The icons represent five aspects of toxicology:

• science
• people (consumers)
• health
• environment
• regulation and safety

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INTRODUCTION
Many people have questions and concerns about different substances in our environment. These substances might be man-made or naturally-occurring. Regardless, people are concerned about the risk they may pose to human health or the health of the environment. This unit on Toxicology© is the result of a partnership between Alberta Environmental Protection and the Canadian Network of Toxicology Centres. The purpose of this unit is to provide information for those interested, most specifically educators, in this complex and often controversial topic. The unit takes an in-depth look at issues associated with toxicants and toxins that will hopefully promote improved decision-making. This is an opportunity to gain an understanding of the science and issues related to toxicants in the environment. This educational unit is available in printed form as the Educator's Resource Guide, with an accompanying video. Contact CNTC Head Office for information on ordering the educational unit.

A note to the educator:
This resource is organized in a sequence from an introduction to toxicology, to toxicology topics of interest, to a final case study on toxic effects and water. Ideally, a unit of study would include all lessons in this sequence. However, if time does not allow you to use all lessons, each lesson can stand alone.

Organization:
The unit consists of seven lessons. Most lessons contain background information, teacher information, and a worksheet. These are identified by separate headings. In addition to the lessons, there is a list of research topics and a crossword puzzle at the end of the unit. A glossary of terminology includes the boldface terms found throughout the text, and a recommended reading list.

Subject Connections:
This unit is designed to support curriculum in a number of different areas of study. Within secondary science programs, this unit can be used in conjunction with instruction on the following topics:
- Environmental Health and Quality
- Geography and World Issues
- Impacts of Human Actions on Environmental Quality
- Effects of Science and Technology on Society and on the Environment
- Science and Technology Influence and the Influence of Societal Issues
- The Role of Scientific Knowledge in Decision-Making

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"What are little girls made of?" Sugar and spice - well, sugar, anyway, along with a variety of other carbohydrates, proteins, nucleic acids and many other chemical compounds. Life for each of us is an ongoing series of chemical reactions which allow our bodies to function. The food we eat, the air we breathe and the water we drink provide the raw materials for these chemical reactions and our bodies usually are efficient enough to expel most waste products.

Recently, however, there has been concern that our food, water and air are introducing toxic chemicals into our bodies. Are these concerns justified? Just what is a toxic chemical? Is there a risk from the things added to our food during processing? Are there natural components in our food that pose a threat? Are there toxic chemicals in our environment polluting our water and air? If, so, can our bodies cope with these things? How do toxic chemicals differ from other chemicals?

The simple answer to the last question is that all chemicals can be toxic. An old cliche states that "the dose makes the poison" and that is true. The science of toxicology, which overlaps with and incorporates aspects of other sciences including chemistry, biochemistry, physiology, microbiology, statistics, public health and pharmacology, studies the quantitative effects of chemicals on biologic (i.e. living) tissue. In other words, for any given chemical, how much is too much?

Toxicology is not restricted to humans, but can also look at other organisms. For example, herbicides are toxic to plants and antibiotic drugs are toxic to bacteria. Toxic effects vary from species to species. This is known as species specificity and explains why the herbicide 2,4-D can kill dandelions while leaving the grass to grow. There can also be differences in response among individuals of the same species. This causes a problem in medicine when strains of bacteria develop resistance to certain antibiotics.

It also causes a problem when some people develop side effects to drugs that cause little or no adverse reaction in others. Drug side effects also demonstrate another aspect of toxicology - the evaluation of risk versus...
benefit. In this case, do the benefits of disease control outweigh the disadvantage of adverse side effects? Similar risk-benefit analysis is used for many decisions daily, though we seldom think of it in those terms. Toxicology can provide useful information for use in the comparison of risks and benefits.

A grain farmer weighs the risk of pesticide use against the benefit of a healthy plentiful crop. A homeowner weighs the risk of herbicide use against the benefit of a dandelion-free lawn. A manufacturer adds preservatives to a food product to ensure food safety and prolong shelf life. Another adds food colouring to improve the visual appearance of a product. Of course, in this type of analysis, there may be differences of opinion and controversy can result.

Society, primarily through the government, has tried to reduce risk in a number of ways. New food and drug products must be tested for safety and usefulness. Consumers must be given adequate information, whether it is through nutrition labeling on food products, directions for use and warnings on drug products or instructions for use on products such as cleaners and pesticides.

Environmental regulations include standards to prevent serious pollution of air and water.

Of course, there must be personal responsibility as well. Chemicals are neither good nor bad, but harm can result if they are used carelessly. Despite stories that sometimes appear in the media of threats to the safety of our food supply, a child’s greatest toxic risk occurs in the home. Poisonings occur when children swallow improperly stored headache remedies, vitamin pills, or cleaners. Even some houseplants can pose a threat.

If we are to live comfortably and safely in a chemical world, we need to be informed. We need to know the effects of certain chemicals and the associated risks. We need to know how to evaluate the stories we read and hear, so that poor science or poor reporting can’t cause undue alarm. We also, however, have to know how to react if and when a real problem occurs.
The dose-response principle
Organisms respond to toxic substances according to the amount or dose of the substance that gets into the body. This is one of the basic principles of toxicology - that is - with increasing dose or exposure to a substance, you get more effects. This is easily illustrated with some examples from the home. Bread contains alcohol produced by the fermentation of sugars by yeast. The amount of alcohol in a slice of bread, or a loaf of bread, for that matter, is too small to cause a response (drunkenness) in humans. However, a bottle of liquor, also made by the fermentation of sugars by yeast contains a large enough does of alcohol to make most people drunk or even, in some cases, to kill them.

Vitamins are a special case of toxicity where insufficient consumption will make you sick (for example, scurvy from lack of vitamin C). Consumption of moderate amounts of vitamins is necessary for health but excess consumption of some vitamins can be very dangerous.

Figure 3  So many sources of information...
**Teacher Information**

**Objectives**
1) to demonstrate to students the nature of chemicals
2) to have them look critically at the terms "organic" or "natural"

1. Ask students what the terms "natural" or "organic" mean to them and what they mean in today's marketplace. Outline answers on the board. Most will probably respond with positive definitions. Then show the transparencies, asking them to identify each organism and describe it. Can it be harmful?

**Bee** - venom in the sting causes pain and itching in most people but may be fatal to anyone with an allergy to bee stings

**Tarantula** - venom is fatal to small prey, painful to humans

**Rattlesnake** - venom can kill prey

**Tobacco plant** - leaves contain a number of toxic chemicals and were once used as insecticides

**Potato plant** - the top may be poisonous but the tubers are an excellent food source unless they have been stored in sunlight in which case, if they have turned green, they too may cause illness

**Foxglove** - toxic, but carefully regulated doses of digitalis, which is derived from the plant, are important in the treatment of heart disease.

Now do students consider that "natural" and "safe" are necessarily synonymous? Can they think of more examples?

2. Do students think that "natural source" vitamin pills are better for you than other vitamin pills? Show the vitamin C transparency (labeled #1) and ask if students think enzymes in the body can recognize any difference between the two.

Chemically, there is no difference between the molecules. Vitamin C in pure orange juice is preferable to vitamin C in a synthetic orange drink only because it ensures you get the other nutrients present in the juice. There is no difference in the vitamin C itself. If you are taking Vitamin C supplements in pill form, your body cannot distinguish between "natural source" and synthetic forms.

3. Ask students what toxic substances may be found in the home. They might recognize the dangers from some cleaners, pesticides, etc. Hold up a box of table salt. Ask students what it is used for? Do they consider it toxic? Do they know what happens if it is sprinkled on leeches or slugs? (it's toxic - they shrivel and die) In a large enough dose, many everyday compounds can be toxic. For humans, the average single dose of table salt needed to be lethal would be 4 grams per kilogram of body weight. Let them calculate the dose required to kill someone who weighs
60 kg. Then weigh out 240 g to demonstrate the quantity.

4. Ask students to look at the labels of a number of items in the home. Ask each to read the labels of five different products and record for the class:
   a) brand name
   b) purpose of the product
   c) any warnings on the label

   Ask them to include at least one pharmaceutical product (e.g. pain reliever, vitamins, etc.), one cleaning product and one pesticide (e.g. insect spray) if possible. Most probably don't realize that, although vitamins and minerals are taken to promote good health, overdoses of substances such as iron can be fatal and are a danger to children if such products aren't stored safely. Overuse of vitamins A and D can lead to accumulation in the body and such bioaccumulation can have toxic effects. Ask anyone who can to bring in the package insert from a drug. Many over-the-counter medications contain a lengthy insert describing directions for use and warnings. Compare the labels in the next class.

   In designing the experiment, students should recognize the need for controls, replication and the limitation of variables. The salt concentration can be varied among samples by mixing quantities of a saturated salt solution (about 37 g per 100 mL) with quantities of water. After the initial set-up, subsequent waterings should be done with water, not salt solution. If salt solution is used, the salt concentration will increase as the water evaporates. They will be able to show their results using graphical plots.

   a) germination rate mm/unit time versus salt content;
   b) time of germination versus salt content.

