LESSON PLAN / Water City Chapter

Inquiry project: How clean is your water?

In this lesson students will conduct a research study to investigate the toxicity of different water samples of local bodies of water using onion root growth as a bio indicator of water pollution. The activity is geared towards middle school students but can be tailored to accommodate either slightly younger or older students.

Learning Goals

At the end of this project, students will:

- Learn that water pollution directly affects the growth and survival of living organisms
- Know that onion bulbs roots are sensitive to water pollution and therefore can be used as a bio indicator of water toxicity
- Be able to record careful observations
- Understand the need for controls in a science experiment
- Take measurements of length and calculate averages
- Interpret the results obtained in terms of their prior hypothesis
- Identify possible causes of error in their results
- Be able to communicate their findings and conclusions to other students

Background Information

Toxic chemicals are one of the main sources of water pollution. A large amount of them comes from pesticides and fertilizers contained in agricultural run-off, which drains into rivers. Industrial waste is another important source of chemical pollution, especially because some waste of industrial processes is not properly treated before reaching bodies of water. Air pollution such as acid rain also affects the quality of rain water, which in turn becomes part of rivers, streams and oceans. Buried waste can sometimes pollute the underground streams of water that finally reach other streams. Finally, untreated waste water generated in cities is also another large source of water pollution.

The effects of water pollution are not only harmful to human beings but also to other animals and plants. Contaminated water is unsuitable for drinking, recreation, agriculture or industry. More seriously, water pollution destroys aquatic life and is a danger for human health. For example, organophosphates and carbonates present in pesticides, as well as petrochemicals such as benzene, can cause cancer, whereas lead and other heavy metals can originate neural system disorders. The process of treating polluted water involves many steps such as addition of other chemicals, precipitation and filtration, and depending on the kind of pollution can be highly expensive.

The development of the root system in plants is highly sensitive to the presence of chemical pollutants, particularly in the early stages of growth. *Allium cepa*, the common onion, is a simple tool that students can use to assess the toxicity of water samples. By measuring root growth, students can research the presence of toxic chemicals in water from different local sources and compare it to mineral water and to the tap water they drink everyday.

Development of the activity

1. Warming-up

As an introduction to this activity, discuss with the class the following questions:

What is water pollution?
Where does pollution come from?
How can water pollution affect living creatures, including us?
What can we do to prevent water pollution?

Write students' main ideas on the board, and ask them to record their answers on their notebooks. These ideas will be re-discussed at the end of the study and can be used for extension activities.

Students will then conduct their research project in small groups. Prepare in advance the following list of materials:

2. Materials (per group of students):

8 mid-sized onion bulbs, of the same size
8 cups
Toothpicks
Ruler
1 liter of tap water
1 liter of bottled mineral water
1 or more samples of water from a local source, such as a park pond (it cannot be salty water).
1 liter of salty water (10 grams of NaCl per liter)
Newspaper
Permanent marker
Student's journals

3. Experiment

Explain students that onion root growth is very sensitive to chemical toxicity and therefore can be used as a bio indicator of pollution. Tell them that the purpose of the experiment is to investigate whether the samples of local water are polluted. These samples can be collected in advance by students from local parks, rivers, etc, which allows to include a larger variety of samples as well as integrate students' resources to the activity, or can be brought by the teacher (see Go Wild in New York City, page 16, for different examples of water in the city). Students will also assess the toxicity of tap water.

Ask students how they would know whether the water sample tested is inhibiting root growth, and use their answers to introduce the need of experimental controls as a way to compare root growth of different samples. This experiment will include two controls: bottled mineral water, which does not inhibit root growth and can be used as a negative control of pollution, and salty water, which prevents roots from growing and mimics the effect of water pollutants, serving as a positive control.

Discuss and decide with students other details of the experimental design, such as:

- How can we be sure that it is not lack of water which is preventing root growth?
- What is the best way of measuring root growth? Measure all roots? Only the new ones? Only the longest one? Count the number of new roots? Have one people of the group in charge of the measurements? More than one?
- What other observations must be recorded? (for example, the color of the water, its smell, whether the onion gets rotten, etc)
- Why is it important to have more than one onion per experimental group?

