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EPA ENVIRONMENTAL EDUCATION

NON-POINT SOURCE POLLUTION

GRADE LEVEL: 4 – 7

BACKGROUND: This activity is designed to demonstrate to students what an average storm drain collects during a rainfall event and how the water from storm drains can impact the water quality and aquatic environments of local streams, rivers, and bays.

MATERIALS NEEDED:

"Waterway"	"Pollutants"
Aquarium	Green Food Coloring (pesticides/fertilizer)
Rectangular Box	Vegetable Oil (motor oil)
Water	Soil/Sand/Pebbles (erosion)
Watering Can	Grass Clippings (or Shredded Paper) and Twigs
Spray Bottle	Cafeteria Waste and Trash

PREPARATION: Fill the aquarium half-way with water and place it on an accessible area where it can be easily viewed by the students. Cut a hole in the bottom of the box and place the box on top of the aquarium. The box represents the storm drain and the aquarium represents the waterway that the storm water mixes into after entering the storm drain. Leave the sides of the aquarium uncovered so that the students can view its contents.

PROCEDURE:

1. Introduce this activity with a discussion of storm drains and storm drain systems and their purposes. Discuss where the water and objects that float down into a storm drain go. Have students list all of the things that they can think of that might enter a storm drain during a rain storm.

2. Assign a group of students to each pollutant. Discuss each pollutant, including its use or origin and how it could enter the storm drain.

3. Have each group of students place their pollutant into the storm drain. Use the watering can to create rain to wash the pollutant into the waterway. While washing each pollutant into the waterway, review the pollutant and its use or origin. Discuss the following questions: How does the pollutant damage the environment? Do the people who are responsible for the pollutant want to damage the environment? Why did they do what they did? How can this type of pollution be stopped?

4. After adding all of the pollutants, examine the contents of the waterway. Discuss how the waterway has changed and how viewing this change makes the students feel.

FOLLOW-UP QUESTIONS:

1. What types of the pollution are natural?

2. What types of pollution are added by people living in the local communities?

3. How can we remove the pollution from the water?

4. What could be done to stop pollutants from entering storm drains?

VARIATIONS: Have the groups of students responsible for the pollution think of ways to remove the pollution from the aquarium. Try some of the removal methods. Which pollutants were easy to remove? Which were difficult to remove?

HARMFUL ALGAL BLOOMS LESSON PLAN

Bad Algae!

Theme

Human Health Hazards

Links to Overview Essays and Resources Needed for Student Research

http://oceanservice.noaa.gov/topics/coasts/hab
http://www.hab.nos.noaa.gov/
http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca

Subject Area

Life Science

Grade Level

9-12

Focus Question

What are harmful algal blooms, and what can be done about them?

Learning Objectives

- Students will be able to define and describe harmful algal blooms.
- Students will be able to compare and contrast ways in which algal blooms may be harmful.
- Students will be able to describe actions that can be taken to reduce the impact of harmful algal blooms.

Materials Needed

- (optional) computers with internet access; if students do not have access to the internet, direct them to local library resources and/or print Harmful Algal Bloom information from *http://www.cop.noaa.gov/sressors/extremeevents/hab/habhrca* and provide copies of these materials to each student or student group.

Audio/Visual Materials Needed

None

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of 3-4 students

Maximum Number of Students

32

Key Words

Harmful algal blooms
Paralytic shellfish poisoning
Ciguatera
Pfiesteria
Red tide
Brown tide
Amnesic shellfish poisoning
Diarrhetic shellfish poisoning
Neurotoxic shellfish poisoning
Harmful cyanobacterial blooms

Background Information

Algae are critical to life on Earth. Because they are able to convert solar energy into chemical energy through photosynthesis, algae are key primary producers in many marine food webs (that is, they provide the primary energy source for many other marine organisms). Oxygen is another product of photosynthesis, and single-cell algae (phytoplankton) living in the ocean are responsible for half of the oxygen produced on Earth. There are thousands of species of beneficial algae; but there are also a few dozen species that cause problems. These species become noticeable during periodic events known as "harmful algal blooms" (HABs). In the last two decades, HABs are estimated to have caused as much as $1 billion in losses to coastal resources and communities.

