Students simulate a drinking water treatment process in order to better understand the effort and cost involved in meeting water quality standards.

Charting the Course

Use the Warm Up from Project WET's *Reaching Your Limits* prior to this lesson to help students understand parts per million. Review the drinking water quality report for your city.

Objectives

Students will:

- Explain how the distribution of state revenue to provide services might affect water quality.
- Demonstrate the process used to meet drinking water standards through a physical activity.
- Discuss the relationship between water treatment and water quality standards.
- Explain that there is a relationship between clean water and what it costs to keep the water clean and safe for drinking.
- Relate how microorganisms can benefit or harm our water resources.

Materials

- 1 cup of "river water" to begin the lesson (water mixed with sediment, rocks, sand, leaves, etc.)
- Copy of the Georgia Water Quality Report from http://water.epa.gov/drink/local/ga.cfm (also available annually for your city using a web search)
- Cones or flags to mark field area
- 21 small open containers (buckets, bowls or tubs) to hold the contaminants and additives cards. Provide one container for each contaminant and additive
- Contaminant and Additive cards, cut apart and laminated, enough for one of each per student, (pages 23-24)
- Clips or tape to affix contaminant and additive labels to each container
- 2 hula hoops to simulate pipe entrance and exit
- 4 large cards labeled coagulation, sedimentation, filtration, and disinfection, and a copy of small process chart for Treatment Plant Manager (pg. 19)
- 1 whistle for the Treatment Plant Manager

For each student:

- 1 Contaminant and Additive Class Total score card (pg. 26)
- 2 resealable baggies, one labeled "C" for contaminant and the other labeled "A" for additive.
- pencil or crayon
- 1 student standards score card (pg. 25)

Making Connections

Students may be aware that clean water comes from the faucet but they may have no idea how that happens and who sets the standards for safety and quality. They may not have thought about the connection between clean water, health, and cost to the consumer that comes with drinking water treatment.

Background

Each day Georgia's cities supply over a billion gallons of treated drinking water to residents. Most of the water processed is surface water that is pumped from a river. Some cities, such as Savannah and Brunswick, get their drinking water from groundwater or aquifers.

Drinking water, no matter its source, must meet or exceed all safety and quality standards set by the State of Georgia and the U.S. Environmental Protection Agency (EPA). Since 1970 the EPA has had the responsibility to protect the quality of the American environment and control the effects of pollution on public health. There are also laws that help protect citizens concerning water quality. The ***Federal Water Pollution Control Act*** was amended and became a law known as the ***Clean Water Act in 1977***. The Clean Water Act established the structure for regulating discharges of pollutants into the waters of the United States. It gave EPA the authority to implement pollution control programs such as setting wastewater standards for industry. The Clean Water Act also mandated requirements to set water quality standards for all contaminants in surface waters. The Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters,

unless a permit was obtained under its provisions. It also funded the construction of sewage treatment plants under construction grants programs and recognized the need for planning to address the critical problems posed by **nonpoint source pollution** (pollution carried by runoff during heavy rains that ends up in storm drains and eventually our waterways where the source is not easily identifiable).

Another law that protects our water quality in Georgia is the **Safe Drinking Water Act (SDWA)**, which requires water systems to monitor for unregulated parameters in order to assist the EPA in determining where certain contaminants occur and whether additional regulations may be necessary. Annually, over 12,000 samples of untreated (raw) and treated (finished) water are collected and over 50,000 tests are conducted that screen for more than 150 potential contaminants. Water quality standards are set and contaminants are carefully monitored. Each contaminant has a standard or level at which it can be in the water without causing harm to human and aquatic health.

Stormwater is a major contributor to contaminants in a river. As stormwater travels over various surfaces it picks up contaminants along the way. These contaminants include: bacteria and viruses, pesticides and herbicides from agriculture and lawn care, stormwater runoff that carries many types of nonpoint source pollution, salts and metals from industrial or domestic wastewater discharges, oil and gas production, sediment from erosion and development, organic chemicals from urban runoff, septic tank pollutants, and radioactive waste from oil/gas production and mining.

To remove contaminants from the water, the raw river water enters the water treatment plant pipe. Control room operators add lime for pH control, potassium permanganate for disinfection, and powdered carbon for taste and odor control. Then the alum and other chemicals are added to the water causing coagulation to occur. Tiny sticky particles form that are called “floc” and the “floc” attracts other particles. The “floc” finally gets heavy and settles to the bottom during sedimentation. The clear water moves to the filtration process where water passes through filters that help to remove even smaller particles. The next step is disinfection where a small amount of chlorine is added to kill any remaining bacteria or microorganisms, phosphate to prevent any corrosion contamination, and fluoride to prevent tooth decay. Water is then placed in a closed tank or reservoir and sent on through the water delivery system that takes water to homes, schools, and businesses in the community.

