Reaching Your Limits

Would you like to be considered one in a million? How about one in a billion?

Summary
By playing a game of limbo, students gain a better understanding of the effort involved in meeting drinking-water quality standards—especially when water quality declines.

Objectives
Students will:
- describe the relationship between water quality and water treatment.
- recognize the ratio of one to a million and one to a billion.

Materials
Warm Up
- Four 100 or 250 ml beakers
- Water mixed with blue food coloring
- Clear water
- 10 ml graduated cylinder or pipette

Part II
- 3" x 5" index cards
- Lightweight wood or metal poles, broomsticks or yardsticks
- Ruler

Making Connections
Most students know that water flowing out of municipal faucets has been treated. Drinking water standards are set to ensure that water is potable. Students understand the concept of meeting standards—for example, when a parent expects them to keep their room neat. Students can also relate to the energy involved in cleaning up a dirty room versus that required to tidy up a neat room. Similarly, treating more polluted water to meet water quality standards requires a greater expenditure of money, technology and energy than treating less polluted water. By simulating this process, students will appreciate how important it is that water departments meet standards and provide excellent water to citizens.

Background
In the United States, state and federal agencies determine water quality standards. The U.S. Environmental Protection Agency (EPA) and state environmental protection or health agencies work together to monitor the quality of surface water (streams, rivers and lakes) and ground water sources (aquifers). These agencies and local units of government are responsible for assessing the quality of water, setting acceptable or safe drinking water standards, monitoring the water for changes and recommending water quality improvement practices.

Cities and towns have water quality experts that monitor water quality daily, and every drinking water treatment plant must produce an annual Consumer Confidence Report (CCR). CCRs document the average measured levels of contaminants—chemicals, metals or other substances that can pollute water. CCRs are available to all consumers and can be found in local newspapers, on the Internet or at local water treatment facilities.

Contaminants are measured to ensure that their concentrations—the mass of chemical and other pollutants per unit volume of water—do not exceed the Maximum Contamination Level (MCL) established by
the EPA. It is important to monitor these contaminants because some of them can cause health problems when they exceed the MCL. Concentrations of contaminants can vary widely, and some are more harmful (or toxic) than others, even at very low concentrations (e.g., arsenic, lead, mercury, cyanide). Some contaminants that pose less risk to human health may be regulated by what are known as secondary MCLs. These contaminants include iron, fluoride, and aluminum. Though secondary MCLs are not federally regulated, many are regulated by state laws.

Water quality standards are based on the assumption that drinking water with concentrations of organic or inorganic compounds above a designated limit could cause health problems. Scientists measure and report water contaminants in parts per million (ppm), parts per billion (ppb) and parts per trillion (ppt). Although these numbers may seem to identify extremely small concentrations, some chemicals and other pollutants are potentially harmful even at low levels. For example, people can smell petroleum products in water at concentrations as low as 10 parts per billion.

Treating drinking water involves filtering the water, allowing sediments to settle and adding a disinfectant (such as chlorine) to kill bacteria and other pathogens. Sources of drinking water include surface water such as reservoirs, rivers and lakes and ground water.

In addition to the chemicals that treatment plants add in order to disinfect water, human activities sometimes inadvertently add chemicals to water sources (e.g., urban and agricultural runoff, discharge from industrial plants). Chemicals can also occur naturally. In some areas of the country, the natural or baseline water quality of a river, lake or aquifer may have high levels of certain chemicals; for example, if the rock material surrounding the water contains a high concentration of a certain compound (such as arsenic), the chemical will likely be present in water.

