LESSON PLAN GRADES 9-12 FOR TEACHERS

Lesson Plan: A Comparative Study of Surface Water Quality with Dietary Connections

A three-step lesson customizable to your class with sample data and discussion Q&A sheets

Grade Levels and Subjects: Grades **9-12** science, health

Length: 2-3 class periods with extensions as chosen by instructor

Purpose: To evaluate surface water quality of samples collected from a recreational use area and those from areas used for farming or animal-based agriculture. Samples will be compared over the period of one day, one week, or one year, as time and resources permit. Possible parameters to be examined:

- pH
- temperature
- turbidity
- nitrate concentration
- phosphate concentration
- fecal contamination
- antibiotic contamination
- dissolved oxygen (DO)
- biological oxygen demand (BOD)

Objectives: As a result of conducting this investigation, students should be able to:

- identify multiple measures of water quality;
- collect environmental water samples and assess their composition and quality;
- display and interpret data in tabular and graphical forms;
- apply computational, analytical, and scientific reasoning skills to make comparisons and contrasts concerning water quality;
- propose ways to mitigate human-influenced negative effects on water quality.

National Science Content Standards Correspondence:

NS.9-12.1 *Science as Inquiry* As a result of activities in grades 9-12, all students should develop

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

NS.9-12.2 *Physical Science* As a result of their activities in grades 9-12, all students should develop an understanding of

- Structure and properties of matter
- Chemical reactions
- Interactions of Matter and Energy

NS.9-12.3 *Life Science* As a result of their activities in grades 9-12, all students should develop understanding of

- Interdependence of organisms
- Matter, energy, and organization in living systems

NS.9-12.5 *Science and Technology* As a result of activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

NS.9-12.6 *Personal and Social Perspectives* As a result of activities in grades 9-12, all students should develop understanding of

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

*Education World (2008) *U.S. National Education Standards*. Retrieved September 18th, 2009 http://www.education-world.com/standards/national/index.shtml

Materials Needed *(lab supplies needed only if instructor selects a particular test. Companies which sell the products listed include www.carolina.com; http://las.perkinelmer.com; www.coleparmer.com; www.sci-bay.com; and www.fishersci.com. There are inexpensive kits to test for some of the parameters listed in this lesson plan available from www.worldwatermonitoringday.org and www.lamotte.com/pages/edu/5886.html)***:**

- Whiteboard markers, whiteboard, blackboard, or overhead projector
- pH paper
- thermometers

Prior Knowledge and Skills Needed:

- Farm run-off and erosion as major sources of surface water pollution
- Animal manure, treated or not, discharged into freshwater bodies or spread on fields
- Fresh water as a requirement for healthy living and a healthy environment
- Reading information from test strips, portable field testing machines, and tables
- Making predictions
- Collecting data in the field
- Arranging data into tabular and graphical forms

Assessment:

Students will be assessed through these means:

- Successful completion of teams' data collection sheets while in the field
- Successful completion of data tables and graphs
- Participation in the composition of a written letter to a local government official

Vocabulary:

- **natural resource:** an economically valuable, naturally occurring material (e.g., timber, oil, minerals, water)
- **water conservation:** the preservation and careful management of water
- **water pollutant:** a contaminant of waterbodies that renders them harmful to animals, plants, and/or humans (e.g., animal manure, motor oil, etc.)
- **pH:** refers to a measurement scale that indicates the acidity or basicity of water; pH = 7 is neutral; less than 7 is acidic and greater than 7 is basic
- **nitrate:** a nitrogen-based nutrient that makes plants grow; often found in fertilizer. Too much contributes to eutrophication.

- **eutrophication:** an increase in nutrients, especially in nitrogen- or phosphorus-containing compounds, in a land-based or water-based ecosystem. Usually refers to excessive plant growth and decay.
- **phosphate:** a phosphorus-based nutrient that makes plants grow; often found in fertilizer and detergent. Too much contributes to eutrophication.
- **turbidity:** degree to which water is cloudy or unclear; may be due to dissolved solids (e.g., manure) or to an abundance of microscopic organisms
- **fecal contamination:** refers to the presence of coliform bacteria from the fecal matter of animals in water; high values mean water is unsafe for drinking and swimming
- **dissolved oxygen (DO):** the amount of oxygen available in water for fish and other marine animals; low values implies eutrophication (possible algal blooms) and suggests impending death to animals, plants and possibly of the waterbody itself
- **biological oxygen demand (BOD):** refers to how fast oxygen in water will get used up by aquatic life present in water; a high value means there is a lot of organic matter (e.g., decaying leaves or manure) present