The specific events that accompany HABs vary depending upon the species of algae involved. In some cases, algae grow at unusually rapid rates and overgrow other species, alter

habitats, or deplete oxygen (even though the algae produce oxygen while they are alive, large amounts of decaying algae can consume enough oxygen to cause a net depletion). Rapid growth of phytoplankton may produce enough cells to discolor the water. When discoloration occurs, the event is often called a "red tide," even though the actual discoloration may be green, yellow, or brown, as well as red; and the event has nothing to do with tides. Some algae are capable of producing powerful toxins that are harmful or deadly to other species. Observed impacts of HABs may include fish kills, injuries to marine invertebrates, and human illness or death.

The causes of HABs are not fully understood. In some cases, environmental changes such as alteration in water flow or water temperature have been observed to coincide with HABs. To live and grow, all plants need certain chemicals known as nutrients. Nitrates and phosphates are familiar examples. In many aquatic ecosystems, nutrients are scarce and this limits plant growth. When additional nutrients are added by various types of water pollution, this control is removed, often resulting in rapid growth of aquatic plants. When these plants die, the large mass of decaying vegetation depletes oxygen in the water and damages many other organisms in the system. Scientists suspect that increases in nutrients may also play a role in some HAB events.

HABs are becoming a global threat to living resources, fishing, tourism, and human health because the number and intensity of these events appear to be increasing in many countries. In 1987, the United Nations established a program focussed specifically on HABs and their impacts. In the United States, a research program on the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) was launched in 1995 to develop methods for predicting where and when HABs are likely to occur, as well as techniques for preventing and controlling these events. The National Centers for Coastal Ocean Science (an office of the National Ocean Service) is the primary administrator of ECOHAB, and sponsors the program in partnership with the National Science Foundation, EPA, NASA, and the Office of Naval Research.

In this activity, students will investigate eight types of HABs, including an example of how scientific perspectives can change rapidly as a result of new research.

Learning Procedure

1.

Briefly review the basic biology and consequences of harmful algal blooms.

2.

Assign one of the following types of HABs to each student group:

- Brown tide
- Amnesic Shellfish Poisoning
- Diarrhetic Shellfish Poisoning
- Neurotoxic Shellfish Poisoning
- Paralytic Shellfish Poisoning
- Ciguatera fish poisoning
- Harmful Cyanobacterial Blooms
- *Pfiesteria piscicida*

Tell students that their assignment is to prepare a written report on their assigned topic that includes the following information:

- What type(s) of organisms are responsible?
- What are the observed ecological, economic, and social impacts?
- What species are affected?
- What are possible causes?
- What can be done to reduce, eliminate, or manage this type of HAB?

3.

Have each student group summarize and discuss their research. Discussions should include the following points:

- Brown tides are caused by golden-brown algae. *Aureococcus anophagefferens* and *Aureoumbra lanunensis* have been identified from these events. Microscopic drifting animals (zooplankton) that normally feed on phytoplankton seem to lose their appetite during brown tides. An algal bloom can significantly reduce the amount of sunlight that would normally reach plants growing beneath the water's surface, killing them. Widespread deaths among blue mussel and

bay scallop populations also have been associated with brown tides. Some brown tide events have coincided with changes in the flow of groundwater, suggesting that nutrient input may be involved.

- Amnesic Shellfish Poisoning (ASP) is caused by two species of diatoms (single-cell algae with glass-like shells). *Pseudo-nitzschia multiseries* and *P. australis* produce the toxin domoic acid, which can cause permanent loss of short-term memory, and may be fatal to some victims. Domoic acid has been detected in shellfish and in the organs of fish and crabs. In 1998, 70 California sea lions were fatally poisoned by domoic acid. Pelicans and cormorants have also been affected.

