TOPIC 4

How Much Is Too Much?

Figure 3.17 This lake in the Canadian Rockies is a renewable source of fresh water.

Water is an essential ingredient for living organisms, and Canada is fortunate to have vast supplies of it. Some countries, such as Kuwait or Bahrain, have no renewable fresh-water supplies. How much of a shock is it then, to find that most authorities would recommend against drinking the water directly from the lake shown in Figure 3.17? To be safe, you need to filter or boil the water at least five minutes to remove the parasite, Giardia, which can cause the intestinal illness, commonly known as beaver fever. Would you agree that the water in such a lake is polluted? Could you tell just by looking?

In some cases it might be obvious that pollution is present; in others it is not so obvious. So, when can we be sure that a body of water is polluted?

To answer this question, you first need to know the difference between pollution and a pollutant. In general, a **pollutant** is any material, or form of energy, that will cause harm to a living organism. The harm may be the result of physical, chemical, or even biological mechanisms that threaten the health or survival of that organism.

Pollution is any alteration of the environment producing a condition that is harmful to living things. For example, you have read about the effects of the pesticide DDT. That is a case of pollution. The harm may not be immediate, but it does occur; the only question is when.

At what point does the concentration of a pollutant become a problem? Does it happen when the pollutant causes the immediate death of an organism? When the pollutant is only somewhat harmful? Perhaps when the pollutant is present at a level that you can detect? The next investigation will give you an appreciation for how difficult a question this can be to answer.

INVESTIGATION 3-G

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Where Does Pollution Begin?

Chemicals are all around you. The water you drink, the foods you eat, the air you breathe — are all chemicals. Of the thousands of chemicals in use, some are human-made and some are natural. Some are harmless, and some are hazardous. Others are of unknown toxicity, either because they have not been tested or they are difficult to detect. The amount, or dose, of a chemical determines how much harm will be caused, so it is important to be able to detect the presence of chemicals. Unfortunately, the only way to determine the level of a hazardous chemical is to observe its effect on a living organism. To complicate matters, different organisms respond differently to the same dose of a chemical. To find out how dangerous a chemical can be, you must find out what its effects are—it must be tested on a living thing.

Question

How much of a chemical needs to be present in order to be detectable?

Safety Precautions

- Do not use laboratory glassware. It may look clean, but is it? Obtain plastic drinking glasses and carry out this activity only in a classroom, or in a cafeteria.
- It is not usually recommended to taste anything during experiments however, this investigation includes a safe tasting situation.

Apparatus

8 clean plastic drinking glasses of the same size and shape
3 clean plastic drinking glasses of any size or shape
marking pen
spoon
ruler

Materials

5 mL of salt
tap water
5 mL of sugar

Part 1

Preparing Serial Dilutions

Procedure

1. Make a mark near the top of one of the glasses using the marking pen. This glass will become your standard glass. The mark on the glass will help you fill the glass with the same amount of water each time.

2. Use the marker to label the remaining glasses from 1 to 7

3. Put 5 mL of salt into the standard glass and fill the glass to the mark with warm tap water. Stir until the salt dissolves.

4. Pour the salt solution from your standard glass into the glass labelled number 1. Using a ruler, **measure** from the top of the solution to the bottom of the glass. Use the marker to place a mark on the glass that is one-tenth of the way down from the top of the solution.

5. Carefully pour off the top one-tenth of the salt solution from glass number 1 (that is, down to the mark) and put it into your standard glass. Place glass number 1 aside for later testing.

6. Add warm tap water to the standard glass to fill it back to the original mark and stir.
7. Pour the diluted salt solution from your standard glass into glass number 2. Again, **measure** and mark a spot one-tenth of the way down from the top of the solution to the bottom of the glass. Carefully pour off one-tenth of the salt solution from glass 2 and put it back into your standard glass. Place the glass aside for later testing.
8. Repeat steps 6 and 7 with glasses numbered 3 to 7 to produce weaker and weaker dilutions of salt solution.

Part 2

The Taste Test

Procedure

1. Use the three clean, unmarked glasses. The person tasting (the test subject) should have no knowledge of which glass contains the salt solution. This is called a "blind" test.
2. Away from the view of the test subject, pour a little of the salt solution from glass number 7 into one of the unmarked glasses. Fill the other two with tap water.
3. Ask the test subject to taste the water in each of the three glasses and try to identify which has the salt solution in it. **Record** the accuracy of this guess.
4. Repeat steps 2 and 3 with each of the remaining numbered glasses, working backward from glass number 6 to glass number 1.

