Lesson Plan
Introduction to Risk Analysis (9-12)

Estimated Time: 1-2 class periods.

Central Benchmark
3B Design and Systems (9-12)#4
Risk analysis is used to minimize the likelihood of unwanted side effects of a new technology. The public perception of risk may depend, however, on psychological factors as well as scientific ones.

Objective
Students will be able to complete a simple risk analysis.

Advance Preparation
Read the lesson to be sure you are thoroughly familiar with risk analysis. Duplicate the handouts.

List of Materials
Copies of the textbook *Chemcom* (American Chemical Society); alternatively, use copies of page 317, 2nd edition.
HANDOUTS:
The Effects of Exposure to Certain Agents
Destroying Chemical Warfare Agents in Russia
Choosing Nuclear Power Plants for the Planet Krypton
Storage of Radioactive Waste

A. What Is Risk Analysis?

1. The Safest Journey.
Say: *Suppose you have to take a trip to visit someone who lives 500 miles away. What do you think is the safest way to get there? Your have a choice of methods of travel.* (Write on the board:)

Bicycle
Auto
Commercial Airline
Train
Bus

How would you rank these modes of travel with respect to risk? Now look in your (Chemcom) *textbook, page 317. The distance at which one person in a million will suffer accidental death is given in the table.* (Answer: bicycle–10 miles; auto–100 miles; commercial airline–1000 miles; train–1200 miles; bus–2800 miles.) *Are you surprised?*

2. What is Risk?

Continue: *People sometimes think that an event is more risky if a lot of people are killed. Some people think air travel is very risky because, when an air crash occurs, a lot of people are killed, while in a fatal car accident usually only 1 or 2 people are killed. Risk analysts define risk as the probability that an event will occur multiplied by the magnitude of the event. In the case of fatal accidents, the risk is* (Write on the board):

Risk of a fatality = Probability x No. of people killed

For commercial air accidents, on the average 200 people might be killed, and the probability of having an accident might be 1 chance in 200 million for every 1000 miles traveled. How do we calculate the risk of traveling 1000 miles by air? (Write the answer on the board as students respond.)

$$\textbf{Risk for 1000 miles} = \frac{1}{200{,}000{,}000} \times 200 = 1 \times 10^{-6}$$

Another way of saying this is that if you take a 1000–mile trip by air, you are increasing your chance of dying by one millionth. (Write:)

Chance of death increased by 0.000001

It is only when we can calculate the risk this way that we can compare risks intelligently.

Use the table from your textbook to calculate the risk of dying if you take your 500-mile trip by bike. (Write:)

$$\frac{0.000001}{\textbf{10 miles}} \times \textbf{500 miles} = 0.00005$$

Say: *Risk calculations can be very uncertain, especially when we are dealing with very low risks. The Union of Concerned Scientists estimates that a nuclear reactor accident can take 2 days off your life. However, the Atomic Energy Commission estimates that a nuclear reactor accident can take 0.02 days off your life. Why is there such a difference? Notice that the low estimate was made by the Atomic Energy Commission. What reason might the AEC have to understate the risk?*

(Possible answer: The government is promoting the construction of nuclear energy plants.)

Say: *The high estimate was made by the Union of Concerned Scientists, an advocacy group that has severely criticized the AEC and is trying to get the AEC to require design changes that will make reactors less risky. Notice that, even by their estimate, the risk of a nuclear accident is very low.*

B. Making Decisions Based on Calculation of Risk.

1. Background.

Say: *In World War I both sides used chemicals to kill the enemy. The most potent of these was a liquid chemical called mustard. This substance was not, of course, the mustard we put on hot* *dogs. Mustard is a blistering agent that causes skin or lung tissue to swell up. Soldiers exposed to mustard would die from suffocation or from blisters on the body. Chemical agents called nerve agents, many times more toxic than mustard, were developed during and after World War II but were never used. The United States has a large stockpile of both mustard and nerve agents. These munitions are obsolete and some of them are starting to leak. Several years ago Congress ordered the Army to destroy the chemical agent stockpiles and more recently the U.S. signed an agreement with the Russians for the complete destruction of all chemical warfare agents. The U.S. Army designed and built sophisticated robot-controlled equipment to do this and has started the difficult task of destroying the agents. The Russians have expressed an interest in using the technology developed by the U.S. Army to destroy their stockpile*. (For additional background information see "The Effects of Exposure to Certain Agents.")

2. Destroying Agents: Comparing Risks.

Say: *We are going to do an exercise where we compare the risks of two alternatives for destroying chemical munitions. What are the two factors that we must take into account when determining the risk?*

Answer: The probability that an event will occur and the consequence (e.g., number of deaths) if that event were to occur. Write on the board:

Risk = Probability x Consequence.

