Marine Risk Assessment

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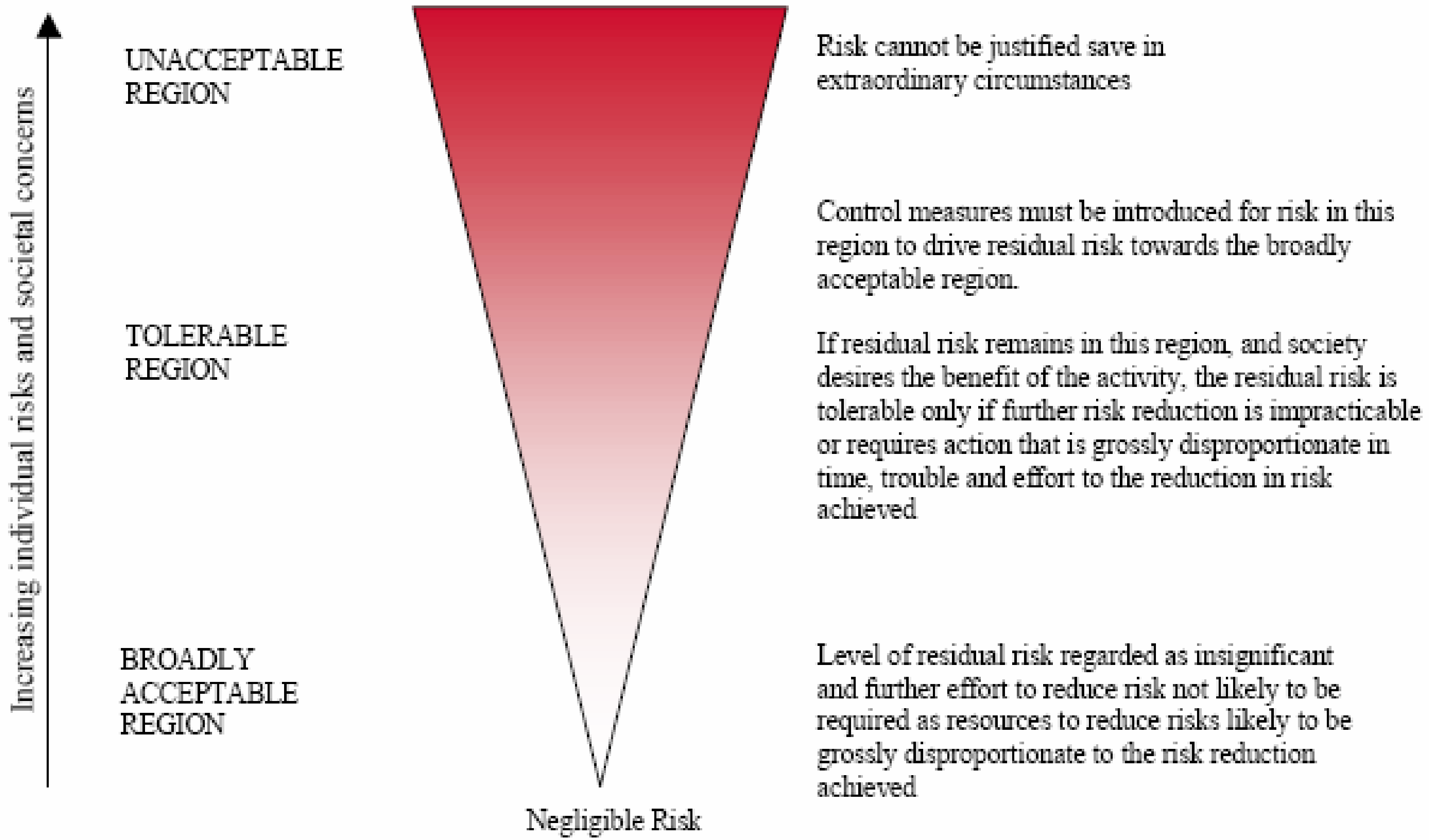
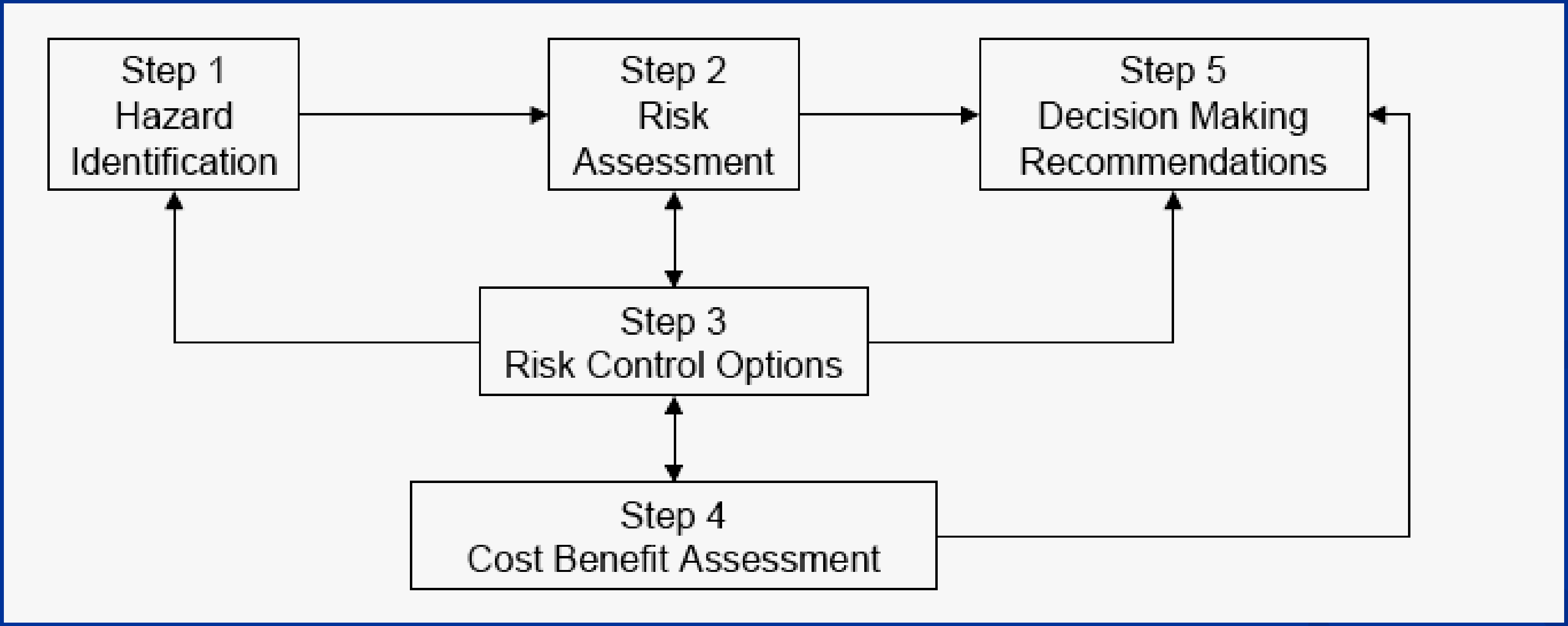
What is Risk assessment?