Preparation

Use the contaminant and additive copy pages and make enough contaminant cards so that each student will have at least 14 different contaminants in his/her contaminant baggies marked “C” and make at least one additive card of each per student that can be gathered on the field.

Designate a field area for the water treatment facility and place cones or flags around the perimeter of the area. Make the field area large enough to accommodate the 14 contaminant containers and the 7 additive containers and enough space for students to move around freely, the larger the space, the more difficult the challenge to clean the water.

Place 14 containers in the center of the field randomly, each labeled with a different contaminant. (See field diagram).

Set up 4 additive containers near the beginning of the water treatment facility/field area labeled carbon, lime, potassium, and alum and 3 near the end of the treatment process to represent the additives in the disinfection area. Label these fluoride, chlorine, and phosphate. Make the additive areas look different from the contaminant area. Use different colored containers or labels to help students distinguish between contaminants and additives. Place the additive cards in the matching containers. There should be at least one additive card for each student in each container. Students will pick up one additive from each area and add it to their additive bag during treatment.

Procedure

Warm Up

1. Begin by asking students if they have standards they set for themselves. Write their answers on a board. Explain that there are also standards for water quality that are set by laws and by the State of Georgia.

2. Use the warm up activity in the lesson ***Reaching Your Limits*** **from the Project WET Curriculum and Activity Guide.** The warm up activity gives students a visual of what parts per million might look like. Since removing all the pollutants is economically impractical, explain that the government sets standards to define how much of each pollutant is allowable in the water while remaining at safe levels for human health. Most of these standards are set in parts per million (ppm) or parts per billion (ppb).

3. Hold up the glass of "river water" and ask students if they would like to drink it. Ask them why they wouldn't like to drink it. Tell the students that it is easy to say no when you see the sediment, rocks, wood, litter, debris etc. but what if it contained contaminants you couldn't see, like bacteria or chemicals? This is why water treatment is necessary. Ask students what has to be done to the river water prior to becoming the drinking water that comes from their faucets.

Activity (Field Portion)

1. Tell students they are going to do an activity that simulates the effort required to clean water for drinking and meeting water quality standards. Brainstorm possible contaminants they might find in raw water prior to water treatment. **Tell them they are going to be raw water from the river and will go through water treatment.** They will try to get rid of their contaminants and pick up the additives that help clean the water.

Use the glossary at the back to review vocabulary.

2. Select a Water Treatment Manager (or use an adult). The remaining students in the class will represent raw water in the field activity and the Water Treatment Budget Managers in the class portion of the activity. The Water Treatment Manager is in charge of the movement through the process. The Manager begins by having everyone enter the field through a hula hoop

to represent water moving through a pipe from the river. Water students will also leave the field through a hula hoop at the end of the treatment process for distribution to homes, schools and businesses. At the end the Treatment Manager will also collect all of the completed contaminant scorecards. Managers are held accountable for standards and for any fines.

Give the four large process cards labeled **coagulation, sedimentation**, **filtration**, and **disinfection** and this chart to the Treatment Manager:

Blow Whistle, hold up Sign and Shout:	Water Student Action
COAGULATION	Immediately hold hands with 2 other students and walk together to the next stations
SEDIMENTATION	Drop the hands of the floc group and will sit down and count to 10, which represents the settling of particles on the bottom
FILTRATION	Circle at least 3 other students to represent filtration of the water.
DISINFECTION	Go to the 3 containers at the end of the field and gather phosphate, chlorine, and fluoride before going to storage tanks and then to homes, schools, and businesses

3. Select a time keeper to give the water students 5 minutes to move through the treatment plant. To provide more safety have the students walk through the water treatment area.

4. Give each water student a baggy marked with a "C" containing the 14 contaminant cards. Ask students to find a contaminant in their bag and read it to the class. Ask the class where the contaminant might come from. *You can have students do research on the contaminants ahead of time by going to -- http://www.epa.gov/safewater/hfacts.html*

5. The water students will also each have a baggy marked with an "A" that has nothing in it. This is the additive bag and will be used to gather one each of the additives.