Water quality standards have been established for hundreds of chemicals (sulfate, arsenic, benzene, lead, etc.). Some chemicals are not considered dangerous, while others are extremely toxic. Municipal and rural water suppliers strive to provide water to users that either meets or exceeds established drinking water standards. If a test confirms that an established standard has been violated, a representative of the water system will be contacted and asked to take appropriate action to clean the water and meet the standard. If the water cannot be treated to meet the standard, the water provider will be asked to improve its treatment capabilities or find a new source of water. Either case involves high costs and could result in increased taxes or water fees to pay for new systems.
Polluted water also affects aquatic plants and animals. Unlike humans, wild animals and plants do not have the option of treating the water they live in. As water quality in a river or lake degrades, plant and animal life also changes. Most fish and wildlife species have a range of tolerance within which they can survive. They might tolerate only a certain amount of variation in the water's temperature, oxygen level or pH, and they always depend on food availability. For example, if a fish is adapted to living in a cool, clear, shallow stream and feeding on insects, changes affecting these stream characteristics will affect the survival of the fish.

Water quality standards for aquatic life are established to protect fish from unnecessary death and impaired growth and reproduction. Other standards are set to prevent the accumulation of chemicals in fish flesh, which can pose a health hazard to humans if they eat large quantities of contaminated fish. Most changes in water quality happen over months or even years. Constant testing and monitoring establishes trends that can be mapped over the long term but is also important in the case of a serious water quality problem that occurs suddenly, such as the introduction of a waterborne pathogen.

**Procedure**

**Warm Up**

- Show students a glass of water. Ask how they know the water is safe to drink. Have students list things they would like to know about the water before they drink it. Why would they drink water from a faucet but probably not from a mountain stream?

  NOTE: For simplicity, only metric measurements are used in the following demonstration. Carefully measure out 100 ml of water mixed with a small amount of blue food coloring. Tell students that the blue-colored water represents a pollutant. Ask them if they would like to drink it. Take 10 ml of the pollutant and add it to 90 ml of clear water. Calculate the concentration of the pollutant in the water. (1 part per 10) Would they drink it? What if they were thirsty? Take 10 ml of this diluted solution and add it to 90 ml of water. What is the concentration of the pollutant? (1 part per 100). Would they drink the water now? What if they were in the desert? Dilute the pollutant one more time: add 10 ml to 90 ml of clear water. What is the concentration now? (1 part per 1,000). Tell them this measurement is known as parts per thousand (ppt). Repeat three more times until you reach parts per million. Would they drink the water now?

- Explain to students that although dilution reduces the concentration of a pollutant within a sample, other forms of treatment are necessary to ensure that water is safe to drink.

**The Activity**

1. Discuss reasons why water is treated. Explain that because removing all chemicals is economically impractical, the government sets standards to define how much of a pollutant is acceptable in drinking water. Often these amounts are set at parts per million or parts per billion.

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**Dilution of the blue pollutant**

10 ml

Original Solution

1 part per 10

1 part per 100

1 part per 1000
For example, only five milliliters of a certain pollutant may be allowed per one million milliliters of water (5 ppm). To give students a sense of this quantity, remind them of the Warm Up demonstration. Then have them imagine a line of one million white cars. (They would stretch across the United States.) If five of these cars were exchanged for blue cars, five cars per million (or five parts per million) would be blue. Have students provide additional examples that illustrate the concept of five parts per million.

2. Give students an example of a standard that could be set for the class. Have students count how many of them are wearing jeans out of the total number of students in class. If six out of 25 students are wearing jeans, the concentration of jeans would be six parts per 25.

How would students feel if a standard were set limiting the number of students per class who could wear jeans? Tell them that you might establish a jeans standard; for example, the student concentration of jeans on any single day could not be greater than six. To meet this standard, your students would have to create a system to ensure that the standard was not violated.

3. Explain to students that this analogy relates to water quality standards. The government sets standards for a wide range of biological and chemical parameters. A city’s water department attempts to locate water that is as pure as possible at the source (ground water, river or lake) and then treat it to meet or exceed the standards.

Part II

1. Tell students that a game of limbo will be used to demonstrate the amount of effort required to meet drinking water quality standards. The height of the limbo bar will represent water quality. Students who make it under the bar symbolize successfully treated water. As water quality declines, the bar will be lowered and the effort required to meet standards will increase.