5. Lab design - Ask students to design and carry out an experiment to determine if salt affects the germination and growth of seedlings. Large seeds such as beans should give an obvious difference in water absorption when salt is added to the growth medium (soil, vermiculite or filter paper). Soil or vermiculite should be used if you want them to carry through beyond the initial germination stage. You may want to use a variety of seeds to see if there are species differences. These may be placed in small plant pots, sandwich boxes with clear lids or even cut-off milk cartons.

   Figure 5 Experimenting with bean germination and various salt concentrations.
LESSON 2: TOXIC SUBSTANCES - WHAT WE KNEW THEN, WHAT WE KNOW NOW

? Background Information

"The Mad Hatter" was not totally a figment of Lewis Carroll's imagination. In the 19th century, mercury nitrate was used in the production of top-hats to prevent the growth of fungi in the natural fibers during damp London weather. Repeated exposure to this mercuric compound caused hatters to develop tremors and brain damage. Hatters often really did go mad. It was an occupational hazard. Today regulations are in place to limit workplace exposure to chemicals that are known to be hazardous.

Still, we are exposed to toxic substances every day of our lives. While some of these compounds have been introduced into our environment in recent years (many the result of new industrial processes), humans and all other organisms have been exposed to a variety of toxins throughout history. Many foods contain natural toxins, often developed as a defense by the plant against insects or other organisms. Water may contain substances dissolved from the soil and carried in run-off. Air contains many gases which, in larger proportions, could prove dangerous. As a result of these exposures, we have evolved systems which help our bodies cope with such materials. These systems generally involve enzymes - proteins produced by our bodies to mediate biochemical reactions. Consequently, genetics can help explain why not every individual reacts to the same extent to a given toxic substance or toxicant.

Toxic substances can invade our bodies in three ways - ingestion (through the digestive system), inhalation (through the respiratory system) and dermally (through the skin.) The effects of the toxic substance will depend on the dose and on how the body deals with that dose. Some substances are very poorly absorbed by the body and others may be excreted rapidly. Poorly absorbed substances are less of a risk because poor absorption reduces the exposure. Some toxic substances are distributed throughout the body and may be stored in particular tissues, in which case a buildup may occur so that over time a dangerous level is reached. This property is found in relatively few substances. These bioaccumulative substances have special chemical and physical properties that prevent their breakdown in the organism and cause them to accumulate in fats. Examples of these substances include the polychlorinated...
biphenyls (PCBs) that have been banned because of their tendency to bioaccumulate in organisms.

There can also be interactions between chemicals. This is a particular concern when medications are prescribed. Sometimes one chemical will interfere with the action of another. For example, the vitamin K in broccoli can reduce the effectiveness of anticoagulant drugs. That is called antagonism. Sometimes a chemical which is not toxic itself increases or promotes the toxicity of another. When two chemicals act more strongly in combination than the combined effects of each separately, it is known as synergism.

Toxic chemicals can also build up through the food chain. When chemicals do not break down easily, they may be ingested at safe levels by organisms low on the food chain but build up in higher feeders. For example, a rodent may not be harmed by an insecticide that accumulates in its body, but a bird of prey that feeds on many rodents may accumulate a sufficiently large quantity within its body to cause harm. Similarly, naturally occurring products such as mercuric compounds in water systems can build up in fish which feed on smaller organisms and then accumulate to even higher levels in birds and animals (including humans) who feed extensively on the fish. This buildup is known as bioaccumulation.

The body has developed some mechanisms to detoxify certain chemicals. The liver and kidneys contain enzymes which function to protect the body and are the main sites of detoxification. The functioning of these enzyme systems and the body's overall response depend on a number of factors:

- Genetic: some families or groups may not produce a particular enzyme and so the detoxification process is impaired.
- Age: children are more susceptible because their systems are not fully developed. Seniors too may have some impairment of such metabolic functions.
- Size: size affects concentration so a large person can usually tolerate more than a small person. This is an important factor to be considered by doctors when they prescribe some types of drugs.

A person whose body is under stress is less able to deal with toxic substances. Poor nutrition or poor health usually make a body more susceptible to damage. There are also differences between males and females. The most significant difference occurs during pregnancy when something of minimal risk to an adult may cause severe problems in a developing baby. This effect is known as...
teratogenicity. Alcohol, tobacco and many commonly-used drugs, if taken during pregnancy, can affect the health of the newborn.

Normally, although factors such as age may affect the degree of response, the type of response, for example the organs affected, will be similar in all individuals. In the case of allergies, the response is different. Here, some individuals develop antibodies after an initial exposure to a product that most people tolerate without difficulty. Immune reactions are most often to proteins, for example, those associated with seafood, peanuts or grass pollen. This is an immune system response and in severe cases, the slightest subsequent exposure may be life-threatening.
Teacher Information

Objectives
1) To help students understand how toxins and toxicants get into the body
2) To look at some occupational health issues
3) To explain some factors which influence a toxic substance’s effect on the body

Ask students to name hazards associated with chemicals in the workplace. Examples: Lung damage to miners (silicosis) or those who work with asbestos (e.g. insulators) Asbestos is no longer used as insulation but is still present in many older buildings. It is safe in place but when buildings are remodeled it may get into the air. Some solvents (e.g. tetrachloroethylene used in dry cleaning or some used in industrial processes) can cause liver damage. Skin disorders may result from exposure to a number of industrial chemicals.

Worksheet Answers:
Part A - see glossary

Part B
1. synergism
2. promotion
3. antagonism

Part C
1. digestive system, respiratory system, skin
2. a) improve air circulation and use filters to clean the air as it passes through the system

b) limit the amount of time worked in that atmosphere

c) some labs are equipped with fume chambers for work with hazardous chemicals. These are vented separately from the regular air circulation system.

d) use safety equipment such as particle masks or respirators

3. Farmers are exposed to exhaust fumes from farm equipment, pesticides, dust and molds in stored crops

4. a) calcium is used for bones and teeth

b) he could cut his rhubarb intake but he could also eat calcium-rich foods such as dairy products

c) eat a balanced diet without concentrating too much on any one food

5. a) $\text{C}_2\text{H}_5\text{OH} \rightarrow$ alcohol dehydrogenase $\rightarrow$ $\text{CH}_3\text{CHO}$ (acetaldehyde) + energy

b) $\text{CH}_3\text{CHO} \rightarrow$ aldehyde dehydrogenase $\rightarrow$ $\text{CH}_3\text{COOH}$ (acetic acid) + energy

c) Individuals without the aldehyde dehydrogenase enzyme will be unable to detoxify alcohol fully so will show effects at lower doses than other people.

d) If the kidney and liver are functioning less efficiently, there will be less ability to detoxify chemicals so there will be a lower tolerance e.g. to alcohol, some drugs.
Worksheet

A. Define the following terms: carcinogen, teratogen, bioaccumulation, toxin, toxicant, dose, tolerance, metabolism

B. Following are examples of antagonism, synergism and promotion. Put the appropriate name beside each example:

1. __________ Smokers who, during their work, are exposed to asbestos, (a risk factor for lung disease) have a much higher than expected risk of lung cancer.

2. __________ In experiments, croton oil had no effect on mice. However, if the mice were exposed to carcinogens, more tumour development was observed in those who were also exposed to croton oil after the carcinogens.

3. __________ Calcium reduces the absorption of lead by the body.

C.

1. List three ways chemicals may enter the body.

2. In many workplaces, there may be potentially dangerous chemicals in the air. Suggest two ways that workers' exposure to such contaminants may be limited.

3. Farmers do much of their work outside. Does this protect them from airborne contaminants? Explain your answer.

4. Rhubarb contains oxalates, compounds which bind calcium so that it is unavailable to the body. In high doses, it may be dangerous.

   a) Calcium plays an important role in muscle contraction. What else is calcium used for?
   b) Dan loves rhubarb pie. Should he adjust his diet in spring when he usually eats a lot of rhubarb?
   c) Many foods contain compounds which may be toxic if high levels are eaten. How should this knowledge affect our food choices?

5. Alcoholic beverages contain ethyl alcohol. To detoxify ethyl alcohol, the alcohol dehydrogenase causes a reaction in which alcohol is changed to acetaldehyde (CH₃CHO). This is converted by the aldehyde dehydrogenase to acetic acid, which is eventually converted to carbon dioxide and water and excreted from the body. Acetaldehyde causes symptoms of hangover. Most alcohol metabolism takes place in the liver. Excess consumption of alcohol may lead to liver damage and accumulation of fat in the liver. This often leads to liver disease in alcoholics.

   a) Write balanced equations for the two catalase reactions.
   b) What will be the effect of drinking on individuals who do not produce the aldehyde dehydrogenase enzyme?
   c) If a person suffers from kidney or liver disease, would this affect the body's ability to deal with toxicants such as alcohol?