Part 3

How Sweet It Is!

Procedure

1. Rinse all of the equipment you have used. Repeat Parts 1 and 2 of the procedure, substituting sugar for salt.

Analyze

1. Glass number 2 contained a salt (or sugar) solution that is approximately one-tenth as salty (or sugary) as glass number 1. In other words the solution in glass 1 is about ten times more concentrated than the solution in glass 2. Approximately how many times more concentrated is the solution in glass 1 than in glass 7?
2. At what dilution (in which glass) could your test subject taste the salt? The sugar? Compare your results with the results from other groups. Did other groups obtain similar results?

Conclude and Apply

3. Explain why there might be a difference in the results you obtained using salt and sugar. Was there a difference in results between people? What do you think would cause this discrepancy?
4. The purpose of a "blind" study is to ensure that your results are less likely to be influenced by bias. What do you think a "double blind" study is? Why would such a study be used?

How Much Is That?

In the previous investigation you used 5 mL of salt or sugar in a glass of water. After one dilution, you obtained a salt or sugar concentration that was one-tenth of the original, or 10 percent. Your serial dilutions produced concentrations of hundredths (1 percent), thousandths (0.1 percent), ten thousandths (0.01 percent), and so on.

For many of the products that you use or buy, the standard way of indicating *how much* of a substance is present is to refer to the percentage (%) of weight or volume it represents.

Yogurt is a good example. When the label states 1 percent milk fat, it means that 1000 g of yogurt contains 10 g of milk fat. Or, to put this in a simpler ratio, 1 g of milk fat is mixed into 100 g of the other substances that make up yogurt. In fact, the term "percent" actually means parts per hundred. In your studies you will already have encountered the unit parts per million (ppm), and even units of parts per billion (ppb). The iodized table salt that you probably used in your investigation contains about 76 g of potassium iodide (KI) for every 1 000 000 g of sodium chloride (NaCl) for a concentration of 76 ppm potassium iodide. Did you notice that you were able to taste the iodine in the diluted salt solutions in the last activity before you were able to taste the salt?

It is hard to imagine such small amounts of a substance as being detectable, never mind harmful, but in fact you will see even smaller amounts being considered. The element cadmium is considered toxic when it reaches concentrations of 17 parts per trillion (ppt)! To picture one part per trillion, imagine one quarter in a stack of quarters 2000 km high.

Figure 3.18 Read the nutrition information on the label to find out the percent milk fat of the yogurt you eat.

Example:

If the nutritional information label on a container of yogurt specifies that each 125 g serving contains 7 mg of cholesterol, what is the concentration of cholesterol in a serving of yogurt in parts per million (ppm)?

Solution:

First, state your information as a ratio.

$$\frac{7 \text{ mg cholesterol}}{125 \text{ g yogurt}} = 0.056 \text{ mg/g}$$

Second, express that ratio in the form of mg/kg

$$0.056 \text{ mg/g} \times 1000 \text{ g/kg} = 56 \text{ mg/kg}$$

Since mg/kg is equivalent to ppm, there are 56 ppm of cholesterol in each serving of this yogurt.

The Danger Is in the Dose

Toxicity is the ability of a chemical to cause harm to an organism. The harm can either occur directly or be caused by the substances that form in the organism as it uses that chemical. A chemical has **acute toxicity** when serious symptoms occur after only one exposure to the chemical. Methyl isocyanate is one such chemical. **Chronic toxicity** is diagnosed when symptoms appear only after a chemical accumulates to a specific level after many exposures over time. Lead is an example of this type of substance. For both acute and chronic toxicity, exposure to a chemical is critical. Regardless of how the damage occurs, or even why it occurs, it is the amount of the chemical causing that damage that matters. Unfortunately, it is not always easy to establish the level at which a substance is toxic. Due to differences in body mass, metabolism, and even lifestyles, different organisms will vary in their response to a particular toxin.

Word CONNECT

The word "pollution" comes from the Latin *pollutus*, which means "made unclean, foul, or dirty." Look up the term "pollution" in a thesaurus and list as many synonyms for pollution as you can find.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

How critical is the state of our water supplies? What solutions can we come up with for the problem of polluted water sources? Go to the web site above, and click on Web Links to find out where to go next. Write the answers to these questions in your notebook.

