Radiological Risk Management

"Come, come!" I cried, dragging my uncle along; for the first time, he made no resistance to my wishes."

—Henry Lawson in "Journey to the Center of the Earth" by Jules Verne.

We take risks all the time

Risks are the unwanted consequences of an event. There are risks associated with almost everything we do. We take risks when we drive a car to the grocery store. We took risks when we came to class today.

We take risks all the time

We accept many risks because our experiences tells us that either the undesirable event is unlikely to happen or if it does, we know how to resolve the situation.

What questions to ask?

How do we live with risks? We compare the benefits to the risks. For example: We can ask "Are benefits of having a smoke detector worth its radiation risks from ^{241}Am?"

There is no good answer to the question: "What is a safe level of radiation exposure?" This is like asking "What is a safe driving speed?"

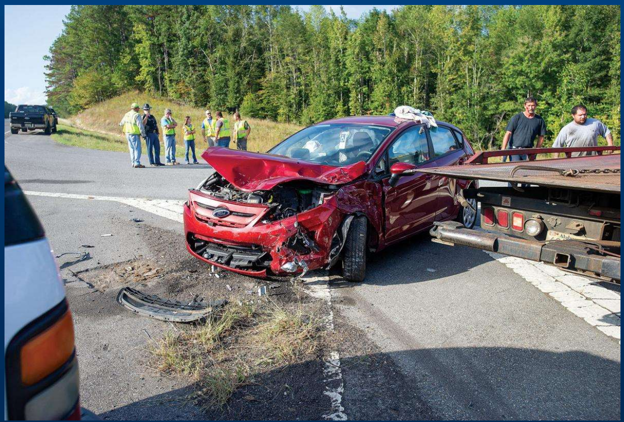
What questions to ask?

Appropriate question to ask is:

What is the risk associated with a given level of exposure to the smoke detector?

Or for the driving question:

What is the risk of injury for this situation and speed?



Acceptable Risk: loss of life expectancy

Jobs with radiation exposure: 40 days

Low economic status: 1.9 years

Being 25% overweight: 2.5 years

Being a coal miner: 3.0 years

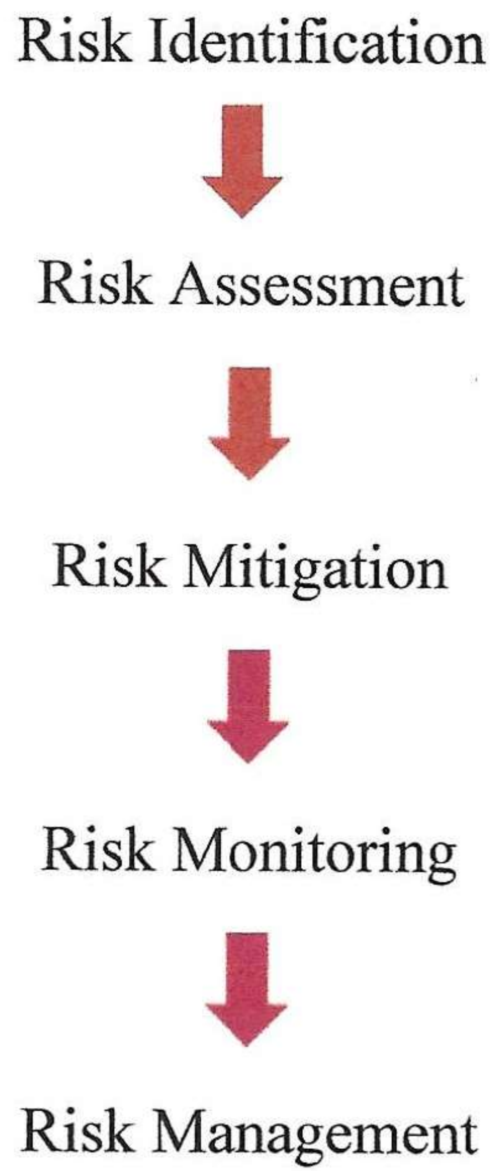
Cigarette smoking (male): 6.2 years

Being unmarried (male): 9.6 years

Fischhoff et al. (1981) Acceptable Risk


THIS IS WHY WOMEN
LIVE LONGER THAN MEN

The Risk Management Plan



Risk Identification

Risk identification, as the term implies, is envisioning any and all potential events, problems, or barriers that may hinder progress. Essentially, we ask *"What could go wrong?"*