- Diarrhetic Shellfish Poisoning (DSP) is associated with a variety of phyoplankton species (including *Dinophysis acuminata*, *Dinophysis fortii*, and *Prorocentrum lima*) and a variety of toxins (including okadeic acids, pectenotoxins, yessotoxins, and dinophysistoxins). Affected species include mussels, oysters, scallops, and humans who consume contaminated shellfish. Symptoms in humans include nausea, vomiting, abdominal pain, and diarrhea.

- Neurotoxic Shellfish Poisoning (NSP) is caused by dinoflagellates (single-cell algae that have two whip-like flagellae that enable the algae to swim). The dinoflagellate species *Karenia brevis* produces brevetoxin, which affects manatees, bottlenose dolphins, oysters, fish, clams, and birds. Humans are exposed to the toxin by eating shellfish that have fed on toxic algae or by breathing seafoam containing the toxin. Symptoms include diarrhea, vomiting, neurologic symptoms such as tingling fingers or toes, and asthma-like symptoms if the toxin is inhaled. There is no known antidote, but most victims recover within a few days.

- Paralytic Shellfish Poisoning (PSP) is caused by a toxin, saxitoxin, produced by algae belonging to the genus *Alexandrium*. Affected species include mussels, clams, crabs, oysters, scallops, herring, sardines, marine mammals, and birds. Humans are exposed by eating contaminated shellfish. Symptoms include numbness, paralysis, and respira-

tory failure. There is no known antidote, and death from respiratory arrest may occur within 24 hours.

- Ciguatera fish poisoning (CFP) is caused by toxins (ciguatoxin and maitotoxin) produced by dinoflagellates that live in coral reef communities (particularly *Gambierdiscus toxicus*; other species implicated include *Amphidinium carterae*, *Coolia monotis*, and several others in the genera *Prorocentrum*, *Ostreopsis*, and *Thecadinum*). The toxins are transferred through the food chain and accumulate in the flesh of carnivorous fishes. If consumed by humans, CFP may causes nausea, vomiting, and neurologic symptoms such as tingling fingers or toes and sometimes reversal of heat and cold sensation (cold things feel hot, etc). There is no cure for CFP, and symptoms may last for years but are rarely fatal.

- Harmful Cyanobacterial Blooms (HCB) result from excessive growths of certain species of cyanobacteria (blue-green bacteria, formerly thought to be blue-green algae). Cyanobacteria are generally beneficial and are believed to have been responsible for producing the oxygen that changed the Earth's atmosphere more than 2,000 million years ago. A few species (including *Anabaena*, *Aphanizomenon*, and *Microcystis*), however, produce toxins that affect nerves, liver tissues, and other cells in a variety of mammals, birds, fishes, and invertebrates. These toxins are stored in the cells of the cyanobacteria and can be released into the surrounding water when the bacterial cells rupture or die. Humans can be exposed to cyanobacterial toxins by drinking or swimming in water containing the bacterial cells and/or toxins, as well as by breathing mists containing the toxins or cells. For example, such mists can be produced by waves breaking on shore, or by watering a lawn with contaminated water. Symptoms of cyanobacterial poisoning include nausea, diarrhea, stomach pain, difficulty breathing, allergic reactions, skin irritation, liver damage, and neurologic symptoms such as tingling fingers and toes. HCBs can also cause increased turbidity and reduced light penetration. This type of shading has been associated with destruction of underwater plants (especially "seagrasses" which are actually flowering plants that grow on the sea bottom), sponge beds and coral reefs.

- Some HABs cause fish kills through mechanisms other than toxicity. The diatom, *Chaetoceros convolutus* has long bristle-like structures called setae and secondary spines that cause the cells to become lodged in fish gills where they cause excessive mucous production that suffocates the fish.