6. Lead students to the field area and give these instructions: *"You are now "raw" water moving through water treatment and you will need to get rid of the contaminants in your bag in the next few minutes.*

"You will walk/run to the buckets and drop in the ***contaminant*** *that is labeled for that bucket. Fecal Coliform goes in the Fecal Coliform bucket and Oil goes in the Oil bucket for example.*

"You will also have to pick up ***additives*** *that the treatment plant puts in the water to disinfect, or to protect your teeth or to make the water clump together for example. There are 7 additives all together, 4 up near the front in the pre-treatment process that include: lime, alum, potassium, and powdered carbon, and three at the end that are picked up when the manager shouts* ***'disinfection'*** *before finished water leaves the treatment plant. You will need to get one of each of these additives and put it in your additive bag 'A'****.***

*"At the same time you are moving, you will go through the treatment process. The Water Treatment Manager will blow a whistle and say "****COAGULATION****". That means that something is added to the water to create a clumping of particles that is called 'floc'****. Immediately hold hands with 2 other students and walk together to the next stations."***

*"Then the water treatment manager will blow a whistle and will say '****SEDIMENTATION****.* ***You will drop the hands of the floc group and will sit down and count to 10, which represents the settling of particles on the bottom.*** *Then you can resume visiting the containers.*

"Then the water treatment manager will blow the whistle and say ***'FILTRATON.'*** ***You will weave around at least 3 other students to represent filtration of the water.***

"Finally the water treatment manager will blow the whistle and say ***'DISINFECTION.' All raw water students must go to the 3 containers at the end of the field and gather phosphate, chlorine, and fluoride before going out the pipe to storage tanks and then to homes, schools, and businesses****."* Practice these movements with the students.

7. When students have released contaminants and have picked up their additives they can pass through the pipe (hula hoop) at the end of the treatment plant area. The timekeeper calls time. Some students may not have finished the course.

8. **At the end of the time period each water student will count the contaminants in their bag and check them off on the contaminant scorecard. They will also record the additives they do not have.** If any additives are missing, put an X on those that are missing. The Water Treatment Plant Manager will collect all the completed scorecards to compile the data and see if they have met standards. Return to the classroom.

Activity (Classroom Portion)

Tell the class that they are now part of the water treatment staff and have a budget for the year. The water treatment facility budget is $50,000 for the year.

Ask the students to look at their contaminant and additive Student Standards Scorecards. Remind them that water treatment must meet water quality standards set by the State and by EPA.

1. Ask the class to raise their hands if they had OIL left as a contaminant and record the total number on the board.

Continue to record the class totals for each contaminant. Note on the contaminant score card that each contaminant has a standard and it will say 20 ppm

or 10 ppm for example. That means in this activity that the treatment plant cannot exceed more than 20 ppm of that contaminant or it will not be an acceptable standard and be considered unsafe and unhealthy for consumption and out of compliance with the law. **Therefore the plant will be fined according to the amount listed for every number over 20.**

If Oil is listed at 12 ppm and the class had 10 Oils total, the treatment for oil met standards. However if the standard for oil is 10 ppm and the class totaled 15 ppm, the Oil is 5 over the limit. The fine is $50.00 for each number over the standard. The treatment plant is fined **5 X $50.00 = $250.00** just for oil. **Ask the students to get out their Contaminant and Additive Total Worksheet. They should work through the rest of the totals for each contaminant. Point out that Very Toxic Contaminants cost $1000 for each point over the standard!**

2. For every additive missed add another $50.00.

3. When the total fine is assessed then the treatment plant will determine if they can pay the fine within their budget ($50,000 for the year).

Wrap Up

Each standard has a number of parts per million that is acceptable. If they go over that number during treatment they will be fined by the State EPD (Environmental Protection Division). They will add up the money that must be paid if they are out of compliance and not able to clean the water. Since the Water Treatment Plant has no money in the budget to pay a fine, EPD will send the fine to the Mayor. The Mayor will go to the City, the Department of Watershed Management, and ask for the funds. If the City cannot pay the fine, the Mayor and City Council will have to find another way to pay it, which could include a rate increase for citizens. Students can role-play using actors for the City and the Mayor, City Council, and residents. The students in their roles can decide how they will pay for the water treatment upgrades. The Mayor and City Council will have to make the final decision if no one else has a plan.

Have students discuss what expenses might have to be paid out of the water treatment plant's budget besides a fine (energy bill, infrastructure upgrades, employee salaries, etc.). Lead a discussion on why students think a water bill may sometimes need to increase.