Risk Identification

In the context of radioactive waste management, a group of experts and decision makers create a detailed list of potential risks during multiple meetings. The process will benefit greatly from careful studies of other disposal sites. In that context, the question is *"What has gone wrong before?"*

Risk Assessment

Once the potential risks have been identified or envisioned and compiled after numerous meetings of experts and decision makers, each risk must be evaluated by two criteria:

1. How likely is it for this potential risk to occur?

2. If the potential risk becomes an actual incident, how severe will the consequences be?

Risk Assessment

Numerous approaches have been used to conduct a risk assessment, but the most widely used to conduct a quantitative assessment is the product of the likelihood and the outcome:

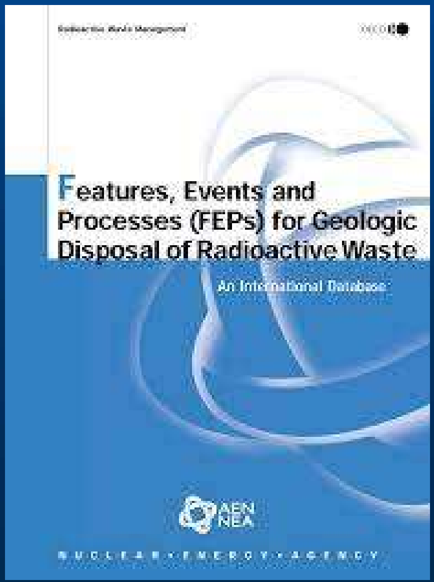
(likelihood or probability of occurrence)
x (the negative impact(s) of the event)
= risk magnitude or risk index.

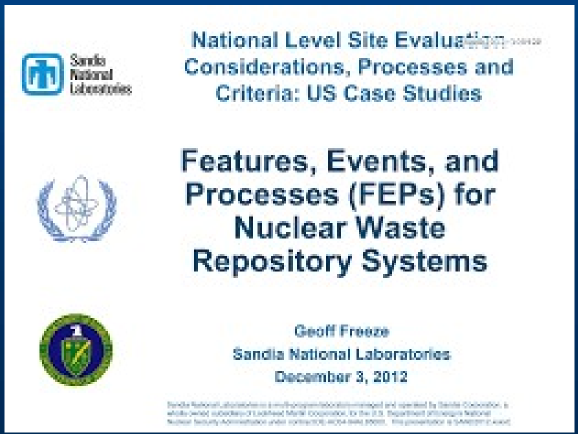
FEPs

In order to calculate a risk magnitude value, numerical data must be assigned to both the likelihood and impact terms. An approach that can be used to assign numerical values is called Features, Events, and Processes (FEPs).

FEPs

The FEP approach was used in site assessments for the proposed Yucca Mountain Nuclear Waste Repository and in site assessments for carbon capture and storage studies.





Features

The definitions of the individual FEP terms will be defined in the context of their application. Generic definitions and descriptions can, however, be provided:

Features

Feature. A physical component of a site under study that can influence the behavior of the site during waste disposal. For example, the presence of sandy zones may conduct groundwater into the disposal area.

Events

Event. An event could be any undesirable incident that could complicate or compromise the success of the waste site. Examples could include the collapse of cover, the failure of a waste container, or the disposal of incorrectly classified wastes.

