Environmental Risk Assessment

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2022-10

Origins of risk assessment

- Military operations research during World War II
- Avoidance of chemical & nuclear plant failure.

Notorious industrial accidents

- 1976 dioxin release in Seveso, northern Italy
  - Seveso-III Directive (Directive 2012/18/EU)
- 1984 methyl-isocyanate incident in Bhopal, India.

July 10, 1976
3000 kg of various chemicals wafter towards Seveso.
They also contained 10 to 20 kg of dioxin.
37,000 people were exposed.
Animals died, people did not!
A statistically unlikely number of female babies were born the next 7 years!

December 13, 1984, 2 am.
Workers and their families lived in shanties near the plant.
Toxic cloud of methyl isocyanate killed 3,800 people in their sleep.
Those who ran inhaled more than those in cars!
Children inhaled more!
Thousands more permanently disabled.

Defining and expressing risk

- Probability that something undesirable will happen

For humans, we are mostly talking about death or illness

- Deaths from specific cause per 100,000 persons
- Deaths from specific cause per 1,000 deaths from all causes
- Relative risk: comparing rates of death among different populations
    - Relative risk of death = Standard mortality ratio (SMR)

In the United States about 260,000 smokers die every year as a result of lung cancer and chronic obstructive pulmonary disease. If the population of the United States is 280 million, what is the risk of death (from these two factors) associated with habitual smoking?

$$\frac{260{,}000}{280{,}00{,}00} = 0.00093 \text{ smoking related deaths per person in the USA}$$

Because the answer is such a small number, typically the risk of death is expressed as per 100,000 population, or

$$\frac{260{,}000}{280{,}000{,}000 \,/\, 100{,}000}$$

$$= 93 \text{ smoking related deaths per } 100{,}000 \text{ people in the USA}$$

In other words, a habitual smoker in the U.S. has an annual risk of 93 in 100,000, or about one in a thousand, of dying of lung cancer or other smoking-related diseases during any given year.

TABLE 2.1. Approximate Annual Deaths in the United States.

Cause of Death	Annual Deaths
Cardiovascular disease	918,000
Cancer (all)	65,600
Chronic obstructive pulmonary disease	112,000
Motor vehicle accidents	45,400
Alcohol-related disease	52,200
Other causes	1,663,000
All causes	3,351,600

Of the 3,351,600 deaths in the United States every year, 918,000 of these are due to cardiovascular disease. If a person dies, what is the chance (probability) that he or she will die of cardiovascular disease?

$$\frac{918,000}{3,351,000} = 0.273$$

That is, about 27% of the deaths in the United States are due to cardiovascular disease.

$$R_3 = \frac{[R_1]_+}{[R_1]_o}$$

where

R_3 = relative risk

$[R_1]_+$ = risk of dying of a given cause for a population having some attribute or characteristic

$[R_1]_o$ = risk of dying of a given cause for a population not having some attribute or characteristic

If in a population of 280,000,000, there are 260,000 deaths annually from smoking-related diseases, not all of the people dying of these diseases are smokers. Of the 260,000 annual deaths, about 21,000 people who die of lung cancer and cardiovascular problems are non-smokers. This means that the relative risk of fatal lung cancer in smokers

$$R_3 = \frac{[R_1]_+}{[R_1]_o} = \frac{[D/P]_+}{[D/P]_o} = \frac{[D]_+}{[D]_o} = \frac{260{,}000 - 21{,}000}{21{,}000} = 11.4$$

That is, the chances of a person dying of lung cancer or cardiovascular problems is over 11 times higher if the person smokes cigarettes.

Three important characteristics of epidemiological reasoning are illustrated by the above example:

- Everyone who smokes heavily will not die of lung cancer.
- Some non-smokers die of lung cancer.
- Therefore, one cannot unequivocally relate any given individual lung cancer death to cigarette smoking.

Thus when the Tobacco Institute claims that there still is no smoking gun, they are right. We do not have *proof* that smoking causes lung cancer. All we can say is that if persons really wanted to get lung cancer, the best thing they can do is to smoke cigarettes. This will result in a high probability of contracting that disease.

Main objectives of risk assessment

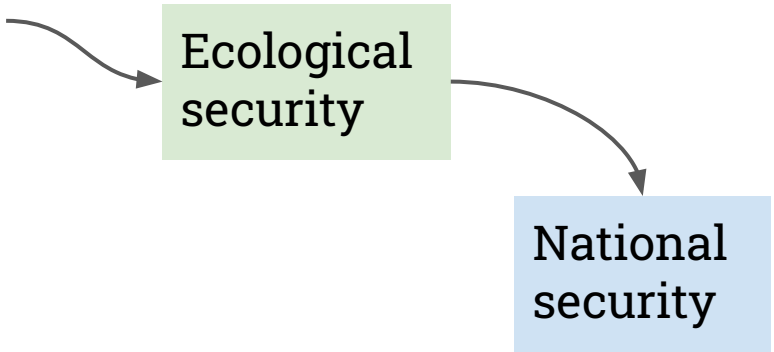
1. Identify hazards and assess risks (associated with development projects)
2. Recommend appropriate risk management strategies.

