Risk Assessment: Tools of the Trade

Subjects
Biology, Chemistry, Debate, Environmental Science, Health, Human Anatomy & Physiology, Language Arts, Visual Arts

Concepts
- Humans use tools and technologies to adapt and alter environments and resources to meet their physical, social, and cultural needs. (2.1)
- The application of scientific knowledge and technological systems can have positive and negative effects on the environment. (8.1)
- Governmental, social, and cultural structures and actions affect the management of resources and environmental quality. (12.2)

Skills
Analyzing, Debating, Defining Problems, Identifying Relationships, Interpreting, Organizing Information, Predicting, Problem Solving

Objectives
Students will (1) investigate four different ways to assess risk, (2) explore the use of fault trees to assess a risk, (3) understand how toxicological and epidemiological research is used when studying risk, and (4) communicate and defend a debate position.

Materials
Copies of the Student Pages "What's Going On???," "Table of Tools," "Examples of Risk Assessment Tools," "Fault Tree for Car Failing to Start," and "A Second Look at Saccharin" on pages 53–60; "Debate Score Sheet" on page 193 in Appendix 5; packets of an artificial sweetener containing saccharin.

Time Considerations
Preparation: 20 minutes
Activity:
Part A—one 50-minute period plus homework
Part B—one 50-minute period
Part C—one 50-minute period

Overview

When attempting to determine the degree of risk associated with an event, experts conducting risk assessments rely on a variety of *tools of the trade* to generate a risk estimate. In this activity, students will learn about the applications of some of these tools, interpret information generated from using different tools, and understand how the information can be used to set priorities and make decisions.

Background

Risk assessment is the process by which one attempts to evaluate and predict the likelihood and extent of harm (in quantitative and qualitative terms) that may result from a health or safety hazard. A risk assessment is usually performed with the goal of assisting the risk management decision-making process (Siu, Novack, Hill, et al. 1995, C). The elements of a commonly used risk assessment process include hazard identification, dose/response assessment, exposure assessment, and risk characterization. (Please refer to pages 7–9 in the Background Information for Educators section for more information on risk assessment.)

Risk assessors use many different methods of assessment as they characterize risk and define the exposure-response relationship. Some tools include model-based techniques, such as ***event tree*** and ***fault tree*** analysis, and experimental techniques such as toxicity testing and epidemiological studies. The tools experts use depends on the nature of the risk (mechanical, chemical, microbial, physical, and so forth), and the type of information they are interested in uncovering (failure rate, toxicity, incidence of disease in a population, and so forth).

An ***event tree*** *begins with an initial event and asks where the event might lead.* For example, a systems analyst might develop an event tree to calculate the probabilities of possible outcomes in the event of a mechanical failure such as a pipe break in a sewage treatment plant. The first example on the Student Page "Examples of Risk Assessment Tools" shows a *simplified* event tree that illustrates possible outcomes of the initial event, lightning striking the electrical circuit connected to your computer. Each potential outcome is calculated as the product of the probabilities of the success or failure along the chain of events. Thus, in the example of the lightning strike, the probability that your computer hard drive may be damaged is the product of $P_1 \times P_2 \times P_3$. Similar probabilities may be calculated for the other possible outcomes.

A ***fault tree*** may be constructed to better understand the failure of a system. For example, a mechanical engineer might use fault tree analysis to map out a car's failure to start or the accidental release of radioactive waste into the biosphere. (See the Student Page "Fault Tree for Car Failing to Start" for an illustration.) Construction of a fault tree *begins with the undesired outcome and works backward to determine all possible chains of events that could lead to this result.* (A fault tree may be viewed as the opposite of an event tree.) A complete fault tree diagram is an attempt to integrate *all* factors that affect the failure of a product or process, and thus is used to define the complex relationship between the parts of a system.

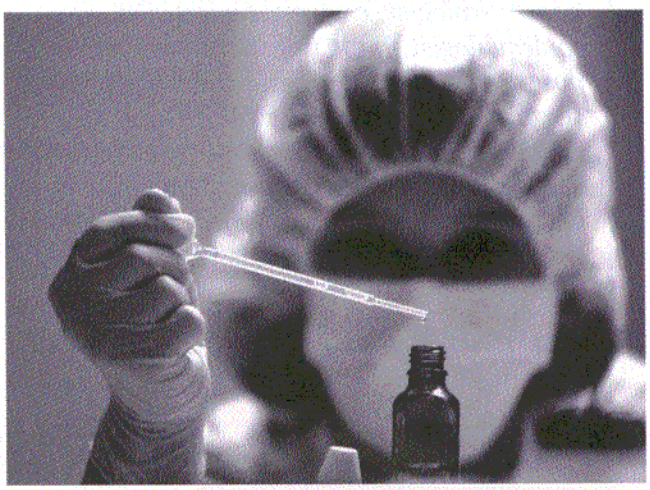
Event tree and fault tree diagrams show the relationships between the parts of a system being investigated. In general, both do the following:

- Define the undesired consequence.
- Identify the initiating events that could lead to the undesired consequences.
- Identify barriers that could interrupt the chain of events.
- Develop event tree models that depict possible scenarios of the success or failure of the barriers or develop fault tree models that depict how the barriers can fail.
- Estimate model parameters and quantify scenario probabilities. (Siu, Novack, Hill, et al. 1995, C)

Other risk assessors are interested in determining whether or not exposure to a certain chemical is dangerous to humans or the environment. If so, at what ***dose*** is the chemical dangerous? Because it is not acceptable to perform toxicity tests on humans, ***toxicologists*** use animals such as rats and mice. The results from animal experiments are ***extrapolated*** to identify the levels dangerous for humans. One way of expressing the results from a toxicity test is through a graphic display of the response to the dose in what is called a ***dose/response curve.*** (See the Student Page "Examples of Risk Assessment Tools" for an example of a dose/response curve.)

Although the use of human subjects in experimental studies is not acceptable, it is sometimes possible to obtain human data on the relationship between exposure and response through research in ***epidemiology***. For example, an **epidemiologist** might measure the distribution and factors of an existing disease in a given population. An epidemiological study may be either retrospective or prospective. In a retrospective study the researcher selects ***cases*** and ***controls***, looks for past exposure to the risk factor in each group, and compares the data. In a prospective study, the researcher selects a group of people who are all free of a disease but who vary in exposure to the risk factor. The group is then followed over a period of time and observed for the frequency with which the disease is developed (Mausner and Kramer 1985, A).

Epidemiological tools of measurement include ***rates***, ***ratios***, and ***proportions***. For example, if we are interested in estimating how many students develop a cold over a school year, we could set up a prospective epidemiological study to measure the ***incidence rate*** (a measure of the probability that a disease will



occur in a defined, previously disease-free population). The Student Page "Examples of Risk Assessment Tools" gives examples of some of the types of information that epidemiological studies provide. Additional information on epidemiological studies can be found in the background section of the Special Topic, "Electromagnetic Fields."

Please refer to the Student Page "Table of Tools" for more information on these risk assessment tools. (The number after each tool refers to a corresponding number on the Student Page "Examples of Risk Assessment Tools.")

All of these tools have limitations and generate risk estimates based on probabilities. It is, therefore, critical that the characterization of uncertainty is included in any risk assessment. Descriptive statistics such as ***standard deviation***, ***confidence intervals***, and ***p-values***, as well as information regarding the study's ***sample*** size and ***sampling*** techniques, help to characterize the degree of uncertainty.

Part A

TOOL TIME

GETTING READY

Review and duplicate the Student Pages "What's Going On???," "Table of Tools," and "Examples of Risk Assessment Tools" for each group.

DOING THE ACTIVITY

1. Write the following words on the chalkboard: *ecologist, engineer, toxicologist, epidemiologist, fault tree, event tree, dose/response*. Ask the class members if they are familiar with any of these terms. If so, can they can offer any definitions? Explain that the words on the board can be categorized into two groups: risk assessment tools and professions that use those tools. (At this time, you may want to share with your students the biographies of toxicologists in Appendix 6.)

2. Divide the class into cooperative learning groups of 4-5 students. Give each group *one* scenario from the Student Page "What's Going On???" Each group should assign the following tasks within the group: two student recorders (one for Step 3 and one for Step 4 below), one student to keep the discussion moving, and one reporter. All group members are expected to participate in the brainstorming session.

3. In their groups, have the students identify the risk in their scenario and then brainstorm how they might assess the risk while the first recorder takes notes. During this time, the teacher should go around to each group to monitor the discussions.

4. Next, hand out the Student Pages "Table of Tools" and "Examples of Risk Assessment Tools" to each group. Have each group read the information and discuss which tool they think would best assess their risk. Next have students explain why that is the best tool and then identify the limitations the chosen tool presents for estimating the risk. Finally, have them compare their ideas from Step 3. Have the second recorder take notes.

FOR THE TEACHER

Answers to the Student Page "What's Going On???"

1. Fault tree analysis (undesired event = bicycle not working)
2. Toxicity test—dose/response curve
3. Epidemiological study—incidence rate
4. Event tree analysis (initiating event = leaky faucet; consequences = major flood, puddle on kitchen floor, sink full of water, nothing)