Process

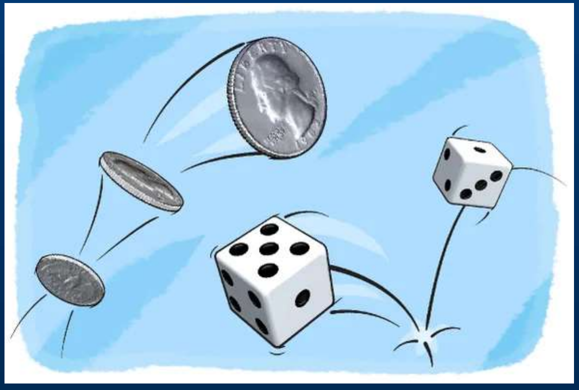
Process. A process is a continuous action that takes place for a time frame that is longer than an event. Examples of undesirable processes could be the chemical corrosion of metal waste containers, the erosion of a side of a disposal cell while it is being filled, or the spread of contaminated groundwater off-site.

FEPs can overlap

The distinction between Features, Events, and Processes can overlap. An active fault can be an undesirable Feature while the movement along the fault can trigger an earthquake Event. Events are usually regarded as relatively sudden incidents whereas a Process can operate over a time frame of years.

Likelihood L

The next step in applying the FEP technique is to classify each potential risk into a Likelihood or probability category (L). The creation of likelihood criteria will be based on the specific type of disposal technique or event being assessed.



Likelihood L

Numerical criteria may be based on statistical treatment of historical data from similar sites. Professional judgement may also be required. If an adverse incident happened only once in 50 similar disposal events, it may be regarded as unique and unlikely to occur again.

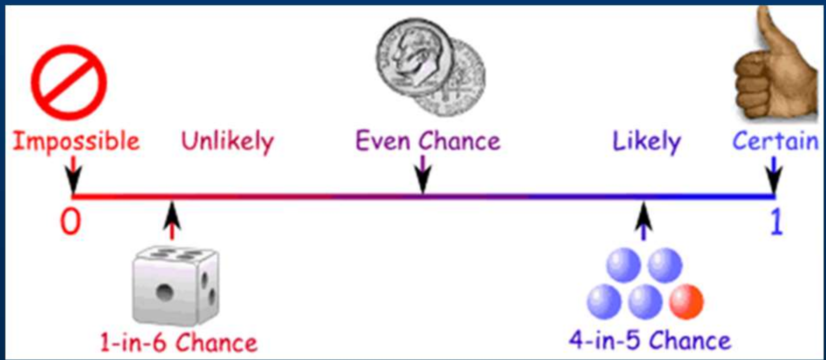


Table 2.1. A five-level classification system based on past and anticipated occurrences.

Likelihood	L score	How often?
Improbable	1	Probably never
Unlikely	2	Less than 5 times at 100 similar sites or during 100 similar events
Possible	3	5 to 5 times at 100 sites or during 100 similar events
Likely	4	At about 50% at 100 sites or during 100 similar events
Probable	5	At most or nearly all 100 sites or during 100 similar events

Table 2.2. A three-level classification system based on probability.

Probability	Classification	L score
Less than 10% probability of occurring	Low	1
10 to 80% probability of occurring	Medium	2
Greater than 80% probability of occurring	High	3

Table 2.3. A five-level classification system for the decommissioning of a nuclear facility.

Likelihood	Description of event occurrence	L Score
Not Probable	Events cannot occur because of safeguards.	1
Extremely Rare	Events not expected to happen.	2
Rare	Events have a slight chance of occurring.	3
Occasionally	Events may occur a few times.	4
Frequent	Events are expected to occur several times.	5

Severity S

The next step is to classify each potential risk into a Severity category (S). Like L values, what is considered a significant impact and how it is defined will depend on the specific waste-disposal event, and the priorities of the experts making the assessment. The question now is that "If it [the L risk] happens, how bad will it be?"

Table 2.4. A five-level classification system based on worker health, the scale of the incident, and economic impacts.