- At present, control strategies center primarily upon predicting HAB events and providing adequate and timely public warning to allow people to avoid contaminated waters. This strategy has been particularly effective in reducing incidences of human exposure to toxins produced by HCB in Australia, and of NSP in Florida through the use of satellite imagery to detect algal blooms (visit *http://www.nccos.noaa.gov/news/june02.html* for more information).

- *Pfiesteria piscicida* is a dinoflagellate that is often included in discussions of HABs, because it has been linked to several well-publicized fish kills. Moreover, a number of commercial fishermen have reported health effects including flu-like symptoms, skin rashes, and memory loss. Since *Pfiesteria* was only discovered in 1988, relatively little was known about this organism at the time of the fish kills. Early studies reported that *Pfiesteria* had a highly complex life-cycle with 24 reported forms, a few of which (the amoeboid phases) were capable of producing toxins. Because the fish kills had significant economic impact and no one really knew how serious the threat from *Pfiesteria* might be, federal and state agencies gave high priority to learning more about this alga and the risks it might pose to public health.

  One problem with these studies was that it was not always possible to be certain which organisms in water samples were actually *Pfiesteria*; remember that researchers thought there were 24 possible forms of this one species. This problem was solved with a new molecular research technique using a fluorescent chemical that would bind only to a sequence of genes unique to *Pfiesteria piscicida*. Organisms containing this chemical glow brightly under infrared light. Since only *Pfiesteria* organisms can contain the chemical, it was easy to distinguish these organisms from other species.

Using this tool, researchers discovered that many of the forms thought to be part of *Pfiesteria's* complex life-cycle were actually other species. The researchers concluded that *Pfiesteria* has a simple seven-stage life cycle typical of other dinoflagellates found in coastal waters. No amoeboid phases were observed. Moreover, amoebae were isolated from a tank containing *Pfiesteria* and in which fish kills had been observed. During a two-year study, none of the amoebae transformed to *Pfiesteria*. Since the amoeboid life cycle stages were the ones that were supposed to be toxic, it is now much less certain that *Pfiesteria* forms HABs. Visit *http://coastalscience.noaa.gov/news/press/nccos/062002.html* for more details.

The case of *Pfiesteria* is a good example of how new techniques can provide new evidence that can quickly alter scientific perspectives. Ask students whether they think it was reasonable to undertake an accelerated research program to learn more about *Pfiesteria*. Be sure students understand that the case is not yet closed; there is still the question of what caused the fish kills and human symptoms. Additional research may reveal that *Pfiesteria* can indeed produce harmful toxins under the appropriate environmental conditions.

The BRIDGE Connection

http://www.vims.edu/bridge/ – Type "HABs" in the Search box to retrieve links about harmful algal blooms.

The Me Connection

Have students list three actions they could take to avoid being a victim of HABs.

Extensions

1.

Visit *http://coastalscience.noaa.gov/news/feature/0604.html* for information on how autonomous underwater vehicles are being developed to detect and monitor HABs.

2.

Visit *http://www.bigelow.org/edhab/index.html* for additional educational activities involving HABs.

Resources

http://www.habhrca.noaa.gov/habfacts.html – Fact sheet on HABs from the National Centers for Coastal Ocean Science

http://oceanservice.noaa.gov/websites/retiredsites/sotc_pdf/hab.pdf – "State of the Coastal Environment" essay on HABs

http://www.cdc.gov/nceh/hsb/algal.htm – *Pfiesteria piscicida* and other harmful algae information from the Health Studies Branch of the Centers for Disease Control and Prevention

http://www.whoi.edu/redtide/ – The Harmful Algae Page of the National Office for Marine Biotoxins and Harmful Algal Blooms at Woods Hole Oceanographic Institution

http://www.bigelow.org/hab/organism.html – Web site provided by the Bigelow Laboratory for Ocean Sciences on toxic and harmful algal blooms

http://www.nccos.noaa.gov/news/pfiesteria_press.html – New NOAA Research Sheds Light on *Pfiesteria* Life Cycle (National Centers for Coastal Ocean Science)

http://www.hab.nos.noaa.gov/pfiesteriafacts.html – What about *Pfiesteria*? (National Centers for Coastal Ocean Science)

National Science Education Standards

Content Standard A: Science as Inquiry

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

Content Standard C: Life Science

- Interdependence of organisms
- Behavior of organisms

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- Environmental quality

- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science

- Nature of scientific knowledge

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H1

Ecosystems can be reasonably stable over hundreds or thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.

