commercial containers of Roundup, Atrazine and 2-4-D to show product.
• Live amphibian for display.

BACKGROUND INFORMATION:

Herbicides are chemicals used to kill unwanted plants. Although used by homeowners, gardeners, and forestry managers, the bulk of herbicide usage is by farmers. These herbicides make their way into water supplies when rainfall and irrigation washes them into streams. Most of these herbicides are not considered to be persistent in the environment by the EPA.

Glyphosate is better known by its commercial name of Roundup. It is a broad-spectrum herbicide that kills broadleaf plants and grasses. Roundup was created in 1970 by Monsanto, and is the most popular herbicide based on its annual usage of over 200,000,000 pounds. Monsanto’s patent for glyphosate expired in 2000, but the company has created a line of genetically modified crops, like corn, soybeans and cotton, that can be sprayed with Roundup and suffer no effects. Glyphosate kills plants by inhibiting an enzyme so the plant will not be
able to make certain amino acids. Because of this, Roundup must be applied to actively growing plants, it can’t be applied to the field before the plants come up.

Atrazine is the second most used herbicide in the United States. Invented in 1958, it is most commonly used on corn crops. It kills plants by breaking down the electron transport chain which stops photosynthesis.

2-4-Dichlorophenoxyacetic acid is better known by its commercial name of 2-4-D and is an ingredient in products like Weed B Gone. Discovered in 1941, it is the third most commonly used herbicide in the United States. Agent Orange, the controversial herbicide used in Vietnam, had 2-4-D as a main ingredient. It kills plants by acting as a synthetic hormone, travelling to the meristem tissue and causes uncontrolled growth.

Bellweather species are sensitive to environmental changes and show effects before most organisms. Amphibians are usually considered bellweather species because they have moist skin that allows for easier contamination by chemicals. There has been a worldwide decline in most amphibian species, which includes frogs, toads, and salamanders.

There are options for farmers who wish to reduce herbicide runoff. The most obvious option is to not use as much herbicide. Farmers can level their fields to reduce runoff. Drip irrigation systems allow the farmer to use less water, thereby reducing runoff. A buffer zone should be established between the agricultural fields and bodies of water to prevent runoff from going directly into the waterways.

ADVANCE PREPARATION:

Refer to the teacher manual that comes with the Advion mass spectrometer for installation. Solutions (if not sent already prepared) need to be made at a concentration of $10^{-5}$. Make 10 mL for each herbicide tested. Check to ensure all the links are still active in the student handout for day one. It would be best to collect the day one worksheets, grade them, and return them to students so they can be used as a reference on day two.

PROCEDURE AND DISCUSSION QUESTIONS WITH TIME ESTIMATES:

Assign the day one worksheets as homework. Collect, grade and return the worksheets to the students to use as reference for day two. Read through the scenario on the day two worksheet. Ask students if they can predict which herbicides the farms are using based on their previous worksheet. Ask students to explain reasons why they think a particular farm might be the source of contamination. This should only take 5 minutes since the samples will take about 40 minutes to run. Run samples A, B, and C representing the three farms as indicated on page two. Students need to fill out the molecular mass and determine the name of the herbicide based on the molecular mass value. It will take about 10 minutes to run each sample. Then run sample from the natural area of the lake which will take another 5 minutes to get results. Based on the molecular mass attained, students should be able to determine that the source of the
contamination was the Baxter Farm (A). Ask students what steps could be taken to reduce runoff from the farm. Point out that the farm is bordering the creek, and a buffer should be established between the fields and the waterway. Other options could be reducing herbicide usage, leveling the field and reducing water usage by employing drip irrigation systems. Since there is some ‘down time’ while the samples are running, it would be a good time to show the video clips listed in the extension section.

EXTENSIONS:

ACTIVITIES:

• Show video clip Science Nation- Disappearing Frogs at http://www.youtube.com/watch?v=ZWHibAQ0sso
• Show video clip Nature – Frogs: The Thin Green Line at http://www.youtube.com/watch?v=nBbkwlGM7X0

LITERATURE:

RESOURCES/REFERENCES:


This database has toxicity data for pesticides across many species, and provides a good starting point for finding pesticide use, occurrence, and effects data on the web.