Assessments

Ask the students to write the process for their "raw" water journey. What contaminants did they pick up? What additives did they pick up? Did the class meet the standard? How much did it cost the City to clean the water and where did the City get the money to do it? What physical and chemical processes happened along the way? (See rubric on pg. 27)

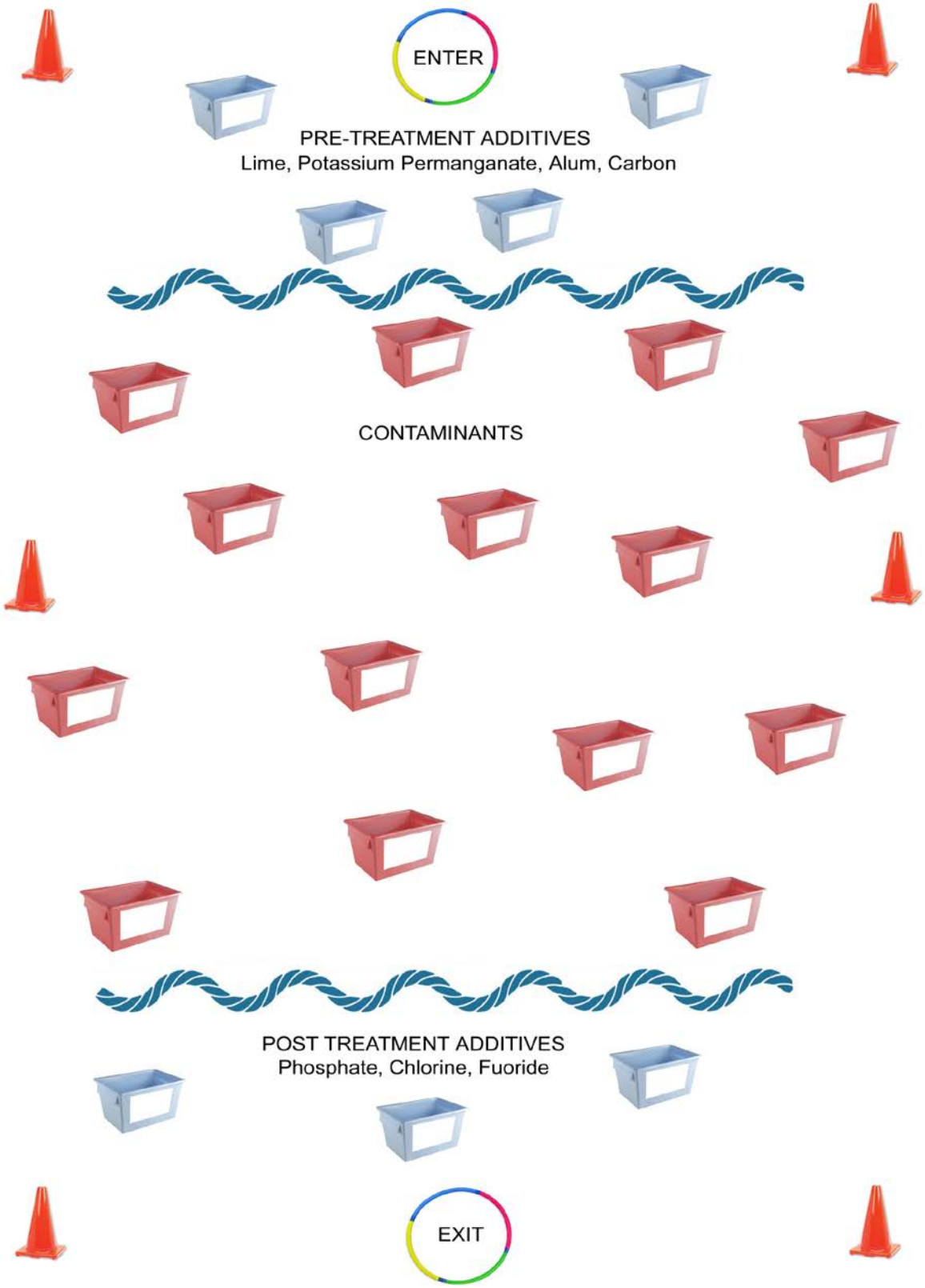
Extension

Choose a drinking water topic to report on from a reliable website such as this EPA site http://water.epa.gov/drink/info. Students could develop models and dioramas that show what they have learned.

Resources

1. National Environmental Services Center/Drinking Water www.nesc.wvu.edu/drinkingwater.cfm
2. US Environmental Protection Division http://water.epa.gov
3. US Geological Society http://ga.water.usgs.gov/

FIELD DIAGRAM FOR WHAT'S YOUR STANDARD?



CONTAMINANTS

Duplicate this page x the number of students onto cardstock. Cut apart and place each set into baggies marked "C".
Enlarge as needed.