Risk assessment is a review as to acceptability of risk based on comparison with risk standards or criteria, and the trial of various risk reduction measures. (Health & Safety Executive ; HSE , 2001)

Tolerability of Risk Framework (HSE, 1999a)



Flowchart for Risk Management (IMO, 1997)



Hazard Identification (HAZID)

A **hazard** is defined as a situation with a potential for causing harm to human safety, the environment, property or business. It may be a physical situation, an activity or a material.

purposes

- to obtain a list of hazards
- the measures for reducing the risks from them

Tools for HAZID

- Hazard Review
- Hazard Checklists
- HAZOP
- FMECA
- SWIFT
- Influence Diagrams

Hazard Review

a hazard survey or safety review is a qualitative review of an installation to identify the hazards that are present and to gain qualitative understanding of their significance. It is one of the most commonly used HAZID techniques for MODUs (Ambion 1997)

Hazard Checklists

A hazard checklist is a written list of questions intended to prompt consideration of a full range of safety issues. They are used to check a design and confirm that good practice is incorporated

Example for Hazard checklist

Generic Keyword Checklist (Ambion, 1997)

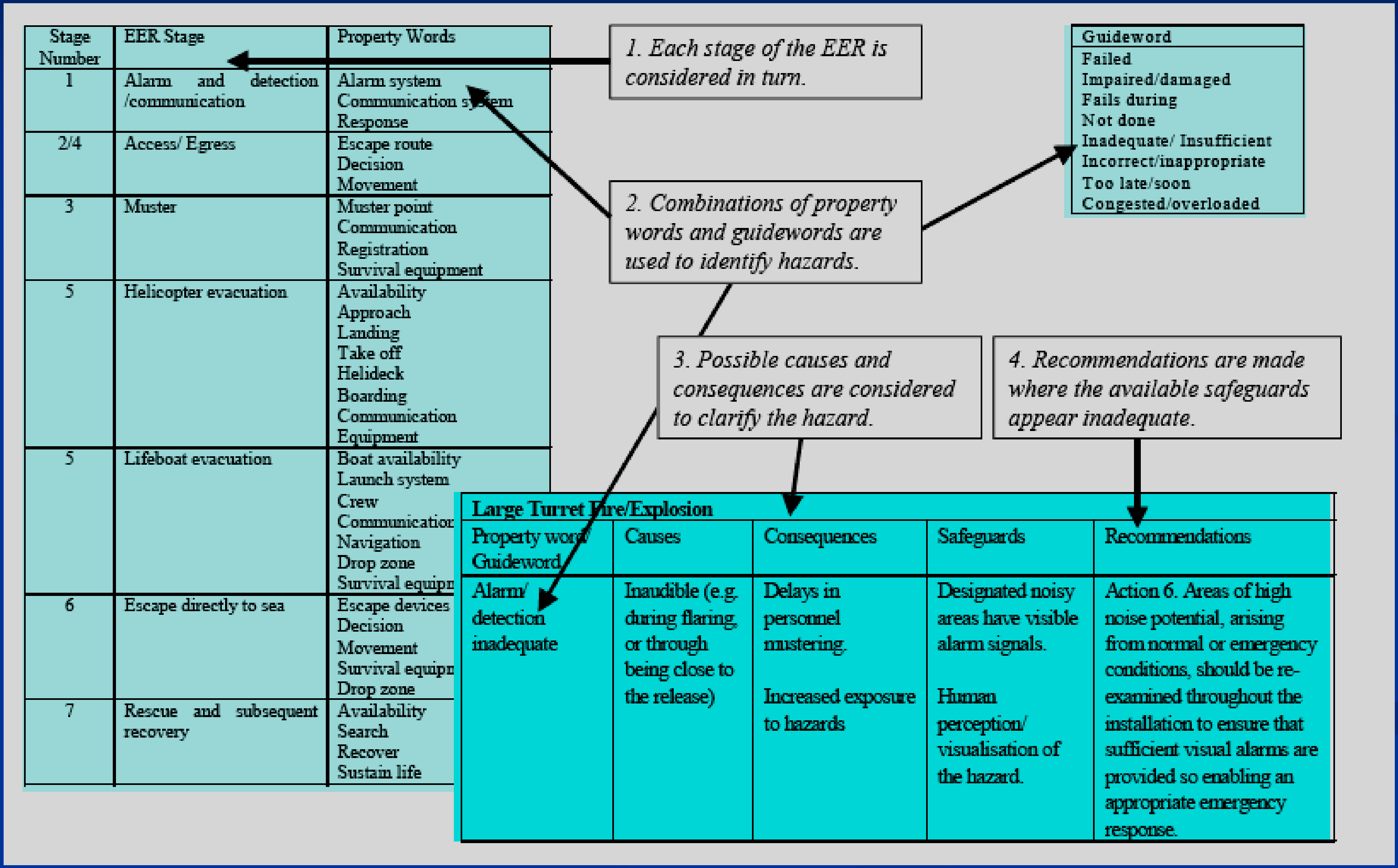
Key Word used in HAZID	Example of Hazard
Direct fire	Ignited blow-out Ignited process fire Fire in paint store
Loss of breathable atmosphere	Smoke ingress from HVAC Asphyxiation
Direct toxic	Toxic gas release
Explosion overpressure	Explosion from process gas leak
Dropped objects	Dropped load from crane Swinging load hit to process
Vehicle collision	Helicopter crash Ship collision to legs
Structural collapse	Crane collapse Leg failure in design load Extreme weather
Mechanical failure	Gas turbine rotor blade failure
Electrocution	Occupation accident
Pressure/loss of containment	Air receiver failure Unignited process vessel failure
Water/drowning	Deluge in process Man overboard
Direct chemical	Drilling chemical leak Lab chemical exposure
Occupational accidents	Trips, falls
Hydrocarbon leak general	Diesel tank failure Process leak

HAZOP

(hazard and operability)

A hazard and operability (HAZOP) is a method of identifying hazards that might affect safety and operability based on the use of guidewords. They use a standard list of guidewords to prompt them to identify deviations from design intent.