Lesson Background:
Teachers may look at the United Nations' 2006 report titled *Livestock's Long Shadow* available at http://www.fao.org/docrep/010/a0701e/a0701e00.htm Chapter IV deals with water pollution due to animal agriculture. Both national and global issues are discussed. The major conclusion of this Report is that livestock production is a leading source of environmental damage including climate change; water and air pollution; land degradation; and loss of biodiversity. The Report suggests that a human diet that is plant-based would prevent much of the environmental damage caused by animal agriculture, including the feed crop production associated with it.

Please see the section titled *Water Facts* (below) for tabular information and other relevant statistics involving direct and indirect (i.e., through diet) personal water use. The Resources section (below) lists many websites filled with all kinds of supplemental information that may be helpful in science fair project development.

This lesson runs like a basic course in environmental science. Many tests analyze variables, such as pH and temperature, that students may be familiar with, but in a new context. Teachers may choose the extent of this lesson and suit it to their purposes. It may serve as an Earth Day or World Water Monitoring Day activity.

A lesson plan similar to this one which is accompanied by a document which explains what the field results mean can be found at www.chicagoriver.org It contains many illustrative examples of several key vocabulary terms used here.

Procedure:
NOTE: Although designed as a one-year investigation, teachers may wish to restrict the study to a single day, week, or season. Teachers may also wish to reduce the number of parameters tested due to time, resource, or facility constraints.

Lesson Step #1: Introduction and Topic Setting
Teacher introduces the topic by referring to Chapter IV of the United Nations' *Livestock's Long Shadow*, http://www.fao.org/docrep/010/a0701e/a0701e00.htm
Water pollution facts and figures are given throughout the chapter. Teacher may wish to copy and put on overhead Table 4.10 that shows ranges of BOD concentrations for various livestock wastes; and Table 4.19 which shows statistics on the amount of livestock contributions of nitrogen and phosphorus to surface waters in the U.S. Teacher may show pictures of polluted waterways, manure piles at livestock farms, etc. Teacher asks students to predict which would be cleaner: a lake at a state park or a stream running by a hog farm, and why.

Lesson Step #2: Field Activity: Collecting and Testing Water Samples from Two Sites

1. Teams of students research the meanings of the parameters considered in this study; how they are quantified in the field; and how to interpret values:
    - pH *uses inexpensive test paper*
    - temperature *uses inexpensive thermometer*
    - turbidity *uses an expensive portable machine; see DO and BOD below for inexpensive kit alternatives*
    - nitrate concentration *uses an inexpensive test kit; see DO and BOD below for inexpensive kit alternatives*
    - phosphate concentration *uses an inexpensive test kit; see DO and BOD below for inexpensive kit alternatives*
    - fecal contamination *easy-to-do explanation of method with inexpensive supplies:http://www.science-projects.com/fecaltest.htm; see DO and BOD below for inexpensive kit alternatives*
    - antibiotic contamination *testing recommended at a local university or private company*
    - dissolved oxygen (DO) *http://www.worldwatermonitoringday.org offers inexpensive kits for DO and for testing some other parameters included in this lesson plan*
    - biological oxygen demand (BOD) *GREEN Low Cost Water Monitoring Kit offered by http://www.lamotte.com/pages/edu/5886.html with instructions in English and Spanish*
2. Students present information collected about #1 and present to teacher and class.
3. Using maps and other data, teams and teacher decide which locales to designate as study sites. A local state park with a waterbody and freshwater running near a farmland/livestock facility are preferable.
4. Dressed appropriately with all necessary equipment, teams and teacher collect water samples at designated sites on designated days throughout the testing period.
5. Whether in the field, at school, or at some other appropriate place, students conduct sample tests.
6. Students test samples and record data.
7. Steps 5 and 6 are repeated as specified.
8. After all data is collected, students use appropriate software to tabulate and graph data.