6. Hydrogen peroxide (H₂O₂) is produced by organic oxidations within the peroxisome, a cell organelle found prominently in liver and kidney tissue. Since hydrogen peroxide is also toxic, the enzyme catalase causes it to be broken down to water and oxygen. Catalase can also cause some oxidation of ethyl alcohol by hydrogen peroxide to produce acetaldehyde and water.

   a) Write balanced equations for the two catalase reactions.
   b) What will be the effect of drinking on individuals who do not produce the aldehyde dehydrogenase enzyme?
   c) If a person suffers from kidney or liver disease, would this affect the body's ability to deal with toxicants such as alcohol?
LESSON 3: MAMMALIAN RESPONSES TO TOXIC SUBSTANCES

? Background Information

When a single exposure produces an acute reaction, symptoms of toxicity can be described quite accurately. However, the results of long-term or chronic exposure are less easy to identify since other factors may also be involved. Sometimes, analysis of statistical data can indicate correlation between exposure to chemicals and later development of symptoms. Such correlation may then be tested in an experimental design. Carcinogenicity, the development of cancer from chemical exposure, is one example where exposure and development of symptoms can be separated by many years. Such cases are further complicated by the fact that, while everyone exposed to a toxicant such as chlorine gas will experience respiratory symptoms, not everyone exposed to carcinogens will develop cancer. Chlorine gas is therefore an example of a consistent effect while carcinogenesis is a random effect.

Airborne agents may cause respiratory problems such as irritation of the nasal or bronchial membranes. Sometimes these agents are present in the environment. For example, pollution caused by automobile emissions or acidic emissions from coal-fired electricity generating stations or metal smelters. However, exposure to airborne toxicants may be the result of carelessness, such as using solvent-based paints and varnishes without proper ventilation. One noteworthy airborne toxicant is carbon monoxide, which often escapes detection because it is colourless and odorless. Carbon monoxide is formed as a result of incomplete combustion of fuels; it is a highly toxic component of vehicle emissions, and may be found in the home due to improperly functioning furnaces and gas appliances. The indoor use of charcoal barbecues is especially dangerous in this regard. Carbon monoxide binds tightly to hemoglobin, reventing the transport of oxygen to the tissues, and resulting in severe cases of brain damage or death.

Sometimes exposure to chemicals produces skin reactions. One natural example is poison ivy. In Italy, a dioxin spill following an industrial accident in 1976 caused a skin disorder called chloracne among some of those exposed. There were no other acute symptoms confirmed that could be directly linked to the spill. Although some reports have suggested dioxin contributes to birth defects, no increase was observed in the contaminated area following the spill. Some chemicals may be absorbed through the skin but produce effects elsewhere in the body. The skin is not a passive covering but is a complex organ and recently, scientists have shown that some chemicals can be detoxified in the skin.

Ingestion of toxic substances can cause a wide variety of effects. Acute exposures to some may cause nausea and vomiting - a way for the body to eliminate some of the ingested compound. Chronic low exposure may produce less dramatic results. Although most paints sold for indoor use now are lead-free, some in the past contained lead concentrations up to 40%. Children who chewed on painted objects could develop a number of symptoms,
including brain damage, causing severe learning disabilities.

Cancer has received a lot of publicity recently and when the safety of compounds such as food additives is questioned, it is usually because of possible carcinogenicity. However, most of the dangers from ingested material come, not from additives or contaminants but from our own dietary choices. It has been estimated that 80 - 90% of cancers are avoidable. Scientists have discovered that a high fat, low fibre diet, obesity and the use of alcohol all contribute to the incidence of cancer. Some foods, particularly vegetables, contain compounds that seem to protect against some types of cancer. In fact, up to a third of cancer deaths in Canada are estimated to result from poor diet. Another 30% of cancer deaths result from use of tobacco products. These factors also contribute to the incidence of vascular disease leading to heart attacks and strokes.

The human body has many ways of dealing with toxic substances. In very low doses, we can handle a lot of different chemicals. However, sometimes we don't give our bodies much of a chance. While some environmental exposure is inevitable, most toxic incidents result from poor choices or carelessness in the home or workplace.

Figure 9  Estimates of the Percentage of Cancer Deaths in Canada and the United States from known Causal Factors
Teacher Information

Objectives:
1) to describe some effects of toxic substances
2) to look more closely at cancer-causing agents and activities

Note: students will need to have an understanding of cell division prior to completing the worksheet.

1. Ask students what they had for breakfast. Discuss the choices we make in our diets. Do students know what constitutes a good balanced diet? The graph in the information sheets is taken from the 1992 Government of Canada publication "A Vital Link: Health and the Environment in Canada." In the graph, "reproductive patterns" refers to childbirth since pregnancy and childbirth seem to offer protection from some types of female reproductive cancers. "Sexual activity" statistics include cancer of the cervix which is more common in women who have had multiple sex partners.

2. Distribute the worksheet.

Worksheet Answers:

1. during DNA synthesis (S phase of interphase)

2. there will be a number of colonies because some of the mutations in the gene for histidine production will allow growth without added histidine; highly mutagenic compounds should produce more colonies than slightly mutagenic compounds

3. the DNA repair system is defective so the strain is particularly susceptible to mutation

4. spontaneous mutations can occur and since the DNA repair system is defective, these will all show up as well if they are in the histidine gene so that histidine is again produced

5. yes, slightly; increasing cell divisions increase the chance of a spontaneous mutation in a control gene

Ask students if they know why the culture is grown on a complete medium first. It allows a number of cell divisions so that daughter cells of mutated bacteria will multiply to significant numbers and be more likely to show when plated.

Auxiliary activity: You might like to invite a guest speaker e.g. pharmacist, nurse, doctor, dietician to discuss some aspects of toxicity, poisoning, role of diet in health, etc.
Worksheet

How do scientists determine if a substance is carcinogenic? Cancer is a complicated disease. Its development requires a number of events at the cellular level. At least two processes are involved. Mutation is a change in the genetic material. Mutations can occur spontaneously in living organisms. However, there are repair systems that usually correct any changes to DNA. In cancer formation, mutation generally causes damage to or the loss of some control measure in gene expression. Therefore, compounds which are mutagenic can increase cancer risk. Rapid cell division is also part of the process for cancer development. Stimulation of cell division is known as mitogenesis.

In evaluating compounds for carcinogenesis, one of the common tests to assess mutagenesis is a bacterial procedure known as the Ames test. If the substance is a mutagen in bacteria, the risk that it is also a carcinogen in mammals is increased.

Ames test: A strain of Salmonella bacteria requiring histidine in the growth medium is exposed to the compound to be tested. The bacteria are grown on a complete culture medium containing histidine. Then the culture is plated on a medium without histidine and incubated at 37 degrees Celsius for 2 days. If the compound is non-mutagenic, the plate show very few colonies, as a result of spontaneous mutations.

Questions:

1. At what stage in a cell’s life cycle does mutation occur?

2. Predict what the plates will look like if the compound is mutagenic. Explain why this might occur.

3. Besides the histidine requirement, this strain of Salmonella has another important characteristic in its genetic makeup that makes the test more sensitive and increases the chances of mutations showing quickly. From the information given above, suggest what this characteristic might be.

4. Why would a plate show some growth even if the compound was not mutagenic?

5. Would a non-mutagenic but mitogenic compound increase the chance of cancer formation?
LESSON 4: RISK

Background Information

Crossing the street can be hazardous to your health. Of course, you've known that since kindergarten. "Look both ways" is part of the curriculum at that age! The fact is, almost everything we do carries some risk of harm — riding a bike, learning to ski, even eating a hot dog. Hot dogs may cause choking and day care centres have to slice them in half lengthwise to ensure that small children don't choke. Still, we do all these things and a lot more. Whatever the risk (the probability of harm), we decide that the benefit — whether it is transportation, nutrition, or just plain fun — is worth it. We evaluate risks and make decisions many times a day without even realizing it.

On the other hand, we sometimes make decisions based on information that is available without properly understanding the significance of such information. How is risk calculated when the safety of a food additive is evaluated? In building a new industrial facility or registering a new pesticide, do we somehow calculate in the risk to animals or other components of the environment? Who makes these decisions?

Risk is the probability of experiencing a hazard. The hazard from chemical exposure depends on the toxicity of the substance and dose received and/or the length of exposure. Relative toxicities are often evaluated using an LD50. That is the dose at which 50% of a population of experimental organisms dies. For many chemicals, small doses may have no effect or, in the case of vitamins or medications, may have a beneficial effect. A threshold value is the exposure which will not cause harm. This is also known as the NOEL (no observed effect level) or the NOAEL (no observed adverse effect level.) When limits are set for food products, a safety factor is built in to the to determine an ADI (acceptable daily intake.) Often the ADI is one percent of the NOAEL.

In determining these levels, assumptions are made about residue levels and about intake. Calculating an average daily intake assumes that foods are eaten in approximately equal amounts by everyone in the population. Usually food additives or trace contaminants are present only in levels measured as parts per million or even parts per billion. One part per million (ppm) is a ratio the same as one minute in two years or one cent in $10,000 while one part per billion (ppb) is equivalent to one cent in ten million dollars. Even such small amounts of some compounds can cause problems.

Many chemicals have a long latent period between the time of exposure and the

Figure 10 Risk is part of our daily lives
development of adverse effects. This is the case with cancer. Therefore for a hazard like carcinogenesis, it is necessary to look at long-term studies to determine if people in a particular occupation or particular location are more susceptible. If an increase is detected statistically, then some detective work is necessary to determine the carcinogenic cause. In this way, epidemiology (the study of the occurrence and causes of disease) and toxicology (the study of adverse health effects of chemicals) are combined.

The risk of carcinogenesis is particularly difficult to estimate, not only because of the length of time elapsed between exposure and development of symptoms, but also because it is a random event, depending on the occurrence of a number of factors within the DNA of our cells. The time lapse also means that there are many other variables such as diet, smoking and workplace exposure that can affect cancer rates. For example, in determining if farmers using 2,4-D are at increased risk of cancer, it is important also to consider factors such as smoking habits, exposure to molds and fungi, exposure to other agrochemicals and sources of drinking water.