DidYouKnow?

Some of the minerals you take into your body could be harmful rather than helpful. Intake of "heavy metal" ions such as mercury and lead may cause death of nerve cells, which results in permanent neurological damage. The Government of Canada has established guidelines for acceptable amounts of such metals in our fresh-water supplies. This table shows some of those limits.

Mineral pollutant	Maximum permitted level (in ppb)
arsenic	5.0
barium	1000.0
cadmium	0.017
chromium (trivalent)	8.9
chromium (hexavalent)	1.0
lead	7.0
mercury	0.1
selenium	1.0
silver	0.1

DidYouKnow?

Strawberry crops are severely damaged by cyclamen mites. Attempts to control cyclamen mites with the insecticide parathion failed drastically. In one study, a cyclamen mite population increased as much as 35 times after the application of parathion. Upon investigation, it was found that another mite species, one that normally preyed on cyclamen mites, was even more sensitive to parathion. With the predator species wiped out by the parathion, the surviving cyclamen mites were able to reproduce and grow without being eaten by their normal predator.

Lethal Dose 50

A common measurement of the toxicity of a substance is by its Lethal Dose 50. **LD50** refers to the dose of a chemical that will kill 50 percent of the population to which it is applied. The LD50 for a chemical takes into account that some individuals within the target population may be more resistant to the toxic effects of the chemical. Table 3.4 summarizes just a few of the LD50s that have been established for the human population. Each LD50 in the table is expressed in parts per million within the human body. An LD50 does not refer to parts per million in the environment or in materials ingested by humans.

Table 3.4

LD50s for Various Chemicals

Toxin name	Source	Approximate LD50s (in ppm)
botulinum toxin A	*Clostridium botulinum* bacterium	0.00000003
tetanus toxin A	*Clostridium tetani* bacterium	0.000005
dioxin	contaminant in some herbicides and in PCBs	0.03
nicotine	cigarette smoke	0.86
strychnine	pesticide	5.0
solanine	potatoes	6.0
chlordane	insecticide	40.0
dieldren	insecticide	80.0

The most lethal poison known arises from the bacterium, *Clostridium botulinum*. This bacterium is common in foods and can be destroyed by high temperature and acidity. Other bacteria species produce toxins that are almost as lethal. In fact, you may have noticed in reading Table 3.4 that the toxins produced by bacteria are much more lethal than dioxin, the most deadly of the human-made toxins.

The LD50 of a chemical is only a useful guide to how we should handle that substance. For example, a chemical with LD50 of 15 ppt is one for which proper safety precautions should be followed.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

To find out more about how toxic substances affect us. Go to the web site above, and click on Web Links to find out where to go next. Choose three substances, and describe their effects in your notebook.

***Word* CONNECT**

Preserved foods that have not been exposed to sufficiently high temperatures in the preservation process are often the source of the fatal illness "botulism." The name comes from *botulus*, the Latin word for sausage. The origin of this weird "link" originates with an outbreak of the illness in nineteenth-century Germany. Contaminated sausages were identified as the culprit, so the disease became known as botulism. When the bacterial culprit was eventually isolated and identified, it was named *Clostridium botulinum*. Which other English words have their origin in the Latin word *botulus*?

An Acceptable Risk?

Government agencies and legislative bodies are often pressured to relax the strict testing required before a new drug or substance is approved for everyday use. Many people view the waiting period as inconvenient and unnecessary. However, there are good reasons why these waiting periods are in place. What do you think they are?

Since not all individuals or species react the same to a particular chemical, establishing risk is often difficult. First, a dose that kills one individual may cause only mild discomfort in another. Second, the toxicity of a chemical often depends on how the chemical enters the body. Inhaling or ingesting a chemical is much more likely to cause harm than spilling the same chemical on your skin. Third, you can't completely rely on published toxicity values to determine the effects on humans, because few actual measurements have been made. Most of the information regarding humans is the result of studying accidental-exposure cases. Why would that be? Would *you* volunteer to be a test subject for a toxicity experiment? Another reason to question the reliability of toxicity values is that they are merely guesses based on the assumption that humans will react to a chemical in the same way that a laboratory rat or mouse will. So despite the best efforts of scientists, sometimes a substance will be approved for use with tragic effect.

Figure 3.19 In light of the fact that thalidomide is one of the most effective drugs doctors have for the treatment of many diseases, such as lupus and rheumatoid arthritis, should it be struck from the list of approved drugs?