Although the experimental details will be discussed and decided with students, we describe here a typical experiment. Ask students to:

1. Cover the work area with newspaper.
2. Label the 8 cups (2 cups, Sample water; 2 cups, Tap water; 2 cups, Salty water; 2 cups, bottled mineral water).
3. Fill the cups with the appropriate solutions.
4. Peel the onions carefully with their hands.
5. Insert 4 toothpicks in each onion, forming a cross.
6. Place the onions into the cups, roots down. Roots have to be in contact with the liquid.
7. Put the cups with the onions in an undisturbed sunlit place, not directly exposed to sunlight.
8. Record their initial observations (number of roots, description of the onion, color of the water, smell, etc) in their science journals.

As onions start consuming water, students will have to refill the cups with the appropriate solution during the experiment. After three days, the students will start recording the roots length. Each group will have to:

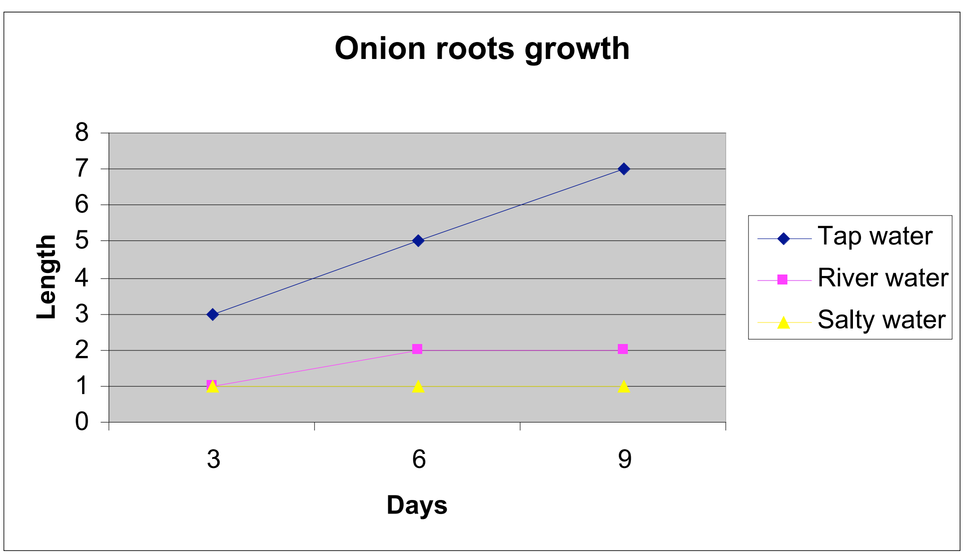
1. Remove each onion at the time.
2. Count the number of new roots.
3. Measure the length of each root with a ruler, and record it on the table provided below.

Students will record data twice again, after six and nine days of the start of the experiment, using the following template:

Date:

Type of water	Number of new roots	Total root length	Average root length	Observations
Mineral water 1				
Mineral water 2				
Mineral water average				
Tap water 1				
Tap water 2				
Tap water average				
Sample water 1				
Sample water 2				
Sample water average				
Salty water 1				
Salty water 2				
Salty water average				

At the end of the experiment, students will chart root growth for each sample in order to compare them, as in this example (we only include three water samples here in order to make the chart easier to read; "river water" is the water sample to be tested)



Analysis and presentation of results

Each group of students will orally present their results to the rest of the class. Then, all group results will be charted on the board and discussed. Make sure to include the following questions in the discussion:

During each group presentation:
Did you find any differences in root growth of the onions that were placed in the same type of water? (e.g. The roots of the two onions placed in tap water grew the same?) Why (or why not)? Was it useful to include more than one onion per group?
What did your group conclude about the toxicity of the samples of water that you tested?