Distribute copies of "Destroying Chemical Warfare Agents in Russia." When most students have had time to complete this hypothetical scenario, have them share their answers with a neighbor. Then ask some students to share their answers with the class. The risks are

a. $5 \times 10^{-4} \times 1000 = 0.5$
b. $5 \times 10^{-4} \times 2 + 1 \times 10^{-5}$/mile x 3000 miles $\times 2 = 0.061$

Continue: *Since the risk of events that have never happened cannot be calculated precisely, how should the values be rounded off? Is there a significant difference between the risks of the two alternatives?*

Students will probably conclude that the risk for alternative b. should be rounded off to 0.06 and that almost an order of magnitude difference is significant. Others may disagree.

Say: *Political and other considerations must always be taken into account when making a decision like this. Which alternative do you think would be preferred by the public that lives near the storage location? Who might prefer the other alternative? Which group of people is likely to prevail?*

Answer: Residents of large population centers are more likely to be influential than dwellers in remote regions along the rail line or in Siberia.

Say: *The risk factors used in this exercise are fictional. It is true that Russia faces the difficult problem of destroying its chemical agent stockpile and has asked for assistance from the U.S. As far as we know, the risk factors have not been calculated.*

3. Comparing Risks of Alternative Nuclear Technologies.
Distribute copies of "Choosing Nuclear Power Plants for the Planet Krypton." Have students work in pairs on this problem.

Have students share answers with the class. The risks may be calculated for one year as follows:

a. 1 event/100 years x 2000 = 20 deaths/year
b. 1 to 10 deaths/year

Ask: *Are there any other factors that should be taken into account?* Elicit the following:

The claim that there can be no catastrophic events with an untried technology is suspect. (There is no such thing as no risk). If the "best estimates" differ by a factor of 10, the actual range of uncertainty may be much greater. On the other hand, if the new technology is installed, improvements can be made over time to decrease the amount of radiation emitted; whereas the risk of a catastrophe with the Chernobyl-type reactor is inherent in the design and much more difficult to correct once the plant is running.

Ask for a vote by a show of hands which alternative the students would select. If some students refuse to make a choice, point out that this is frequently the reaction of the public to any choice they have to make because we don't like to face up to the fact that all technologies have effects other than those intended by the design, some of which may not have been predictable.

Students who have been learning about nuclear power plants will be aware of the problem of disposal of radioactive wastes. Point out that the major problem with nuclear power may not be the risk of a power plant accident but the safe disposal of the large amounts of radioactive byproducts. So far the proposed site for burial of radioactive waste at Yucca Mountain, Arizona, is not ready to receive wastes. So wastes must be stored here and there all over the country. Some nuclear wastes are expected to be highly radioactive for as long as 10,000 years. You may wish to ask whether we should be concerned about what might happen to people living that far in the future.

4. Risks We Encounter in Daily Living.
Student projects can be undertaken on a variety of subjects involving risks. Let students choose a project. Their first task should be to come up with a list of information that is needed to complete the project. Provide publications or direct the students where to get the information only after the students ask for it. Suggested subjects:

- Comparing occupational risks; industrial accident rates are available from the National Institute for Occupational Safety and Health (NIOSH).

- Risks of a variety of toxic chemicals, such as pesticides (insecticides, agent orange), food additives (alar) and ordinary industrial chemicals (vinyl chloride, benzene, PCBs, chlorinated hydrocarbons).

- Risks resulting from behavior patterns (smoking, alcohol consumption, risky sexual activity).

Summary
Have students write a paragraph summarizing what they have learned about risk analysis.

Evaluation
Hand out copies of "Storage of Radioactive Waste." Point out that this scenario is based on the fact that the Calvert Cliffs plant has started to store its waste in vaults because of the Federal government's delay in providing a storage facility (currently planned at the controversial Yucca Mountain site). The rest of the scenario, including the risk, is fictional. This scenario is for Maryland; your students can use it as a model to fit their home situations.

Note that the distance to Yucca Mountain, Nevada, is not given in the scenario. Students should estimate the distance, based on their knowledge of U.S. geography. Any estimate from 1000 to 3000 miles is precise enough for the calculation.

Answer:

Risk of storage at Calvert Cliffs =

$$10 \times 1\text{x}10^{-6} = 1\text{x}10^{-5}$$

Risk of moving and storing at Yucca Mountain =

$$2 \times 1\text{x}10^{-8} + 10 \times 2\text{x}10^{-9}\text{/mile} \times 2000 \text{ miles} = 4\text{x}10^{-5}$$

The risk data do not support the Governor's argument.