However, carcinogenesis is the hazard most likely to gain public attention. We have all heard news reports that "product X causes cancer." How do we put these stories in perspective? We need to ask the right questions if we are to evaluate such reports. What was the original risk? How did that change? Usually the percentages are quite small. How was the result calculated? Animal studies can't always be assumed to apply to humans, though there is often a relationship. Sometimes, scientists report on preliminary results using only a small sample population. Sometimes too other variables may play a role. Good science requires repetition before results can be accepted. Unfortunately, journalists often report on preliminary results without fully understanding the science behind them. One problem is that such studies often use extremely high doses of a compound, levels that would never be approached under normal circumstances. Scientists are not yet in agreement on whether or not there is a threshold level of exposure below which cancer will not occur. Most regulators assume there is no threshold and use a linear extrapolation to estimate a virtually safe dose. However, for some substances, such as saccharin, we know that the cancer causing mechanism has a threshold.

Certainly society should work to minimize risks. Society does that through education, research, regulation of some industries for occupational and environmental health, and establishment of standards for food, air and water quality.
Teacher Information

Objectives

3) To help students understand the concept of risk determination.

1. Ask students to name some behaviours or conditions they consider risky. Most of these will be voluntary behaviours e.g. smoking, drinking, skiing, etc. Ask why people continue to do things that they know can be dangerous - in jobs, it may be money; for some it is the thrill; many have a sense of invulnerability (It won't happen to me!)

2. Using the transparency of the risk of accidental death (Appendix D), ask students where they would consider the risk from pesticides. According to experts in risk assessment, it is actually at 28. A group of college students ranked it at 4, women voters at 9 and business people at 15. Ask the students who is at greatest risk. Those who produce them and applicators such as farmers who deal with them frequently and in large quantities are at far greater risk than the general public.

3. Distribute the ranking sheet and allow students to discuss in groups the rankings below.
4. After discussion, compare results. Probably few will be accurate.

5. Ask students why our perceptions differ from the scientifically-calculated rankings. Media coverage affects our perceptions. Our perception also depends on how much control we feel we have over the risk. If we feel we have no control, we feel more vulnerable, no matter how small the risk.

Worksheet Answers:

Part A

a) A. Possibly there is no effect or the doses tested may be below the threshold level.

b) D

c) B

d) C

e) No one consumes that amount of coffee at once. Over a period of time, the caffeine can be metabolized by the body.
Part B

1) 8 years for those with 5 or more years of exposure
2) 97%
3) the longer the exposure time, the greater the risk of eventually developing cancer; even those with short-term exposure, the risk was higher than for the general population
4) students should consider worker safety, health costs, personal costs. Presumably in many countries, occupational standards are better than when these results were published. Student reactions will depend on the point of view — worker, consumer, taxpayer. Consumers could initiate a boycott of products where employers allow unsafe conditions. While poor conditions might not be legal in Canada, some companies establish businesses in less developed countries where regulation and/or enforcement are minimal and labour costs are low. Students could debate whether or not this is good corporate citizenship.

Questions for discussion:

1. For most foods, ADI is based on the assumption that all people eat approximately equal amounts of a food (national annual consumption divided by population). Is this a valid assumption? Consider foods such as peanut butter, apples and apple juice where intake by children is probably higher or ethnic preferences where certain types of foods are consumed more frequently than others.

2. Ask students if there are costs to society when people choose to participate in risky behaviour - principally health care costs for treatment of injury or disease; there are also personal costs - pain or disability, loss of work time, cost of treatment or help if incapacitated, stress on relationships, etc.

3. Aflatoxin, produced by molds on such crops as peanuts, contributes significantly to the incidence of liver cancer in the tropics. Why is it a greater risk to people in the tropics than to those in North America? (here, aflatoxin is about 2 ppb on peanuts; levels could be higher there since climate there promotes mold growth, storage conditions are probably less controlled; peanuts may form larger part of diet throughout life; maybe differences in use of fungicide for domestic use).
Occasionally sensational news headlines draw our attention to the cancer risks from certain foods. Such stories often scare people so that they stop eating such foods. Nitrate in processed meats such as bacon have been targeted as have the molds which produce aflatoxins in peanuts. Do you consider these foods hazardous when compared with other hazards we face every day?

Following is a list of risks. U.S. scientists gave each of these a relative score. A tap water standard (consumption of 1 quart per day) was given a standard of 1 (low). From this consumption, the actual risk was calculated to be a 3 in 10 million chance of developing cancer over a year. The highest risk in the table is 12000. Place these in the order you think they should go from lowest (1) to highest (12).
<table>
<thead>
<tr>
<th>Risk</th>
<th>Source</th>
<th>Rank*</th>
</tr>
</thead>
<tbody>
<tr>
<td>death</td>
<td>auto accidents</td>
<td></td>
</tr>
<tr>
<td>cancer</td>
<td>eating one raw mushroom per day</td>
<td></td>
</tr>
<tr>
<td>cancer</td>
<td>nitrates from eating 15 strips of bacon per day</td>
<td></td>
</tr>
<tr>
<td>death</td>
<td>electrical shock (home and workplace)</td>
<td></td>
</tr>
<tr>
<td>cancer</td>
<td>aflatoxin from eating 2 tbsp. peanut butter per day</td>
<td></td>
</tr>
<tr>
<td>death</td>
<td>home accidents</td>
<td></td>
</tr>
<tr>
<td>disease</td>
<td>from smoking one pack of cigarettes per day</td>
<td></td>
</tr>
<tr>
<td>cancer</td>
<td>from drinking 12 ounces of beer per day</td>
<td></td>
</tr>
<tr>
<td>cancer</td>
<td>chlorine in tap water</td>
<td></td>
</tr>
</tbody>
</table>


*These ranks are approximations*
Part A

a) Which of the above graphs demonstrates a compound with no observed effect? List two possible reasons why no effect is observed.

b) Which graph represents a drug such as Vitamin A which is beneficial at low doses but toxic in larger doses?

c) Which graph represents a compound such as caffeine which is considered safe at low doses? Indicate on this graph the threshold limit.

d) Which graph represents a compound for which there is not believed to be any safe level?

e) A single dose of caffeine, equivalent to the caffeine in 100 cups of coffee, would be lethal to most people. Explain why coffee drinkers don't die of caffeine poisoning.
Part B

In a study published in 1958, data showed the development of bladder cancer in men exposed to the carcinogen 2-naphthyl amine during their work. The men were divided into three groups, those who had more than five years exposure (Group A), those with 3-5 years exposure (Group B), and those with less than 2 years exposure (Group C). Plot the following data on a graph.

<table>
<thead>
<tr>
<th>Years following initial exposure</th>
<th>% with cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A, &gt; 5 year exposure</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>15</td>
<td>43</td>
</tr>
<tr>
<td>20</td>
<td>72</td>
</tr>
<tr>
<td>30</td>
<td>97</td>
</tr>
<tr>
<td>Group B, &gt; 3 - 5 year exposure</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>30</td>
<td>68</td>
</tr>
<tr>
<td>Group C, &lt; 2 year exposure</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>30</td>
<td>13</td>
</tr>
</tbody>
</table>
1. What was the shortest latent period?

2. What percentage of long-term employees would eventually develop cancer?

3. Explain how time of exposure affected the cancer rate.

4. Discuss the role of government regulation in worker safety. The establishment and regulation of standards is a cost to society that is funded through taxation. Industrial compliance with standards may result in higher costs of production which will be passed on to consumers. Are these costs justified? If you were aware of a workplace where safety standards were not met, how would you react?
LESSON 5: KEEPING FOOD SAFE

Background Information

Everything we do has some risk attached. Our goal is not to avoid risks. That is impossible. Our goal, instead, is to understand risks and make informed decisions that help us to minimize those risks. Where our environment is concerned, we have established government departments to evaluate risks and set limits. These limits should be designed to protect the environment's capacity to sustain plant and animal (including human) life. Many of these regulations come under the Canadian Environmental Protection Act. The Act is designed to control not only agents which have a direct adverse effect but also those which have an indirect effect. Under the Act, the legal definition of toxicity includes three criteria:

- danger to human health
- danger to the environment
- danger to the environment upon which human life depends.

Such regulations protect the air we breathe and the water we drink, with further regulations, both national and international, to ensure the safety of the food we eat.

Food is a prime consideration for all living organisms. Humans are no exception, but unlike most animals, most of us don't find and harvest or kill food for ourselves. Most farming in Canada has become a highly technical operation. Fertilizers and pesticides are used to protect crops while growth stimulants and antibiotics are available to maintain health and efficient growth in animals. Both federal and provincial governments have departments of agriculture and environment, not only to assist farmers,
seriously affected. Fertilizers too must be used carefully, since if they run off into water systems, they can affect the growth of algae and other aquatic species. Some people feel these risks are unacceptable. Others feel that such chemicals are necessary to maximize agricultural production. Some even feel that restrictions are too stringent. Society, through its regulators in government, must evaluate data and balance the desires of all groups. Further control of Canada's food supply comes under the jurisdiction of Health Canada. This department monitors food safety and regulates the use of additives such as dyes or preservatives added during food processing.