Severity of impact	Impacts	S score
Minor	Minor injury if any. No disposal facility downtime. Regarded as a routine problem.	1
Serious	Medical treatment required. Field-scale cleanup required. Short disposal facility downtime. Financial costs of less than $10,000.	2
Major	Permanent worker disability. Evacuation of immediate area required. Disposal facility downtime. Greater than $10,000 costs.	3
Catastrophic	One worker died. Several injured. Uncontrolled release of contaminants. Significant facility downtime. Financial costs in the range of $100,000 to 1,000,000.	4
Multi-catastrophic	Several deaths. Several injuries. Several releases of contaminants. Financial costs are greater than $1,000,000.	5

Table 2.5. A 3-level classification system emphasizing costs, worker health, and the scale of the incident.

Consequence	Impacts	S score
Low	Less than 5% impacts to costs. Minor regulatory compliance issue. Minor, non-urgent threats to human health, the environment, or worker safety.	1
Medium	5% to 20% impacts to costs. Significant regulatory compliance issues. Moderate, but non-urgent threats to human health, the environment, or worker safety.	2
High	Greater than 20% impacts to costs. Serious regulatory compliance violations that could lead to fines or work stoppages. Missing legally required milestones. Significant or urgent threats to human health, the environment, or worker safety.	3

Table 2.6. A 5-level system based on the effects of a dose of ionizing radiation.

Effective dose	**Severity Impact**	**S score**
0.1 mSv	No discernable effect	1
1 mSv	Minor effect	2
1 to 50 mSv	Moderate effect	3
50 to 100 mSv	Severe effect	4
More than 1,000 mSv	Catastrophic	5

Risk Mitigation and Monitoring

A Risk Mitigation and Monitoring Plan needs to be created for each of the FEP items that have the greatest Risk Index. As the names imply, the mitigation plan is written to provide the best control measures if the risk becomes an incident. The question becomes "What will we do about it?"

Risk Monitoring

Risk Monitoring Plans are created to provide guidelines for assessing the efficacy of the Mitigation Plan. The question for this task is "*How do we know it's working?*" The Risk Monitoring Plan should verify that the incidents have been resolved. If not, new mitigation ideas will need to be applied. Hence, risk monitoring should respond to the question "*If it's not working, what's next?*"

Summary of Risk Management

What could go wrong?

What has gone wrong before?

How bad could it possibly be?

What will we do about it?

How do we know it's working?

If it's not working, what's next?

The perception of risk: an in-class exercise

Features, Events, and Processes (FEP) are terms used in radioactive waste management.

Ranking risks

L = likelihood of occurrence

S = severity impact

L x S = rank

NPRE 442. In-Class Exercise

The *perception* of risk: FEP-related risks applied to risk assessment

Features, Events, and Processes (FEP) are terms used in the field of radioactive waste management to define relevant scenarios for risk assessment studies.

For a radioactive waste repository for example, *features* would include the characteristics of the site, such as the type of soil or geological formation the repository is to be built on or under.

Events would include things that may or will occur in the future like earthquakes, or the formation of geologic faults.

Processes are things that are ongoing, such as the erosion or subsidence of the landforms where the site is located on, or near or the slow movement of leachate away from the site.

Ranking system

Likelihood	**L score**	**How often?**
Improbable	1	Probably never
Unlikely	2	Less than 5 times at 100 similar sites or during 100 similar events
Possible	3	5 to 15 times within 100 sites/events
Likely	4	At about 50% of the 100 sites/events
Probable	5	At most or nearly all 100 sites/events

Severity of impact	**S score**	**Impacts?**
Light	1	Minor injury if any, no down time, regarded as a routine problem
Serious	2	Hospital time, cleanup required, down time, financial costs
Major	3	Permanent disability, evacuations, $10,000+ costs.
Catastrophic	4	Fatality, uncontrolled release of radionuclides, down time of one year, costs in the range of $100,000 to 1,000,000.
Multi-catastrophic	5	Several deaths, several releases of radioactive wastes, public ban on similar efforts, costs are millions of dollars.