Thalidomide Issue

The drug thalidomide is an example of just such a tragic effect. Originally developed as a sleeping pill, thalidomide was subjected to the usual toxicity tests and declared harmless. Its use by pregnant women in the 1950s and 1960s resulted in the birth of thousands of babies with absent or extremely shortened limbs. After the first birth deformities were noticed, further testing established that lab rats can take doses of thalidomide as high as 4000 ppm with no ill effect, but pregnant women who received a much smaller dose (0.5 ppm) at just the wrong time during pregnancy, produced a child with missing limbs, as shown in Figure 3.19.

Figure 3.20 Saccharin is a sugar substitute that is 500 times sweeter than sugar. It was first discovered in 1879 and used commercially by 1907. Now it is a controlled substance, since it has been found to produce cancerous effects in some lab animals. While saccharin is still an accepted food additive, it is required that foods containing saccharin be labelled as possibly hazardous to your health. Saccharin generates an almost undetectable risk of cancer in humans.

The Evaluation of Risk

There are often articles in the newspaper relating to toxic spills of chemicals, or concerns about pesticide use. Rachel Carson's *Silent Spring* was a rallying cry for the environmental movement in the 1960s and forced a re-evaluation of how much humans influence the environment.

With all of the publicity surrounding the human use and abuse of toxic chemicals, we sometimes overlook the fact that most of these poisons are natural, not human-made. The chemical defences that plants and animals have evolved to discourage predators and eliminate competitors are in general much more toxic and numerous than synthetic toxins. For every molecule of human-made pesticide in our diet that is a result of agricultural use, there are as many as 10 000 molecules of naturally formed pesticides — some almost identical in structure and function to human-made ones. So how do you calculate the risk involved in our use of pesticides? What is a safe level for any pesticide?

We take risks every day in all kinds of activities. More importantly, we accept those risks as normal. The risk of spraining your ankle does not prevent you from walking down the sidewalk. Perhaps it is better to talk about "acceptable risk" when evaluating the safety of an activity. For example, a cup of coffee contains the alkaloid chemical caffeine, a nervous system toxin that has an LD50 for mice of 130 ppm. Does that make it dangerous for humans? Consider this:

- Humans would have to drink 70 cups at one sitting to get a dose equivalent to the LD50 for mice.
- It may not be accurate to use the established dose for mice to calculate the dose for humans. If thalidomide can have different harmful dose levels for humans than for rats, perhaps caffeine has different dose levels for humans than for mice.

The risk is there, but obviously not much of one. For many people, drinking coffee is an acceptable risk.

Benefits Versus Drawbacks

Every chemical has the potential to be harmful, depending on dose, our susceptibility, and how it reacts with other chemicals. We must decide if its use is more beneficial than harmful. Is it better to treat crops with fungicides known to have cancer-causing properties or to allow moulds to grow, many of which are far more likely to cause cancers? Is the risk from agricultural pesticide residues less than the risk from the natural toxins a plant produces when attacked by insects? The evaluation of the risks and benefits of any chemical form the basis of how chemical use is regulated. Of course, a proper analysis for potential risks and benefits requires an understanding of which chemicals are present. How can we do that? The next Topic will introduce you to some of the methods.

TOPIC 4 Review

1. What is the difference between a pollutant and pollution?

2. What is the difference between acute and chronic toxicity?

3. The maximum permitted level of mercury in our water supplies is 0.10 ppb. A scientist determines that a water source has 0.20 mg of mercury per litre of water. Would this water supply be considered unsafe? Explain your answer.

4. **Thinking Critically** The photograph below shows two children, playing in a river across from a factory that produces a carbon "snowfall," which turns everything in the area black. Would you consider the water to be polluted? What reason would you give for saying so? How could you determine if it actually is polluted?

Did You Know?

Some toxins can make the skin so sensitive to sunlight that even moderate amounts of sunlight can cause sunburn-like symptoms. Upon recovery, the skin is often permanently darkened. Many pesticides and plants are known to cause this sensitivity to sunlight — the carrot is one such plant.

5. Explain the term LD50 in your own words. Why is an LD50 a more accurate way of reporting the effects of a chemical than just the toxic dose that an individual has taken in?

6. Think back to the Inquiry Investigation at the beginning of this Topic. Which glass containing salt water would you consider to be polluted? Why? Check with your classmates. Did they agree with your choice?