Of course, not all our food is produced in Canada. Our climate doesn't allow the growth of oranges, pineapples, bananas and many other foods that we have come to enjoy. We live in a global context and international trade plays an important role. For this reason, the Food and Agricultural Organization (FAO), an agency of the United Nations, founded the Codex Alimentarius to encourage fair international trade in food products and to promote the health and economic interests of consumers. Standards and codes have been developed for the production and trade of food products. The Codex includes 2700 maximum limits for pesticide residues in food. The FAO has also established an international code of conduct for the distribution and use of pesticides. Canada's involvement at this international level helps to ensure the safety of imported food products.

While some people would argue that no pesticide residue should be allowed in food, it is important to remember that most foods contain no detectable levels and the limits set have safety factors so that they are far below the No Observed Affect Level (NOAEL) even if eaten daily. Generally, it is considered that the risk is negligible and is outweighed by the benefits of ensuring a plentiful and inexpensive food supply. Similarly, preservatives are used at levels that are experimentally determined to be safe. They prevent the growth of spoilage and disease organisms, reducing or eliminating the occurrence of foodborne illness and the waste that occurs with food spoilage.
Teacher Information

Objectives:
1) to look at some of the countries where our food originates
2) to recognize some of the regulatory systems which govern chemicals in our foods and our environment

1. Have a world map displayed. Ask students where our food comes from. You could have examples of foods from other countries - New Zealand lamb, Brazil canned corned beef, pineapple from Thailand. Ask the source of bananas, oranges, grapes, etc. A marker on each country will show that our foods come from all parts of the world. (You could ask students during the previous lesson to bring in foods from other parts of the world. Have a contest to see whose has come the greatest distance, whose is produced farthest north or south, nearest the equator, etc.)

2. Do they think our foods are safe? Who do they think regulates food safety? What do they know of conditions in the country of production?

Worksheet Answers:

Part A

1. agricultural chemicals (e.g. fertilizers, pesticides), drugs, food additives, food dyes, food preservatives

2. the taxpayer if government covers all costs, the consumer if the government institutes cost recovery, since the industry would pass the cost on in its pricing system. Perhaps discuss if there is a difference between the taxpayer and the consumer!

3. member countries contribute. (In 1988, Canada was the fourth largest financial contributor to the U.N. although it ranked thirtieth in population size.)

4. examples:
   Federal- pesticide registration, Health Canada testing of food products, international involvement
   Provincial - education and recommendation to farmers
   Municipal- restaurant inspection

5. In many countries, there is little internal regulation of pesticides and their use; some can't afford such programs, some workers are uneducated and don't understand risks, etc. At one time, pesticides which had been banned in some countries because of safety concerns were sold in countries that had little or no regulation. In looking at pesticide use, it is important to remember that in many countries, insecticide use is important in disease control e.g. malaria, yellow fever, etc.

6. a) longer shelf life, less spoilage. Longer shelf life for packaged products e.g. cereals and baked goods may help reduce waste and cut costs
   b) ham, wieners, luncheon meats (e.g. salami), some canned meats
   c) societal choice - regulation of amount allowed in products; individual choice as to amount consumed
7. Using the map again, allow students to compare information on the countries they have chosen.

**Part B**
(This is a hypothetical example)

a) Breads-toast (60) + Sandwich (bread will be 60) + roll (40) = 160
   160 x .02 x .16 x .038 = .019

b) .019 + (150 x .045) + (100 x .074) + (40 x .34) = 27.8

c) ADI = 50 x 2 = 100. Therefore, she gets only about a quarter of the acceptable level.

**Question for discussion** - If you found an insect on fresh vegetables in the grocery store, how would you react? Normally high pressure water sprays clean produce and insects are washed away. Occasionally one manages to hang on (e.g. green larval stage of cabbage butterfly on broccoli or cauliflower) but these are generally harmless. We certainly wouldn't want insecticide sprayed over the produce counter to kill any insects!
Worksheet

1. List three types of chemicals that are regulated by government.

2. Who pays for government regulation of food safety?

3. How is the United Nations funded?

4. List the three levels of government in Canada. Name one way in which each is involved in promoting food safety.

5. Suggest a reason that the FAO would establish a code of conduct for use of pesticides.

6. Nitrates and nitrites are contained in some processed meats as preservatives. These have been associated with increased rates of some types of cancer.
   a) Give some benefits to the use of such preservatives.
   b) Name three products that contain nitrites.
   c) How do Canadians minimize risks from these compounds?

7. Identify one imported food product. Give the product name, brand name, ingredients and country of origin. Describe the country of origin - population, type of government, agricultural products, wealth. How do you think regulation of the food industry in this country would compare with regulation in Canada?

8. Deregulation of the agriculture and food industry could cut government expenditures. Would you be in favour of deregulation if it meant that taxes could be decreased? Explain your answer.
Calculation of Food Safety - Worksheet B

Bug-be-gone is an insecticide used to control crop pests. A tiny amount of residue may be left in some foods. However, these are generally considered to be low enough to be deemed harmless. Cooking reduces the levels of active compound even further. Janet eats the following foods in a day.

<table>
<thead>
<tr>
<th>Food</th>
<th>Grams</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Breakfast</strong> 1 poached egg</td>
<td>46</td>
</tr>
<tr>
<td>1 apple</td>
<td>150</td>
</tr>
<tr>
<td>2 slices toast</td>
<td>60</td>
</tr>
<tr>
<td><strong>Lunch</strong> 1 ham sandwich</td>
<td>160</td>
</tr>
<tr>
<td>1 banana</td>
<td>175</td>
</tr>
<tr>
<td><strong>Dinner</strong> 1 serving chicken</td>
<td>75</td>
</tr>
<tr>
<td>1 baked potato</td>
<td>100</td>
</tr>
<tr>
<td>1 dinner roll</td>
<td>40</td>
</tr>
<tr>
<td>carrot sticks</td>
<td>100</td>
</tr>
<tr>
<td>1 stalk celery</td>
<td>40</td>
</tr>
<tr>
<td>1 bowl ice cream</td>
<td>100</td>
</tr>
</tbody>
</table>

**Bug-be-gone concentration (micrograms/gram)**

<table>
<thead>
<tr>
<th>Food</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>banana, potato, meats, eggs, ice cream</td>
<td>none</td>
</tr>
<tr>
<td>apple</td>
<td>0.045</td>
</tr>
<tr>
<td>cereal grains</td>
<td>0.02</td>
</tr>
<tr>
<td>carrots</td>
<td>0.074</td>
</tr>
<tr>
<td>celery</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Both processing and cooking reduce the amount in wheat. Processing reduces it to 16% of the original amount while cooking reduces it by a further 96.2%.

Calculate the total insecticide ingested in bread products.

b) Calculate the ETDI - estimated total daily intake.

c) If the ADI (acceptable daily intake) is 2 micrograms/ kg and Janet weighs 50 kg, does she take in more or less than the ADI?
LESSON 6: TOXICOLOGY - HOW IT FITS INTO OUR FUTURE

? Background Information

James Lovelock's “Gaia” hypothesis proposes that the earth functions as a living organism just as a bacterium or a dog is a living organism. According to this hypothesis, the earth can be poisoned by toxic substances when its capacity for detoxification is exceeded. As toxic substances accumulate beyond the earth's capability to counteract them, the effects will be felt by every living thing. Contamination of air and water must be avoided or at least limited if the planet and those who inhabit it are to remain healthy.

Whether or not you agree with the “Gaia” hypothesis, it is true that the planet has been exposed to increasing levels of new chemicals since the Industrial Revolution. During the millions of years that life has been present on the planet, most changes in the environment have been slow. Systems and organisms have evolved slowly to cope with many of these changes. In some cases, technology has speeded up the rate of change. We can now cut more trees, mine more ore, extract more oil, and produce more goods than ever before. Yet each of these technological processes produces chemicals which, if not managed carefully, can damage our environment and threaten our own health. These processes are important to our economy and our way of life so it is up to us as a society to ensure that the risks from these processes are minimized.

Everything we do or use has some chemical impact. Even breathing produces CO2 which is a greenhouse gas, one of the chemicals implicated in global climate change! Exhaust emissions from vehicles used for transportation or recreation affect the air. Where electricity is produced from fossil fuels, power use also has an impact on air though technology has reduced emissions significantly in recent years. Industries which produce consumer goods are intensive power users and many also discharge effluents into water systems. Although the composition of these effluents is now regulated, there is still some impact.

We can't turn back the clock, and even if we could, things weren't necessarily better in times past. Coal and wood used for fuel in earlier centuries were dangerous to health. Contamination of food by bacteria and molds was common. There was no way to check water quality. Life expectancy is far longer now than it was even a century ago.

Our economy has been built on a technological base which has introduced new chemicals. Fortunately we are beginning to recognize the dangers if those chemicals are mismanaged. By understanding the power that we have to damage the earth, we can learn to limit our impact and minimize the risks. As management of these risks improves, we are
at far greater risk from personal choices such as smoking or poor eating habits than we are from the involuntary risks we face from chemicals in our environment. Although these environmental risks are low, they are real. We must ensure that society continues to recognize and respond to the dangers.