CRYPTOSPORIDIUM

OIL

GAS

VIRUS

FLUORIDE (CONTAMINANT)

BARIUM

CHLORINE (CONTAMINANT)

FERTILIZER

TURBIDITY

PESTICIDE

FECAL COLIFORM

LEAD

COPPER

ARSENIC

ADDITIVES

CHLORINE (ADDITIVE)

POTASSIUM PERMANGANATE

LIME

ALUM

PHOSPHATE

FLUORIDE (ADDITIVE)

CARBON

Duplicate this page x the number of students onto cardstock. Cut apart and sort into the additive containers. Enlarge as needed.

STUDENT STANDARDS SCORECARDS

CONTAMINANTS Check off what is still in your "C" bag.	✔
Oil	
Gas	
Fertilizer	
Pesticide	
Lead	
Copper	
Arsenic	
Fecal Coliform	
Cryptosporidium	
Viruses	
Turbidity	
Fluoride	
Chlorine	
Barium	

ADDITIVES X what is missing from your "A" bag.	X
Lime (pH control)	
Potassium Permanganate (disinfection)	
Powdered Carbon (odor/taste)	
Alum (coagulation)	
Phosphate (corrosion control)	
Chlorine (disinfection)	
Fluoride (tooth decay prevention)	

Cut here

STUDENT STANDARDS SCORECARDS

CONTAMINANTS Check off what is still in your "C" bag.	✔
Oil	
Gas	
Fertilizer	
Pesticide	
Lead	
Copper	
Arsenic	
Fecal Coliform	
Cryptosporidium	
Viruses	
Turbidity	
Fluoride	
Chlorine	
Barium	

ADDITIVES X what is missing from your "A" bag.	X
Lime (pH control)	
Potassium Permanganate (disinfection)	
Powdered Carbon (odor/taste)	
Alum (coagulation)	
Phosphate (corrosion control)	
Chlorine (disinfection)	
Fluoride (tooth decay prevention)	

CONTAMINANT AND ADDITIVE CLASS TOTAL

CONTAMINANTS	CLASS TOTAL	STANDARD	Is CLASS TOTAL < = > STANDARD?	IF > STANDARD Then calculate: (Class total)- (Standard)=	FINE: Multiply answer X $50 Very toxic X $1000
Oil (Xylene in water)		10 ppm			
Gas (Dioxin in water)		0 ppm			
Fertilizer (Nitrate in water)		10 ppm			
Pesticide (Alachlor) VERY TOXIC!		2 ppb			X $1000
Lead VERY TOXIC!		15 ppb			X $1000
Copper		1 ppm			
Arsenic VERY TOXIC!		10 ppb			X $1000
Fecal Coliform		0 ppm			
Cryptosporidium		0 ppm			
Viruses		0 ppm			
Turbidity		1 NTU			
Fluoride*		4 ppm			
Chlorine*		4 ppm			
Barium		2 ppm			
Total Contaminant Fine Owed					**$**

ppm = parts per million ppb = parts per billion NTU = Nephelometric turbidity unit

ADDITIVES	# of student that did NOT pick up this additive	FINE: Multiply X $50
Lime		
Potassium Permanganate		
Powdered Carbon		
Alum		
Phosphate		
Chlorine *		
Fluoride *		
Total Additive Fine Owed		**$**

COMBINED FINES = $_____

This is the fine owed by the Water Treatment Plant! Is there enough money in the Budget to pay the fine?

*Chlorine and fluoride can be BOTH contaminants and additives.

ASSESSMENT RUBRIC FOR WHAT'S YOUR STANDARD?

Category	4	3	2	1
Organization	Information is very organized in a well-constructed story; each paragraph has a clear introduction, explanation, and conclusion.	Information is organized in a fairly well constructed story. Most paragraphs have an adequate introduction, explanation, and conclusion.	The paragraphs contain related information, but the story is not well constructed. Introduction, explanation, and/or conclusion sentences are frequently missing.	The information is disorganized. Paragraph structure is not clear and sentences are not typically related within the paragraphs.
Comprehension	Student is able to clearly demonstrate the process used to meet drinking water standards, including the roles of contaminants and additives.	Student is able to demonstrate the process used to meet drinking water standards and the roles of contaminants and additives for the most part.	Student is only partially successful in demonstrating the process used to meet drinking water standards OR only partially understands the roles of contaminants and additives.	Student is unable to successfully demonstrate the process used to meet drinking water standards AND does not understand the roles of contaminants and additives.
Comprehension	Student completely understands the relationship between water treatment and water quality.	Student mostly understands the relationship between water treatment and water quality standards.	Student partially understands the relationship between water treatment and water quality standards.	Student does not understand the relationship between water treatment and water quality standards.
Comprehension	Student clearly understands the economic costs of clean water.	Student mostly understands the economic costs of clean water.	Student partially understands the economic costs of clean water.	Student does not understand the economic costs of clean water.