How do these risks compare? How would you rank them?

FEP item	Scenario	L	S	L x S	Rank
A new LLW site	A 20-ton meteor impacts the site while in operation (e)				
Reprocessing SNF	Accidental release of 50 L of acidic raffinate inside a SNF reprocessing plant (e)				
Dry storage of SNF	Heat from decay compromises the structural integrity of a dry storage cask (p)				
U milling wastes	Wastes covered with sand are still a source of radon (f)				
Vitrified HLW	Stored, vitrified wasteforms stolen during a terrorist attack in France (e)				
LLRW burial	Infiltration of precipitation in a humid climate through a trench cover (p)				
Exposure	Exposure to 50 rem of gamma radiation (e)				
Transporting SNF	A semi-trailer carrying SNF casks is struck by drunk driver in a car (e)				
Exposure	Consumption of orange juice containing radioactive ^{40}K mixed with vodka (e)				
Release	Plutonium leaches from a geologic repository and contaminates an aquifer 10 miles away (p, e)				
Classification error	One LLRW drum is disposed as Class A when it is really Class GTCC (e)				
Exposure	Radiation from dry storage casks results in cancer in workers 30 years after exposure (p)				
Exposure	Radioactive vent gasses (^{41}Ar, ^{135}Xe) from a power plant are blown into a school playground by the wind one time (e)				
Exposure	A side of the Weldon Spring disposal cell erodes, exposing the metal-radioactive waste mixture (e, p)				
Decommissioning	Tritium-contaminated soil is not discovered during site remediation, and left in place in the saturated zone (e,f)				
Siting error	The new MOX plant at Savannah is built over an active geologic fault (f)				
Release	Cesium-137 escapes a deep-bore hole from the Pre-Cambrian igneous rock disposal zone in Illinois (e, p)				

How do these risks compare? How would you rank them?

FEP item	Scenario	L	S	L x S	Rank
A new LLW site	A 20-ton meteor impacts the site while in operation (e)	1	4	4	4
Reprocessing SNF	Accidental release of 50 L of acidic raffinate inside a SNF reprocessing plant (e)	2	1	2	
Dry storage of SNF	Heat from decay compromises the structural integrity of a dry storage cask (p)	3	1	3	
U milling wastes	Wastes covered with sand are still a source of radon (f)	4	1	4	4
Vitrified HLW	Stored, vitrified wasteforms stolen during an terrorist attack in France (e)	2	2	4	4
LLRW burial	Infiltration of precipitation in a humid climate through a trench cover (p)	3	1	3	
Exposure	Exposure to 50 rem of gamma radiation (e)	2	3	6	2
Transporting SNF	A semi-trailer carrying SNF casks is struck by drunk driver in a car (e)	3	1	3	
Exposure	Consumption of orange juice containing radioactive ^{40}K mixed with vodka (e)	5	1	5	3
Release	Plutonium leaches from a geologic repository and contaminates an aquifer 10 miles away (p, e)	2	3	6	2
Classification error	One LLRW drum is disposed as Class A when it is really Class GTCC (e)	2	1	2	
Exposure	Radiation from dry storage casks results in cancer in workers 30 years after exposure (p)	3	3	9	1
Exposure	Radioactive vent gasses (^{41}Ar, ^{135}Xe) from a power plant are blown into a school playground by the wind one time (e)	2	1	2	
Exposure	A side of the Weldon Spring disposal cell erodes, exposing the metal-radioactive waste mixture (e, p)	3	1	3	
Decommissioning	Tritium-contaminated soil is not discovered during site remediation, and left in place in the saturated zone (e,f)	3	1	3	
Siting error	The new MOX plant at Savannah is built over an active geologic fault (f)	2	2	4	4
Release	Cesium-137 escapes a deep-bore hole from the Pre-Cambrian igneous rock disposal zone in Illinois (e, p)	3	1	3	

Questions?