9. Teams determine if patterns exist in the test results in light of major events such as heavy rains, manure application, effluent discharge, etc., and suggest reasons for the patterns. Teams describe any seasonal variation in the data. Teams determine if there are any direct or inverse relationships between two or more variables. Teams note any patterns seen in the data sets.
10. Teams publicly display data and major conclusions. (*See http://nces.ed.gov/ nceskids/createAgraph/default.aspx, http://www.smartdraw.com/downloads/ or similar websites for free downloads of graphing software if you do not have access to similar software at school.)*

Lesson Step #3: Culminating Activity

Teams write to local officials with graphical summaries of their data and analyses. Teams propose ways that local surface water quality may be maintained and improved. *Livestock's Long Shadow* serves as a good starting point for these proposals.

Water Facts:

Table 1. Water Consumed during Daily Activities (data taken from EPA website http://www.epa.gov/reg5rcra/wptdiv/p2pages/water.pdf)

Activity	**Water consumed (gallons)**
Flush toilet	5-7
Run dishwasher	15-25
Wash dishes by hand	20
Water a small lawn	35
Take a shower	25-50
Take a bath	50
Wash a small load in a washing machine	35
Brush teeth with water running	2-5

U.S. and Global Daily Water Intakes

Chapter Four of *Livestock's Long Shadow* cites sources that on average, people consume 30-300 L of water per day for household uses while 3,000 L of water are used to grow their daily food.

David and Marcia Pimentel, authors of *Food, Energy, and Society, 3rd ed.* (2008), cite sources that Americans average 400 L water/person/day. They point out that in eighty-three other countries, the average daily water use per person is below 100 L. In the U.S., daily freshwater withdrawals of surface and groundwater used mainly for irrigation of crops for humans and livestock are 5,700 L per person. Worldwide, the average daily value of water for food production is 1,970 L/person.

Table 2. Estimated Amount of Water Used to Produce Crops and Livestock in the U.S. (Liter/kilogram)

(Note: One liter is approximately the same as one quart. One kilogram is approximately the same as 2.2 lbs.)

Food Item	Hoekstra & Chapagain (L/kg)
Corn	500
Wheat	850
Soybeans	1,900
Rice	1,600
Cow's milk	700
Eggs	1,500
Beef (feedlot)	13,000
Pork	3,900
Poultry	2,400

Note: *Values taken from Chapagain A, Hoekstra A (2004*) Water Footprints of Nations Volume One: Main Report. *Value of Water Research Report Series No.16. Delft (The Netherlands): UNESCO – IHE Institute for Water Education.* http://www.waterfootprint.org/Reports/Report16Vol1.pdf

Table 3. Water Used to Produce Some Common Items

(Note: One liter (approximately one quart) equals 1,000 milliliters (ml). One pound equals 454 g.)

Food Item	Water Needed for Production (L)
1 cup of coffee (125 ml)	140
1 glass of milk (200 ml)	200
1 slice of bread (30g)	40
1 slice of bread (30g) with cheese (10g)	90
1 potato (100 g)	25
1 bag of potato chips (200g)	185
1 apple (100 g)	70
1 tomato (70 g)	13
1 glass of apple juice (200 ml)	190
1 egg (40 g)	135
1 hamburger (150 g)	2400
Dry pasta (made in Italy;1 kg)*	1900
Cheese pizza (made in Italy; 725 g)*	1200 (or 248 L per 150 g = ~1/4 pizza)
Tomato pizza (made in Italy; 600 g)*	300 (or 75 L per 150 g = ~1/4 pizza)

Note:Values taken from Chapagain A, Hoekstra A (2004) Water Footprints of Nations Volume One: Main Report. *Value of Water Research Report Series No.16. Delft (The Netherlands): UNESCO – IHE Institute for Water Education.* http://www.waterfootprint.org/Reports/Report16Vol1.pdf
Asterisked values taken from Aldaya M, Hoekstra A. (2009) The Water Needed to Have Italians Eat Pasta and Pizza. *Value of Water Research Report Series No.36. Delft (The Netherlands): UNESCO – IHE Institute for Water Education.* http://www.waterfootprint.org/Reports/Report36-WaterFootprint-Pasta-Pizza.pdf

RESOURCES:

1. Educational materials, teacher's guides, lesson plans and student pages

http://www.earthday.net
There are several categories of well-developed environmental lesson plans for all grade levels. Topics include climate, sustainability, and organics and food. Site has an environmental jeopardy game that students will enjoy.