5D/H3

Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

FOR EDUCATORS - LESSON PLANS

WATER POLLUTION HOT-SPOTS

Grade Level: 6-8, although it could be adapted for other grade levels
Subject: Environmental Science
Time Allotment: Six to seven 45-minute class periods

Pollution has a profound effect of water worldwide. In this lesson, students will learn about pollution and different types of contaminants found in water. They will then research some of the world's most polluted water hot-spots and devise plans for pollution prevention.

LEARNING OBJECTIVES

Students will be able to

- Relate a method of pollution prevention through words and art
- Name water contaminants
- Describe different causes of water pollution
- Examine the causes of pollution in the world's most prominent pollution hot-spots
- Design a plan for preventing water pollution
- Assess the quality and effectiveness of water pollution prevention plans

MATERIALS

- Internet access
- Dictionaries
- Science journal
- Poster board
- Construction paper
- Computer paper
- Crayons
- Markers
- Other art supplies

HANDOUTS

- Water Contamination Chart
- Water Pollution Hot-Spot Investigation
- Pollution Hot-Spot Notes

BOOKMARK THE FOLLOWING SITES

- **U.S. Environmental Protection Agency: Ground Water & Drinking Water**
  http://www.epa.gov/safewater/index.html
  Use the Office of Ground Water and Drinking Water site to learn what federal and local governments are doing to ensure safe drinking water and protect ground water.

- **BBC News**
  http://news.bbc.co.uk/1/hi/sci/tech/4083331.stm
  View a world map and read brief summaries of some of the places around the world that are hardest hit by pollution.

- **University of Michigan: Water Pollution and Society**
  http://www.umich.edu/~gs265/society/waterpollution.htm
  Read a comprehensive website on water pollution and society, complete with photographs, diagrams of contamination and a wastewater treatment plant, and charts of the world's pollution.

- **United States Geological Survey**
  http://ga.water.usgs.gov/edu/wuww.html
  Learn about wastewater treatment from the United States Geological Survey.

- **Environment Canada**
  http://www.ec.gc.ca/water/en/manage/poll/e_poll.htm
  Find out what Canada is doing to solve the water pollution problem.

- **Shawnee County Conservation District, Topeka, Kansas**
  http://www.cjnetworks.com/~sccdistrict/resubwt.htm
  Read about preventing urban water pollution.

ACADEMIC STANDARDS
http://www.mcrel.org/compendium/browse.asp

- **Science, Standard 2, Level III**
  Understands Earth's composition and structure.

- **Science, Standard 5, Level III**
  Understands the structure and function of cells and organisms.

- **Science, Standard 6, Level III**
  Understands relationships among organisms and their physical environment.

- **Geography, Standard 8, Level III**
  Understands the characteristics of ecosystems on Earth's surface.

- **Geography, Standard 14, Level III**
  Understands how human actions modify the physical environment.

- **Geography, Standard 18, Level III**
  Understands global development and environmental issues.

PROCEDURES FOR TEACHERS:

BUILDING BACKGROUND
(1 class period)

STEP 1

Teacher explains that pollution can be in many forms: toxic substances, organic substances, thermal, and ecological. It comes from primarily three sources: businesses, homes, and farming.

Students brainstorm and share ways the three sources cause water pollution. Students take notes on these causes in their science journals.