2. Ask students to brainstorm a list of things they can do to keep water clean and a list of things that people do that pollute water. Transfer each item from the lists to a separate index card. Mix the cards and place them face down. Put the cards on a table or desk near the limbo pole.
3. Students should prepare to play the limbo game by doing some stretching exercises. Have students form a line. Set the bar height at the median of the students’ heights (the height at which half the students are taller and half are shorter). Most students should be able to pass under the bar. This means little effort is needed to meet water quality standards.

4. Before each student attempts to go under the pole, he or she should pick up a card and read it to the class. Move the bar up three inches (7.5 cm) if the card’s message improves the water quality and down three inches (7.5 cm) if the message degrades the quality. The cards are reshuffled into the deck.

5. Have each student attempt to pass under the bar “limbo style.” When students are unable to make it under the bar, this means the treatment plant is not capable of maintaining the standards; it is taking in water that is more polluted than the plant was designed to handle. Because public drinking water suppliers need to ensure that the water is potable, they will be required to take actions to meet the standards again. These actions might include instituting a different treatment or finding another source of water. Unfortunately, many of the options available to water suppliers can be expensive and time-consuming, or the technology does not yet exist. The good news is that the vast majority of water departments in the United States are providing excellent-quality water.

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<th>Project WET Reading Corner</th>
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<tr>
<td>This book discusses human impacts on habitats and various natural cycles.</td>
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<td>Published in 1962, <em>Silent Spring</em> was the groundbreaking book that brought attention to the problems of pollutants in our environment.</td>
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<td>Learn about the human factor and its impact on our world. Desonie explores the effects of agriculture, water rights and usage, and pollution from fossil fuels.</td>
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<td>Donald traces the causes and effects of various types of water and air pollution and describes wetland conservation.</td>
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<tr>
<td>This is a beautifully illustrated biography of Rachel Carson, the author of <em>Silent Spring</em>.</td>
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Text and color photos examine the causes and effects of water pollution.

This book exposes how rare fresh drinking water is by examining such topics as the water cycle, watersheds, droughts and pollution.

This illustrated children’s booklet discusses the topics of ground water and springs.

This illustrated booklet for children describes the problems and sources of water contamination.

If you have ever wondered where the rain or melted snow on your street goes and what effects it might have, you can find out by reading this illustrated children’s booklet.

Collaborating with a team of students, biologist Tyrone Hayes works to save frogs from pesticide poisoning.

*Listed on one or more state reading lists.

**Assessment**

- write examples that illustrate the concept of one part per million (step 1).
- relate water quality to the pressures on water treatment plants to meet standards (Wrap Up).
Extensions
To increase the challenge of the game and to better represent water treatment processes, use multiple poles. Inform students that at treatment plants, water must be monitored and treated to fall within numerous biological and chemical parameters. Demonstrate this by setting up a row of poles at the class height median. Each pole represents the presence of a different compound in water (sodium, iron, nitrate and lead) that occurs naturally or is a result of human activities. Passing under the bar means the standard for that chemical has been met. Failure to make it under the bar means the standard has been violated. Make a set of cards labeled “same,” “higher” (raise bar 3 inches [7.5 cm]) and “lower” (lower bar 3 inches [7.5 cm]). Randomly draw a card to determine a basic level for each compound; repeat for each bar. Have students attempt to pass under the series of poles. Several rounds can be played; each round begins with drawing cards to adjust the height of each pole. Students may want to research how these pollutants come to be in water supplies.

Instead of water in treatment plants, students can represent aquatic animals and plants that have certain ranges of tolerance. The limbo bar represents water quality. If students can maneuver under the bar, they can tolerate the conditions. If not, the organisms die or must relocate to a suitable new habitat.

Students may obtain water test kits and analyze the quality of their school’s drinking water.

Visit a water treatment plant. Have students compare the processes of drinking water treatment and wastewater treatment.

Teacher Resources
Books

Journals


Websites

DVDs