Among groups:
Did every group obtain the same results? Why (or why not)?
Were there any procedural differences among the groups, such as the way measurements were taken, the onions used, etc?
Which are the possible sources of error in this experiment? What improvements should be added in the future?

Then, analyze with students the whole class chart in order to reach a general conclusion for the whole class, and discuss advantages of making a whole class experiment (Do the whole class results coincide or differ from each group's conclusions? What would have been different if we considered individual groups' results instead of the whole class data?)

Finally, ask each group of students to create a written report including:

- Their experimental design
- Their results.
- Their interpretation of their results.
- Possible sources of errors in the experimental design or procedure
- Possible improvements if the experiment would be conducted again.

Assessment

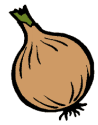
This project provides various opportunities to assess students' learning (see Learning Goals) in formative and summative ways. Student's skills and conceptual understanding can be assessed through:

-Students' performance during the onion experiment (formative)
-Students' participation in the group discussions during the development of the experiment (formative)
-Students' presentations of results and their contribution to the whole class discussion (formative)

-Students' final reports (summative)

We also propose here an individual final written assessment to provide students with an opportunity to reflect individually of what they did throughout the project:

How clean is your water?



Imagine you have to teach your little brother or sister about the onion bulb experiment. Explain him/her each step of what you did. Make drawings if necessary. Do not forget to tell him/her what your reasons for doing this experiment are.

What did you find out through this experiment?

What would you like to know after doing this experiment? How would you find that out?

What would you do different next time in order to improve the study?

Extensions

As a follow up of this activity, students can research the sources of pollution of the local water they tested (if they found any). For example, the class can go on a field trip to the local park to find out whether people are throwing garbage into the pond, and think of ways to make people aware of preserving the pond water clean by developing a "clean water campaign."

This activity can also lead towards an investigation of the effects of water pollution on human health and the different sources of pollution of New York City water. Finally, students can research the location of city sewage plants and the steps involved in the treatment of waste water (see Go Wild in New York City, page 15).

Finally, this experiment was adapted from a larger project which involves a world network of schools engaged in the protection of water and the environment. See http://www.aquatox.net/ for further assays to test water pollution.

Connection to New York City Standards

This activity addresses the following NYC Performance Standards for Middle School Science:

S2d Life Science Concepts: The student produces evidence that demonstrates understanding of populations and ecosystems, such as the effects of resources on populations.

S3d Earth Science Concepts: The student produces evidence that demonstrates understanding of natural resource management.

S4b to e Scientific Connections and Applications: The student produces evidence that demonstrates understanding of:

b. The designed world, such as the reciprocal nature of science and technology, the development of agricultural techniques, and the viability of technological designs.
c. Health, such effects of toxic substances, personal and environmental safety
d. Impact of technology, such as risks, and problems and solutions
e. Impact of science, such as interactions between science and society.

S5a to f Scientific Thinking: The student:

a. Frames questions to distinguish cause and effect; and identifies control variables in experimental and non-experimental research settings
b. Uses concepts from Science Standards 1 to 4 to explain a variety of observations and phenomena
c. Uses evidence from reliable sources to develop descriptions, explanations and models
d. Proposes, recognizes, analyzes, considers, and critiques alternative explanations; and distinguishes between fact and opinion

e. Identifies problems, proposes and implements solutions, and evaluates the accuracy, design and outcomes of investigations
f. Works individually and in teams to collect and share information and ideas

S6a to e Scientific Tools and Technologies: The student:

a. Uses technology and tools to observe and measure objects, organisms and phenomena
b. Records and storage data using a variety of formats
c. Collects and analyzes data using concepts and techniques in Mathematics Standards 4
d. Acquires information of multiple sources
e. Recognizes sources of bias in data

S7a, b, d and e Scientific Communication: The student:

a. Represents data an results in multiple ways
b. Argues from evidence
d. Explains a scientific concept or procedure to other students
e. Communicates in a form suited to the purpose and the audience

S8 a and c: Scientific Investigation: The student demonstrates competence in investigations that integrate:

a. Controlled experiment
c. Design