What do you know about environmental contamination?
Teachers Information

Objectives
1) to encourage students to think beyond human toxicology to look at some environmental issues
2) to see the implications of their choices on the environment

Worksheet answers:

1. Ask students to name some industries which they think may pollute the environment (include both air and water).

2. Ask what the industries or government should be doing to make some changes to improve the problems they have identified.

3. Ask if they think choices they make affect the environment.

4. Distribute the worksheet. Remind students of the ranking of risk from chlorination (lesson 4)

Part A: True - False (page numbers in brackets refer to the Government of Canada publication "A Vital Link"

1. 1. false. Some coastal communities release raw sewage into the ocean.

2. 2. false (p.16)

3. 3. true (p.8)

4. 4. false. Leakage from old sites can contaminate groundwater.

5. 5. false (p.71) - less than 2%

6. 6. true (p.49)

7. 7. true (p.42)

Part B:

1. a) shellfish were contaminated with dioxins and furans, so commercial fishing was closed to prevent human consumption of these shellfish

b) limit release of dioxins and furans into water system

c) cardboard carton

d) some students might suggest government regulation; others might want to encourage self-regulation of the industry. Allow students with differing opinions to present their views to the class.

2. the risk from chlorination would have been far less than the risk of illness and death from cholera

3. Reduce, reuse, recycle. By reducing consumption of consumer products, we reduce the amount of manufacturing and energy consumption, thereby reducing wastes from these industries. Ask students what individual or class actions they might undertake as a result of this discussion.
Worksheet

Part A: True - False

1. ___ All cities in Canada have to treat sewage waste before it is released into any water system.

2. ___ An Ontario study showed that there was no link between hospital admissions in summer and the levels of ozone and sulphur dioxide in the air.

3. In a 1990 survey across Canada, 85% of respondents believed that pollution problems threaten survival of the human race.

4. ___ Old waste disposal sites do not contribute to present chemical contamination of the environment.

5. ___ At least 25% of foodborne illnesses are known to be caused by chemical contamination.

6. ___ The level of carbon monoxide in the air of Canadian cities has decreased to about 50% of its 1975 levels.

7. ___ Lead additives are no longer used in gasoline they caused pollution which allowed accumulation of lead in humans. Lead additives caused pollution which allowed accumulation of lead in humans but they are no longer used in gasoline.

Part B

1. Dioxins and furans are produced during bleaching in the pulp and paper industry. In the past, some have been released in liquid effluents. In water systems, bioaccumulation can occur in aquatic organisms.

   a) On advice from Health Canada in 1988, the federal Department of Fisheries closed commercial shellfish harvesting on the B.C. coast near pulp mills. What reason could there be for this decision?

   b) New regulations are being implemented for pulp and paper mills. What will they limit?

   c) In 1988, some milk samples in Canada showed the presence of dioxins and furans. In what type of container were they sold?

   d) New bleaching processes are available which reduce the production of dioxins and furans. How should governments react to these processes?

2. Cholera is a disease carried by waterborne organisms. A recent outbreak of Cholera in Peru claimed hundreds of lives. For various reasons, officials were reluctant to chlorinate the water. Were the risks weighed adequately?

3. Our lifestyle is a contributing factor to the amount and variety of chemicals in the environment. Identify some of the actions consumers can take to help minimize environmental impacts.
LESSON 7: LIQUID OF LIFE, BUT IS IT SAFE TO DRINK?

Teacher Information - Case Study

Objectives:

1. to look at one possible environmental situation which may have toxic effects

2. to help students evaluate scientific results and demonstrate that not all results are conclusive

3. to emphasize the necessity of exchange of information within the scientific community

Worksheet Answers

1. Discuss water in the environment using the transparency of the hydrologic cycle. (Appendix E).

2. Distribute the worksheet.

Worksheet: (information from the Canadian Medical Association Journal Vol. 138:117; 1988)

1. not enough data are presented to draw conclusions about cause and effect though the information does provide ideas for further research.

2. nitrates could get into the surface water in the area as runoff following fertilizer application. It could also penetrate the soil and get into the ground water, possibly increasing nitrate levels in wells nearby.

3. studies to show if nitrates affect the progeny of lab animals such as rats or mice could be carried out. If such effects were noted, it would support the hypothesis that nitrates do have teratogenic effects but would still not be able to draw the conclusion that such effects exist in humans.

4. there may be species differences in the ability to metabolize compounds such as nitrates so effects may not be the same in all species.

5. drinking habits might differ (was water intake similar?), something other than nitrate that is also in the water might be causing the effect, it might depend on the source of the nitrate(eg. there might be another contaminant associated with fertilizer runoff).

Figure 16 The hydrologic cycle
Questions for discussion:

Sometimes reporters headline stories of chemical risks to food safety or the environment. Do students think that reporters are always objective in their reporting? Are reporters qualified to evaluate technical reports? Where do reporters get their information?

Auxiliary activity:

1. Ask students to prepare a press release based on the results presented. A press release should open with a statement that grabs attention. Main information should be presented first and expanded later. Then ask how two different reporters would headline the story. Reporter A works for a tabloid press which likes to sensationalize stories. Reporter B works for a serious news agency.

2. A computer program which simulates some aspects of groundwater.
Worksheet

The Canadian Congenital Anomalies Surveillance System was established in 1966 by the Health Protection Branch of the federal Department of Health Canada to **monitor** rates of birth defects across Canada. Researchers in the Maritimes, using data from this system, found that in the agricultural area of the St. John River basin, birth defects and stillbirths were higher than in other areas and showed seasonal peaks. However, there seemed to be no correlation between pesticide use and birth defects or stillbirths in those areas. In Australia, researchers found a correlation between nitrate levels in drinking water and an increase in birth defects. Nitrate is a component of fertilizer.

1. Can you draw any conclusions from this information about factors which contribute to birth defects?

2. Combine the Canadian and Australian information into a plausible hypothesis.

3. Although it is not always accurate to extrapolate from studies with lab animals to humans, such studies can provide useful information. Outline an experiment that might help interpret some of the observations described above.

4. Give a biochemical reason why studies from one species may not give the same results as studies from another species.

5. Swedish scientists also studied birth defects and nitrate levels in water but did not find any association. Suggest two reasons why results might differ.

6. What is the importance of communication between scientists?
RESEARCH TOPICS

1. A number of **biochemical** changes occur within the cell during the development of **cancer**. Look at the stages of **cancer** development, including the role of:

   a) **oncogenes** and **tumour suppressor** genes in cellular control and

   b) the modification of these by **viruses and chemical carcinogens**.

2. During World War I, toxic gases (chlorine and mustard gas) were used. The first attack occurred April 22, 1915 against Canadians at Ypres. What are the toxic effects of these gases? What are the long-term effects on the men exposed? How and why were they used? Discuss the use of chemical warfare.

3. Select an environmental issue related to **toxicology** (e.g. industrial **effluents** in water or air, pesticide residues, occupational **exposure**) and discuss its implications for human health. What chemicals are involved? Who is susceptible? What health problems might result? What control measures are used? What more could be done?

4. The safety of Canada's food supply depends not only on foods produced within Canada but on foods from around the world. Discuss how international trade affects Canada's food supplies. Include effects of agreements such as NAFTA (North American Free Trade Agreement) and GATT (General Agreement of Tariffs and Trade).

5. Take a look at aquatic pollution. The Exposure Analysis Modelling System II (EXAMS II) is a user-friendly behaviour program which permits rapid evaluation of the probable behaviour of synthetic organic chemicals in aquatic systems. The software is free if downloaded from the USA EPA Scram Bulletin Board (1-919-541-5742), except for a two-hour transmission cost at 9600 BAUD or could be made available through your school system from the following person. For a user manual and system documentation, as for document "EPA-600/3-82-023" from the:

   US Department of Commerce
   National Technical Information Service,
   Springfield, VA 22161
   at a cost of about $40.00 (US). For more information regarding the use of EXAMS II contact:

   Dr. Jerry Shaw, P.Ag
   Health Protection Branch
   Health Canada
   Room 835, 9700 Jasper Avenue
   Edmonton, AB T5J 4C3
   Tel: 403.495.7005
CROSSWORD PUZZLE

ACROSS
1. An evaluation or ________ of risk helps us to make informed decisions regarding chemical use.

4. One thousand milligrams equals one ________.

6. The body's ________ can be affected by chemicals which enter our systems.

8. A ________ can cause birth defects.

12. Genetic material is contained in the ________ of a mammalian cell.

14. Total dose of an airborne contaminant is determined by both the concentration and the ________ of exposure.

15. Biochemically, the molecules of vitamin C from natural and synthetic sources are the ________.

16. When using medicines, be ________ to use them as directed by a doctor or pharmacist.

18. Health and Welfare Canada ________ the exposure of Canadians to heavy metals (eg. mercury) from food.

21. Toxins can be produced by living organisms so ________ products are not necessarily safe.

24. Depending on assumptions made and how results are interpreted, scientists sometimes ________ agree on conclusions.

25. When taking vitamins, do not exceed the prescribed ________.

26. Carcinogens can cause ________.

DOWN
1. When evaluating an intake that appears to be without risk if taken over a lifetime, it is necessary to calculate "accepted daily intake" or ________.