Sample answers might include:

Farms:

- Farms often use large amounts of herbicides and pesticides, both of which are toxic pollutants. These substances seep into rivers, streams and lakes, and toxic substances can build up over a period of time.
- Farms also frequently use large amounts of chemical fertilizers that are washed into the waterways and damage the water supply and the life within it.
- Allowing livestock to graze near water sources often results in organic waste products being washed into the waterways.
- Runoff from the exposed soil of agricultural fields can contaminate groundwater.

Business:

- Clearing of land can lead to erosion of soil into the river.
- Waste and sewage generated by industry can get into the water supply.
- Many industrial and power plants use rivers, streams and lakes to dispose of waste heat. The resulting hot water can cause thermal pollution. Thermal pollution can have a disastrous effect on life in an aquatic ecosystem because increasing temperature decreases the amount of oxygen in the water, thereby reducing the number of animals that can survive there.
- Toxic or radioactive materials from industry, mine sites and abandoned hazardous waste sites can seep into groundwater.
- Burning fuels causes acid rain that falls into lakes, streams, and ponds. Because of this, air pollution is potentially one of the most threatening forms of pollution to aquatic ecosystems.

Homes:

- Sewage generated by houses or runoff from septic tanks can get into nearby waterways.
- Fertilizers, herbicides and pesticides used for lawn care can run off and contaminate the waterway.
- Improper disposal of hazardous chemicals down the drain put toxic materials in the ecosystem.
- Leaks of oil and antifreeze from a car on a driveway can be washed off by the rain into nearby waterways.

STEP 2

Students go to the Environmental Protection Agency's web page about drinking water standards (http://www.epa.gov/safewater/mcl.html) where they access the list of contaminants and their Maximum Contaminant Level (MCLs).

Teacher explains that contaminants are anything that is found in water, air, or soil, which may be harmful to human or animal health.

Students fill in the Water Contaminants Chart using information from the EPA website and a dictionary.

In small groups of 4-5, students discuss the Water Contaminants Chart, then a spokesperson from each group shares with the whole class.

LEARNING ACTIVITY 1

Research and Investigation (2 class periods)

STEP 1

Divide the class into 7 groups. Assign each group a location from the list of the world's pollution hot-spots:

- Gulf of Mexico, USA
- The Arctic
- Northern Spain
- Chernobyl, Ukraine
- Aral Sea, Kazakhstan and Uzbekistan
- Japan, Whales and Dolphins
- River Tisza and Baia Mare, Romania

Student groups use the Internet and other sources to research their assigned pollution hot-spot.

Students complete the Water Pollution Hot-Spot Investigation worksheet.

STEP 2

Small research groups prepare a 5-minute presentation of their pollution hot-spot.

STEP 3

Groups present research to the class. The class takes notes on all pollution hot-spot locations using the Pollution Hot-Spot Notes handout.

LEARNING ACTIVITY 2

Pollution Prevention Posters (2-3 class periods)

STEP 1

In their science journals, students brainstorm the ways people can help prevent water pollution.

Students share their ideas with their research group. Then the teacher facilitates a class discussion about the different ways people can help prevent water pollution. Use specific examples from the pollution hot-spots. List the ideas on the board.

STEP 2

In the 7 small research groups, students create a poster showing at least one way to prevent water pollution. Teacher encourages students to think about the source of the pollution and ways to prevent or dispose of pollutants.

CULMINATING ACTIVITY

Gallery Walk (1 class period)

STEP 1

Teacher places the pollution prevention posters around the room and instructs the students to walk around the room and appreciate all the posters.

STEP 2

Teacher places pads of sticky notes next to each poster and instructs the students to view all the posters again, but this time writing at least one positive and/or constructive comment and sticking the comment(s) to the edge of the poster. Students are instructed to place at least one comment on every poster.

Hang the posters on the walls of the classroom.

EXTENSION ACTIVITY

- Build an aquifer using 2 plastic cups, sand, gravel, and water.
- Visit a local wastewater treatment plant or wetland area.

- Investigate the Exxon/Valdez Oil Spill.