Example HAZOP EER(Boyle & Smith, 2000)



Stage Number	EER Stage	Property Words
1	Alarm and detection /communication	Alarm system Communication system Response
2/4	Access/ Egress	Escape route Decision Movement
3	Muster	Muster point Communication Registration Survival equipment
5	Helicopter evacuation	Availability Approach Landing Take off Helideck Boarding Communication Equipment
5	Lifeboat evacuation	Boat availability Launch system Crew Communicatio Navigation Drop zone Survival equipm
6	Escape directly to sea	Escape devices Decision Movement Survival equipm Drop zone
7	Rescue and subsequent recovery	Availability Search Recover Sustain life

Guideword
Failed
Impaired/damaged
Fails during
Not done
Inadequate/ Insufficient
Incorrect/inappropriate
Too late/soon
Congested/overloaded

Large Turret Fire/Explosion				
Property word Guideword	Causes	Consequences	Safeguards	Recommendations
Alarm/ detection inadequate	Inaudible (e.g. during flaring, or through being close to the release)	Delays in personnel mustering. Increased exposure to hazards	Designated noisy areas have visible alarm signals. Human perception/ visualisation of the hazard.	Action 6. Areas of high noise potential, arising from normal or emergency conditions, should be re-examined throughout the installation to ensure that sufficient visual alarms are provided so enabling an appropriate emergency response.

FMECA
(failure modes, effects and criticality analysis)

A failure modes, effects and criticality analysis (FMECA) (or its simpler form, FMEA) is a systematic method of identifying the failure modes of a mechanical or electrical system.

List of all components

- Component name.
- Function of component.
- Possible failure modes.
- Causes of failure.
- How failures are detected.
- Effects of failure on primary system function.
- Effects of failure on other components.
- Necessary preventative/repair action.
- Rating of frequency of failure.
- Rating of severity (i.e. consequence) of failure.

SWIFT
(structured what-if checklist)

The structured what-if checklist (SWIFT) technique is a method of identifying hazards based on the use of brainstorming.

"What if",

"How could"

"Is it possible"

Influence Diagrams

Influence diagrams are models for decision-making under uncertainty, developed in the field of decision analysis (Howard & Matheson 1980).

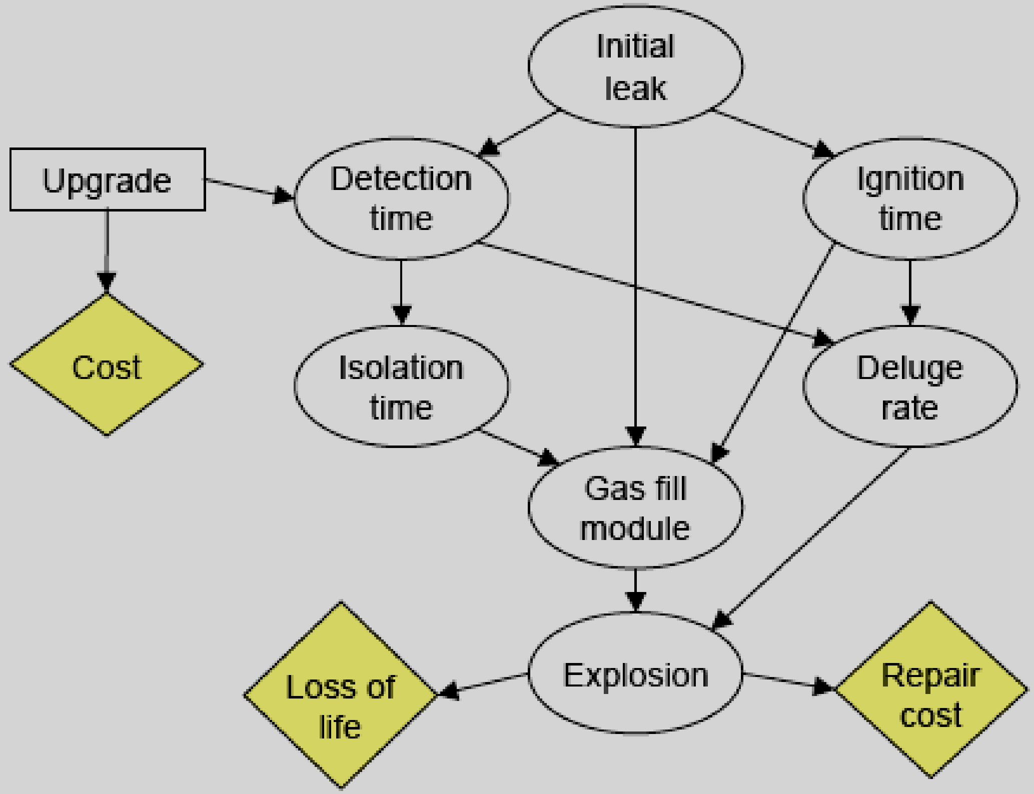
An influence diagram is a graphical between the various factors that could influence the outcome of an event.