2. If everyone handled chemicals safely, the world would be a ________ place.

3. Recent cancer research shows that ________, the stimulation of cell division, is a factor in carcinogenesis.

5. When we try to measure the chances of something happening, we are determining ________.
7. Although some people would like to _______ the use of pesticides, most are willing to allow their application as long as they are used carefully.

8. Below a _______ dose, no effect of a substance is observed.

9. Short-term exposure to a substance is considered an _______ exposure.

10. When exposed at or below the _______ of a substance, no effects can be seen in the animals under study.

11. When working with highly toxic substances handle with _______.

13. Long-term exposure to a hazardous substance can lead to _______ health problems.

16. When industrial contaminants are found in water, it is best to eliminate them at the _______.

17. In the production of proteins in the cell, messages from DNA are carried by _______.

19. Labels carry important information. Read _____ carefully.
# CROSSWORD ANSWERS

<table>
<thead>
<tr>
<th>ACROSS</th>
<th>DOWN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. assessment</td>
<td>1. ADI</td>
</tr>
<tr>
<td>4. gram</td>
<td>2. safer</td>
</tr>
<tr>
<td>6. metabolism</td>
<td>3. mitogenesis</td>
</tr>
<tr>
<td>8. teratogen</td>
<td>5. risk</td>
</tr>
<tr>
<td>12. nucleus</td>
<td>7. ban</td>
</tr>
<tr>
<td>14. time</td>
<td>8. threshold</td>
</tr>
<tr>
<td>15. same</td>
<td>9. acute</td>
</tr>
<tr>
<td>16. sure</td>
<td>10. NOEL</td>
</tr>
<tr>
<td>18. monitor</td>
<td>11. care</td>
</tr>
<tr>
<td>21. natural</td>
<td>13. chronic</td>
</tr>
<tr>
<td>24. dis</td>
<td>16. source</td>
</tr>
<tr>
<td>25. dose</td>
<td>17. RNA</td>
</tr>
<tr>
<td>26. cancer</td>
<td>19. them</td>
</tr>
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<td></td>
<td>20. rate</td>
</tr>
<tr>
<td></td>
<td>22. ASA</td>
</tr>
<tr>
<td></td>
<td>23. LD</td>
</tr>
</tbody>
</table>
GLOSSARY

**ADI** (acceptable daily intake) - the amount of a substance which is calculated to be safe if taken daily throughout a person's lifetime, usually expressed as a function of body weight

**Acute** - in toxicology, a single exposure or dose which is sufficient to cause and adverse reaction

**Aflatoxin** - a naturally-occurring toxin produced by moulds on substances such as peanuts

**Ames Test** - a test which measures the potential of a chemical to cause mutations in bacteria; those causing mutations are probably capable of causing cancer in mammals

**Antagonism** - action between two or more compounds in which one interferes with the action of the other so that there is less effect from a similar dose than if it were present alone

**Bio-accumulation** - the build-up of a substance in an organism due to the presence of the chemical in the food supply (or in the case of plants or aquatic organisms, in the water supply). Accumulation only occurs if the substance is slow to be excreted or metabolized. Sometimes, incorrectly use as a synonym for biomagnification.

**Biochemical** - relating to chemical processes which occur in living organisms

**Bio-magnification** - the build-up of a chemical in a particular organism high on the food chain because of ingestion of prey containing the chemical e.g. a buildup of mercury in people eating fish from waters contaminated with organomercurial compounds, sediment - bacteria - invertebrates - fish - birds - humans

**Bio-technology** - the use or manipulation of living systems to improve their value to humans e.g. genetic engineering of plants, use of bacteria to produce particular substances

**Cancer** - uncontrolled growth of cells which can damage body organs and lead to sickness and death

**Carcinogen** - an agent which can contribute to the development of cancer

**Chronic** - long-term; may be used to refer to a) a disease or b) exposure to a particular substance at a low level which does not cause an immediate adverse effect but which may, if continued for a long period of time be detrimental to health

**Contaminant** - any undesirable substance in food, water or air

**Cost-benefit analysis** - an evaluation of the relative costs and benefits of an action or behaviour
**DNA (deoxy-ribonucleic acid)** - the substance which carries the genetic information in most cells; it carries codes for the building of proteins which control the development and metabolism of organisms

**Dose** - the amount of a substance taken into the body

**Effluent** - outflow; liquid waste which is discharged into a water (e.g. river) system

**Enzyme** - a chemical (protein) produced by a cell to act as a catalyst in a particular biochemical reaction

**Epidemiology** - the study of the occurrence and causes of diseases in humans

**Exposure** - the does of a substance capable of causing toxic effects actually taken into the organism (in the case of a person, through ingestion, inhalation or dermally).

**Gene** - a unit of heredity; each gene is a length of DNA which carries the code for a particular protein

**Hazard** - the potential of a substance to cause harm

**Heavy metal** - a metal of high atomic mass e.g. lead or mercury; these can have toxic effects in living organisms

**Immune system** - the system in mammals which helps a body to fight infection

**LD₅₀** - the dose of a toxin which kills half of a test population of a particular species; it can differ among species

**Metabolism** - the biochemical processes which occur in living organisms, including the use of nutrients to provide energy and materials for growth and maintenance of a body

**Mitogenesis** - the stimulation of cell division

**Monitor** - to keep track of

**Mutagen** - a substance that can cause a change or mutation in genetic material

**NOEL** (no observed effect level) - a level of exposure to a chemical that produces no observable effect; usually it is used to consider adverse effects so NOAEL is "no observed adverse effect level."

**Organic** - chemical compounds which contain carbon atoms
Promotion - enhancement of the action of a chemical by another chemical which, on its own, has no observable effect

Risk assessment - the identification of a danger and estimation of the probability of occurrence

Risk-benefit analysis - an evaluation of a risk versus the benefit to be expected from accepting that risk

RNA (ribonucleic acid) - the genetic material of some viruses; in other organisms, it uses the information from DNA to direct the synthesis of cell proteins

Synergism - the effect of two chemicals which, in combination, each act more strongly than either alone

Teratogen - a chemical that can cause birth defects when experienced by a female before or during pregnancy

Threshold - dose - the lowest dose at which effects may be observed

Tolerance - the increased ability of an organism to resist the effects of a toxic substance

Toxicology - the study of the adverse effects of chemicals on living organisms

Toxicity - the measure of the capacity of a chemical to harm an organism

Toxin - a poisonous substance, having a protein structure, secreted by certain organisms, e.g. a tarantula or bee

Toxicant - a poisonous agent, e.g. chemical compound
APPENDICES

Appendix A: Lesson 1 Transparency
Appendix B: Answers for Lesson 1 Transparency

1. Bee
2. Tarantula
3. Rattlesnake
4. Tobacco Plant
5. Potato Plant
6. Foxglove
Appendix C: Lesson 1 Ascorbic Acid Transparency

Ascorbic acid
(Vitamin C)
Appendix D: Lesson 4 Risk of Accidental Death Transparency

<table>
<thead>
<tr>
<th>Actual Level of Risk</th>
<th>How would you rank the risk from pesticides?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Vehicles</td>
<td>1</td>
</tr>
<tr>
<td>Motorcycles</td>
<td></td>
</tr>
<tr>
<td>Swimming</td>
<td></td>
</tr>
<tr>
<td>General Aviation</td>
<td>10</td>
</tr>
<tr>
<td>Bicycles</td>
<td></td>
</tr>
<tr>
<td>Hunting</td>
<td></td>
</tr>
<tr>
<td>Home Appliances</td>
<td></td>
</tr>
<tr>
<td>Commercial Aviation</td>
<td>20</td>
</tr>
<tr>
<td>Power Mowers</td>
<td></td>
</tr>
<tr>
<td>Skiing</td>
<td></td>
</tr>
<tr>
<td>Spray Cans</td>
<td>30</td>
</tr>
</tbody>
</table>

Perceptions of risk may differ markedly from actual risk. On the left, various causes of accidental death are ranked in the order established for insurance purposes. The risk from spray cans was the lowest among the causes of accidental death considered.

From *Health Issues Related to Chemicals in the Environment: A Scientific Perspective. CAST May 1987*
Appendix E: Lesson 7 The Hydrologic Cycle Transparency

The hydrologic cycle.
Appendix F: Recommended Reading List

Alberta Agriculture, Poisonous House Plants. Garden Fax, Agdex 285/08-1, 1978

Alberta Agriculture, Outdoor Plants Harmful or Poisonous to Humans. Agdex 666-2, 1983


Fairbairn, G.L. Will the Bounty End? Western Producer Prairie Books, Saskatoon, 1984


German Secretary of State (Bundes Ministerium des Inneren). Was Sie schon immer ueber Umwelchemikalien wissen wollten [What You Always Wanted to Know about Environmental Chemicals]. Kohlhammer, Stuttgart, 1982

Jones, C. And S.L. Gadler. Pollution: The Food We Eat. Lerner Publ., Minneapolis, 1972


Klaasen, C.D., M.O. Amdur and J. Doull (Eds.). Casarett and Doull's Toxicology. The Basic Science of Poisons, 3rd Ed. Collier Macmillan Canada, Toronto, 1986

Loomis, T.A. Essentials in Toxicology. Lea and Febiger, Philadelphia, 1974

Lodge, R.W., A. McLean and A. Johnston. Stock-Poisoning Plants in Western Canada. Agriculture Canada, Ottawa, 1975

Ottoboni, M.A. The Dose Makes the Poison: A Plain Language Guide to Toxicology. Vincente Books, Berkley, CA,. 1984


Saskatchewan Environment. The Pesticide Tradeoff. What are the Risks? What are the Benefits? 1984


Small, B.M. and Associates, Ltd. Indoor Air Pollution and Housing Technology. Canada Mortgage and Housing Corporation, Ottawa, 1983


Walkinshaw, D.S. Indoor Air Quality: Issues and Opportunities. NRC-Canada, Division of Building Research, Ottawa, 1985
Appendix G: Study Unit Evaluation Form

TOXICOLOGY: AN ENVIRONMENTAL EDUCATION UNIT FOR SECONDARY SCHOOLS AND COMMUNITIES

Welcome input from teachers who have used this educational resource.