Broadened focus of risk assessment

- Chronic health problems
  - Occupational health risks
    - Carcinogens, teratogens
  - Broader chronic health concerns linked to pollution.

Concept of risk assessment extended to natural systems

- Risks to ecological resources
- Risks from natural disasters
  - Floods
  - Earthquakes.



Risk assessment

1. What can go wrong?
    - Human health
    - Natural environment
    - Financial viability of project
2. How likely it is?
    - Frequency & likelihood (probability)
3. What are the consequences (impacts)?
    - Risks from routine operations vs Maximum credible accident
    - Number of people, geographical area impacted
4. What can be done to manage the risks?
5. Who should be involved?
    - Stakeholders

Hazard vs Risk

- Hazard = anything that could cause harm
- Risk = a combination (product) of
  - The probability (frequency) that a hazard could cause harm $\times$ the severity of that harm
  - Both actual & perceived risks are considered.

Hazard

- Circumstances that could lead to potential harm, e.g. chemical substances, pathogenic microorganisms.
- If hazards occur, they result in adverse consequences
- Hazard assessment
  - Identifies potential hazards
  - Identifies potential receptors,
    - People, plants, animals, natural resources
  - Determines consequences.

Risk

- Function (i.e. product) of
  - Probability (or frequency) of a hazard occurring
  - Magnitude (severity) of consequences (impacts)
- Usually, when severity is high, probability is low
- Voluntary & involuntary risks
  - We tend to accept voluntary risks
- Risk perceptions
  - Subjective appreciation & judgment.

Risk ratio

- Total risk = Background risk + incremental risk
- Risk Ratio = Acceptable/Total risk < 1

Overall risk ratio for environment is given by:

$$r_{envt} = \sum_{i=1}^{N_r} w_i r_i = w_1 r_1 + w_2 r_2 + \ldots \qquad \textbf{(Eq. 4)}$$

R_{envt}	Risk ratio for environment
w_i	Importance weights for different receptors (say w_H for humans, w_{aq} for aquatic species)
r_i	Risk ratio for different receptors (say r_H for humans, r_{aq} for aquatic species)
N_r	Total number of receptors

Risk assessment

- Combination of risk estimation & risk evaluation
  - Risks that are not under voluntary control are considered more hazardous, e.g. seismic events.

Risk management

- Deciding whether to accept or control risks
  - Usually based on cost-benefit analysis.
- Risks may be controlled through
  - Technology
  - Procedures
  - Alternative practices.

Examples of risk assessment

- Potential release of toxic materials in a densely populated area
- Likelihood of seismic damage to a hydropower dam
- Linkages between environmental pollution and other health determinants
- Allocating limited resources to pollution prevention, control and management
- Historical contamination arising from past activities at industrial or utility locations
- Site investigation and assessment for the definition and identification of contaminated land.


She brought a
small town to its feet
and a huge company
to its knees.
Julia Roberts is Erin Brockovich
Based on a true story.

Stages of risk assessment

1. Hazard assessment
2. Probability (frequency) estimation
    - Data?
3. Risk estimation
4. Risk evaluation
5. Risk management
    - Accept or control
6. Monitoring and supervision.

Examples of hazards

- Presence of toxic, flammable or explosive materials
- Failure of dams or storage vessels
- Accidents during the transportation of hazardous materials
- Flooding, wetlands drainage, and other natural disasters.

Causes of uncertainties

- Lack of procedural or mechanical controls
- Insufficient knowledge regarding cause and effects relationships
- Inherent variation in natural systems or insufficient baseline data.

Examples of uncertainties

- Potential for release of hazardous materials
- Equipment failure rates
- Human error or frequency of natural disasters.

Examples of consequences that may be identified through a hazard assessment

- Death or injuries
- Pollution of water resources
- Damage to crops or infrastructure
- Deterioration of ecosystems.

Examples of probability (frequency) estimation

- How often would flooding occur in a given area?
  - Causing damage to crops and infrastructure
- What is the failure rate for a type of pressure vessel containing flammable materials?

For human health or ecological risk assessments, the concern is often

- Related to the evaluation of potential exposure
- Through identification of pathways and receptors.

Risk estimation

- Based on magnitude and frequency of hazards
- May be
  - Qualitative (matrix format)
  - Quantitative (predictive modeling)
- Important considerations
  - Relative toxicity of materials
  - Duration of exposure
  - Dose response of affected people, plants and animals
  - Extent of affected resources
  - Errors in assumptions.

Risk evaluation

- Appraisal of the significance of the estimated risks
- Typically involves evaluating differing perceived risk and benefit scenarios
    - Balance between economic benefits and environmental harm changes
- Iterative process
    - Alternative risk reduction strategies followed by comparative assessments

Risk management

- Making decisions regarding the acceptability of risks
- Implementing mitigation measures to minimize or eliminate risks
  - An iterative process
- Controlling risk is integrated with monitoring
- Things to consider
  - Have stakeholder concerns been satisfied?
  - Are risk control measures effective?

Figure 1. Stages in the risk assessment process