http://www.ec.gc.ca/water/en/info/pubs/lntwfg/e_contnt.htm
Environment Canada, analogous to the EPA of the U.S., has a thorough unit study on water that ranges across the curriculum, complete with activities and assessments of all types.

http://eelink.net/pages/Lesson+Plans
The North American Association for Environmental Education (NAAEE) has a multitude of lesson plans, teacher guides, and student resources at its site.

http://www.epa.gov/kids/
This site is written to appeal to children of all ages. There are many interactive features and many downloadable resources. With art, game, and science rooms, as well as pages devoted to environmental issues of all types, this site could make a good supplemental resource or lesson enhancement.

http://www.footprintnetwork.org
Provides an interactive quiz that students will enjoy to calculate the ecological footprint of cities, businesses, and individuals.

http://kids.niehs.nih.gov/
National Institute of Environmental Health Sciences (NIEHS) has an enormous website filled with useful resources for teachers and students in all grade levels. Certain pages are written at a child's level and cover many different topics related to environmental health.

http://www.unep.org/tunza/children/
The United Nations Environment Programme has a website just for young people of all ages. There are story time videos created by UNEP, youth environmental action updates, competitions, and events among many other pages.

http://www.unesco.org/water/wwap/
The World Water Assessment Programme, a division of UNESCO, provides facts and figures on global water issues. The organization publishes many documents, including the United Nations World Water Development Reports, which serve as good references for educators in many subject areas and excellent source information for student projects.

http://www.waterfootprint.org/?page=files/WaterFootprintCalculator
Quick and extended individual water footprint calculators are available on this website. The publications page of UNESCO-IHE's Institute for Water Education contains many reports and articles of interest.

2. Water non-profit organizations
These groups offer many fundraising ideas and opportunities for a socially-motivated student, class, or school.

http://www.charitywater.org/

http://www.cleanwateraction.org/

http://www.ryanswell.ca/
First grader Ryan Hreljac was inspired by a classroom lesson about children who don’t have clean water around the world and began raising money to provide it. Over ten years later, his Ryan’s Well Foundation is still very active. At this site, children and youth can learn about fundraising projects and ways to get involved so that everyone in the world can have clean water.

http://thewaterproject.org

http://www.waterforpeople.org

A Comparative Study of Surface Water Quality with Dietary Connections

Sample Data Collection Sheet GRADES 9-12

Name ____ **Date** ________________

Team _____________________________

Site Tested ____________________________________

Parameter Tested ________________________________

Date, Time	Reading	Comments

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Discussion Question Sheet GRADES 9-12

Name ____ **Date** ________________

Team ____________________________

Directions: Research, reflect upon, and discuss the following questions with your team members. Be prepared to include this information in your letter to local officials.

1. How clean are the recreational and livestock/farmland areas sampled in your study? Be specific for each parameter tested. Note any extenuating circumstances that may have skewed results to differ from your predictions. Discuss limits of accuracy and precision and any sources of error.

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2. Considering your results and the information presented in Tables 1-3 from this lesson and those in Chapter IV of *Livestock's Long Shadow*, what connections exist between dietary preference, water pollution, and water usage?

Possible answers to discussion questions:

1. Answers may vary. Assuming the state park waterbody has not experienced run-off from local farms or livestock facilities, expected results should be in the normal range for all parameters tested. The pH should be close to 7; turbidity, and concentrations of nitrate and phosphate should be low. Coliform bacteria and antibiotic levels should be negligible or non-existent. Close to a farm, pH may be higher or lower depending on if a limestone bed is present, if acid rain is prevalent, etc. Turbidity should be higher. Some coliform bacteria and antibiotics may be detectable. Nitrates and phosphates should be higher. DO should be lower and BOD should be higher than state park waters in most cases. Recent manure applications and heavy rains should exacerbate levels, possibly in both the park and near the farm, making DO lower; and [nitrate], [phosphate], [antibiotic], and BOD higher.

Possible limits to the reliability of results include: inaccurate and/or imprecise measurement tools; inexact readings (human error); and slight differences in sampling location and time.

2. Tables 1-3 show how much more water is used to produce livestock products including meat, milk, and eggs than is to produce foods typical in vegetarian and vegan diets such as grains, legumes, vegetables, and fruits. Compounding the problem of significantly greater water use is the larger amount of freshwater pollution contributed by livestock as tables in Chapter IV of *Livestock's Long Shadow.*