1. Where did you use this unit?
   a) Junior High □  b) High School □  c) Other ________________________.

2. Which part(s) of the Toxicology Study Unit have you used? (Please check all that apply).

   □ Lesson 1: An Introduction to Toxicology
   □ Lesson 2: Toxic Substances, What We Knew Then - What We Know Now
   □ Lesson 3: Mammalian Responses to Toxic Substances
   □ Lesson 4: Risk
   □ Lesson 5: Keeping Food Safe
   □ Lesson 6: Toxicology, How it Fits into our Future
   □ Lesson 7: Case Study: Liquid of Life, but is it Safe to Drink?
   □ Research Topics
   □ Crossword Puzzle
   □ Glossary
   □ Duplication Masters
   □ Further Suggested Reading
   □ Accompanying 12-minute Video

3. In what subject area(s) have you used Toxicology:

   □ Science                      Grade(s) _________________
   □ Social Studies
   □ Other (please specify) ___________________________

4. If applicable, how would you rate the correlation between the Toxicology material and the objectives of the curriculum you follow?

   1 low correlation  2 moderately low  3 unsure  4 moderately high  5 high correlation

5. Did you find the format of the Toxicology Educator’s Guide (i.e. background, teacher’s information and worksheet) easy to follow? □ Yes □ No

   If No, please suggest an improved format:
6. How would you rate students’ interest in this topic area?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>not interested</td>
<td>moderately interested</td>
<td>very interested</td>
</tr>
</tbody>
</table>

7. How would you rate the case study in terms of helping students understand the issues involved with toxicology?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>not very helpful</td>
<td>helpful</td>
<td>very helpful</td>
</tr>
</tbody>
</table>

8. What other topics relating to toxicology would you like to see addressed in this study unit?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

9. Would you use this Toxicology Unit again? □ Yes □ No
   If no, please explain.
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

10. Where / how did you hear about the Toxicology Study Unit?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

11. Are there any Educators you would like to recommend be sent information on this study unit?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

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12. Have you accessed this educational material via our Internet website:  
   http://www.uoguelph.ca/cntc ☐ Yes ☐ No

13. Please provide any additional comments you wish to make on this page:

________________________________________________________________________

________________________________________________________________________

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Thank you for your input.

Forward your comments to: Program Coordinator, Canadian Network of Toxicology Centres, Rm 2113, Bovey Bldg., Gordon St., Guelph, Ontario N1G 2W1  
(Tel. 519-837-3320; Fax. 519-837-3861 or Email: dwarner@tox.uoguelph.ca)

NAME: ______________________________________________________________________

SCHOOL (include address)
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

BUSINESS TELEPHONE NO.: ________________________________________________
Appendix H: Study Unit Order Form

TO:

Donna Warner, Program Coordinator
Canadian Network of Toxicology Centres, Head Office
Bovey Bldg., Gordon Street, Guelph, Ontario N1G 2W1
Tel: 519-837-3320 Fax: 519-837-3861
Email: dwarner@tox.uoguelph.ca

DATE OF REQUEST: (Current date) ________________________________

FROM: (Include name, complete mailing address, telephone and fax number)

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

UNITS REQUESTED:
Please send one copy of the following study unit(s):

1) Educator’s Resource Guide (7 Lessons, accompanying worksheets) English □ French □
2) Educator’s Resource Video (12-min) English □

ADDITIONAL EDUCATIONAL MATERIALS:
The Canadian Network of Toxicology 15-minute video entitled “Environmental Toxicology: A Question of Balance” is available free of charge. English □ French □

REPRODUCTION & DISTRIBUTION POLICY:
The authors grant permission to reproduce either of these study units provided that the authors are cited and that this educational unit is not sold for profit.

INFORMATION NETWORK:
Please circulate this information to anyone in your region who may be interested in receiving information on this toxicology education unit.
Appendix I: Teacher’s Lesson Guide Notes

LESSON PLAN # 1: AN INTRODUCTION TO TOXICOLOGY

Lesson Knowledge Outcomes

1. Life is dependent on an ongoing series of chemical reactions.
2. Toxic substances in our environment can affect all organisms.
3. How government environmental regulations safeguard our health.
4. We are surrounded by both natural and man-made toxic substances; education on responsible care is the key to a healthy, productive environment.
5. The importance of reading “warning labels” on all consumer products including pharmaceutical products.
6. Definitions:
   - a) What is a toxic substance?
   - b) What is the science of toxicology and how does it affect us?
   - c) How to determine toxicology risks versus benefits by utilizing basic principles of toxicology.

LESSON PLAN #2: TOXIC SUBSTANCES - WHAT WE KNEW THEN, WHAT WE KNOW NOW

Lesson Knowledge Outcomes

1. To be aware of the role of government environmental safety regulations in limiting workplace exposure to potentially hazardous substances.
2. How enzymes, our stress levels, and our body’s genetics affect our responses to potentially toxic substances.
3. What paths toxic substances may take to enter our bodies.
4. How bioaccumulation of toxic substances, particularly medications, can interact to cause potential health problems.
5. How toxic substances build up through our food chain.
6. Examples of immune system responses to ingested chemicals.
7. Definitions:
   - a) Natural toxins versus man-made toxicants
   - b) Teratogenicity; chemical antagonism and synergism.
LESSON PLAN # 3: MAMMALIAN RESPONSES TO TOXIC SUBSTANCES

Lesson Knowledge Outcomes

1. Ingestion of toxic substances can cause a wide variety of effects depending upon the dose of the substance and length of exposure to it.
2. How food additives, diet, and our life style choices can affect our health.
3. How our bodies deal with exposure to acute and chronic exposures to toxic substances.
4. Definitions:
   a) Chronic versus acute exposures; carcinogenicity; cancer, Ames Test; and non-mutagenic and mutagenic compounds.

LESSON PLAN #4: RISK

Lesson Knowledge Outcomes

1. Provide students with a better understanding of risk determination.
2. Understand the definition of “Risk” as the probability of experiencing a hazard.
3. Understand how risk factors are calculated to evaluate the safety of food additives.
4. Explanation of how hazards from chemical exposure depends on the toxicity of the substance, dose received and/or the length of the exposure.
5. Develop awareness of society’s attempts to minimize risks of exposures from toxic substances through education, research, regulation of some industries for occupational and environmental health, and establishment of standards for food, air and water quality.
LESSON PLAN # 5: KEEPING FOOD SAFE

Lesson Knowledge Outcomes

1. To develop a better understanding of how to evaluate risks and make informed decisions that help us to minimize the chances of experiencing a hazard.
2. To understand the purpose of the Canadian Environmental Protection Act.
3. To become aware of how regulations and recommendations for pesticide use are designed to protect the environment as well as our food supply.
4. To be aware of Health Canada’s role in monitoring food safety and regulation of the use of food additives.
5. Awareness of Canada’s involvement in the Food & Agricultural Organization (FAO), an international organization founded to encourage fair international trade in food products and protect the health of consumers of world food products.
6. Most foods contain no detectable concentrations of synthetic pesticides, and the limits set have safety factors so that they are far below the No Observed Affect Level (NOAEL) even when eaten daily.
7. Food preservatives are used at levels that are experimentally determined to be safe in order to prevent the growth of spoilage and disease organisms and the resulting costly and potentially dangerous food spoilage.

LESSON PLAN # 6: TOXICOLOGY - HOW IT FITS INTO OUR FUTURE

Lesson Knowledge Outcomes

1. Our economy has been built on a technological base. Technological processes produce chemicals which, if not managed carefully, can damage our entire ecosystem.
2. Everything we do or use has some chemical impact -- even our breathing.
3. We are at far greater risk from personal life style choices such as smoking or poor eating habits than we are from the involuntary risks we face from chemicals in our environment.
4. To raise student’s awareness of how their life style choices, including to recycle or not to recycle, can have implications on their health and the health of their environment.
LESSON PLAN # 7: LIQUID OF LIFE, BUT IS IT SAFE TO DRINK?

<table>
<thead>
<tr>
<th>Lesson Knowledge Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To examine a hydrologic cycle scenario in order to determine possible environmental situations which may have toxic consequences.</td>
</tr>
<tr>
<td>2. To be aware of the importance of proper evaluation of scientific results and to realize that not all scientific results are conclusive.</td>
</tr>
<tr>
<td>3. To understand the importance of the exchange of information within the scientific community.</td>
</tr>
<tr>
<td>4. To gain an awareness of the power of the media to influence public perception regarding issues affecting our environment.</td>
</tr>
</tbody>
</table>