This publication provides a breakdown of seventy-eight common herbicides organized by translocation mechanism and then mode of action. It further subdivides the information into chemical type and then common and trade names. A brief paragraph describes each mode of action and types of vegetation that the herbicide is often used to control.


This is a recent reference for mechanistic health and environmental toxicity information for pesticides, including herbicides and insecticides.


The aquatic life benchmarks (for freshwater species) provided in this module are based on toxicity values
reviewed by U.S. EPA and used in the Agency's most recent risk assessments, developed as part of the decision-making process for pesticide (including herbicides) registration. Acute and chronic benchmarks are provided for fish, invertebrates, and aquatic plants. The table of benchmarks provides links to supporting ecological risk assessments. Each aquatic life benchmark is based on the most sensitive, scientifically acceptable toxicity endpoint available to U.S. EPA for a given taxon. U.S. EPA’s goal is to add to these benchmarks annually.
Chemistry and the Environment

In tomorrow’s lab, we will be using an instrument called a quadrupole mass spectrometer, which can be used to detect chemicals.

Go to www.youtube.com/watch?v=IowMQnI6Rxc to watch a two minute video about the quadrupole mass spectrometer.

1. In your own words, describe how the mass spectrometer works.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Lake Monsanto is a 100 acre lake in a farming community. In addition to the nice lakefront homes on the south side of the lake, there is a farm on the north side along with two other farms nearby.

2. What is an herbicide?

________________________________________________________________________
Use Wikipedia to find information about the following commonly used herbicides:

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Chemical Formula</th>
<th>Atomic Mass</th>
<th>LD$_{50}$ for rats</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Glyphosate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Atrazine</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2-4-Dochlorophenoxyacetic acid</strong></td>
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</tbody>
</table>

Diagram of molecule
The Environmental Protection Agency (EPA) has information about many types of chemicals, including herbicides.

Go to [www.epa.gov/caddis/ssr_herb_int.html](http://www.epa.gov/caddis/ssr_herb_int.html) to find out more information about these herbicides.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Other commercial names (if any)</th>
<th>Crops applied on</th>
<th>Millions of acres applied on</th>
<th>How does it kill the plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyphosate</td>
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</table>
Lake Monsanto is a beautiful lake, with expensive homes on the south side. In addition to recreational use by the community, the lake also has a natural area on the northwest side and a large farm (Oveido Farm) on the northeast side. Two other farms, the Chan Farm and Baxter Farm, are further north and close to Dawson’s Creek, which flows into Lake Monsanto.

The Oveido Farm grows corn, the Baxter Farm grows GMO corn, and the Chan Farm grows soybeans. Lately, residents have noticed many dead salamander larvae in the early summer near the natural area. As someone who loves salamanders, you need to find out who is responsible for this!

Based on the information given so far, what is the likely source of contamination?

________________________________________________________________________

Explain why you think this. _______________________________________________

________________________________________________________________________

The Oveido Farm grows corn, the Baxter Farm grows GMO corn, and the Chan Farm grows soybeans. Lately, residents have noticed many dead salamander larvae in the early summer near the natural area. As someone who loves salamanders, you need to find out who is responsible for this!

Based on the information given so far, what is the likely source of contamination?

________________________________________________________________________

Explain why you think this. _______________________________________________

________________________________________________________________________
Yesterday you learned about the quadrupole mass spectrometer. Today we can run samples taken from various locations to determine the most likely source of contamination.

Sample A was taken from a pond on the Baxter Farm.

Molecular mass: ______________________
Herbicide: ______________________

Sample B was taken from a canal near the Chan Farm which connect to Dawson’s Creek.

Molecular mass: ______________________
Herbicide: ______________________

Sample C was taken from the lakeshore near the Oveido Farm.

Molecular mass: ______________________
Herbicide: ______________________

Sample X was taken near the natural area of Lake Monsanto.

Molecular mass: ______________________
Herbicide: ______________________

Based on information to you now, what is the likely source of contamination?

________________________________________________________________________

Explain why you think this. _______________________________________________

________________________________________________________________________

Describe three things that could be done to reduce the contamination of Lake Monsanto.

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Why are amphibians, like salamanders and frogs, affected by chemicals more than other animals?

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