Example Influence Diagram for explosions

This influence diagram helps evaluate the decision whether to upgrade a gas detection system.

The diagram shows all the important issues, and uses arrows to represent how the issues influence each other. The ellipses represent issues that have some uncertainty (chance nodes). The rectangle represents the decision, and the diamonds represent associated costs and benefits (utilities).

Probability distributions (not shown here) can be assigned to the chance nodes and used to evaluate the expected benefits



Types of Risk Assessment

- Qualitative method
- Semi - Quantitative method
- Quantitative method

Qualitative Risk Method

- Define and categorize Risk into
  - Acceptable
  - Tolerable
  - Intolerable
- Use risk matrix analysis

Risk Matrix Methods

- Risk matrices provide a traceable framework for explicit consideration of the frequency and consequences of hazards.

Defence Standard Matrix

- derives from Defence Standard 00-56 "Safety Management Requirements For Defence Systems Part 1: Requirements" (1996)
- this sets out a 6 x 4 risk matrix based on frequency and consequence

The severity categories

CATEGORY	DEFINITION
Catastrophic	Multiple deaths
Critical	A single death; and/or multiple severe injuries or severe ccupational illnesses
Marginal	A single severe injury or occupational illness; and/or multiple minor injuries or minor occupational illness
Negligible	At most a single minor injury or minor occupational illness

The frequency categories

ACCIDENT FREQUENCY	OCCURRENCE (During operational life considering all instances of the system)
Frequent	Likely to be continually experienced
Probable	Likely to occur often
Occasional	Likely to occur several times
Remote	Likely to occur some time
Improbable	Unlikely, but may exceptionally occur
Incredible	Extremely unlikely that the event will occur at all, given the assumptions recorded about the domain and the system

Decision classes

RISK CLASS	INTERPRETATION
A	Intolerable
B	Undesirable and shall only be accepted when risk reduction is impracticable
C	Tolerable with the endorsement of the Project Safety Review Committee
D	Tolerable with the endorsement of the normal project reviews

The actual risk matrix (6 x 4) (with the decision classes shown)

	Catastrophic	Critical	Marginal	Negligible
Frequent	A	A	A	B
Probable	A	A	B	C
Occasional	A	B	C	C
Remote	B	C	C	D
Improbable	C	C	D	D
Incredible	C	D	D	D

ISO Risk Matrix

An alternative, more up-to-date approach is given in the draft international standard 17776 (ISO 1999).

This provides a <u>5 x 5 risk matrix</u> with consequence and likelihood categories that are easier for many people to interpret.

ISO (5 x 5) Risk Matrix

CONSEQUENCE					INCREASING PROBABILITY				
Severity Rating	People	Assets	Environ-ment	Reputation	A	B	C	D	E
					Rarely occurred in E&P industry	Happened several times per year in industry	Has occurred in operating company	Happened several times per year in operating company	Happened several times per year in location
0	Zero injury	Zero damage	Zero effect	Zero impact	Manage for continued improvement				
1	Slight injury	Slight damage	Slight effect	Slight impact					
2	Minor injury	Minor damage	Minor effect	Limited impact					
3	Major injury	Local damage	Local effect	Considerable impact					
4	Single fatality	Major damage	Major effect	Major national impact	Incorporate risk reducing measures				
5	Multiple fatalities	Extensive damage	Massive effect	Major international impact				Intolerable	

Risk Ranking Matrix

A risk matrix has been proposed for a revision of the IMO Guidelines on FSA (IMO 1997) to assist with hazard ranking.

It uses a 7 x 4 matrix, reflecting the greater potential variation for frequencies than for consequences.

The severity index (SI)

SI	SEVERITY	EFFECTS ON HUMAN SAFETY	EFFECTS ON SHIP	S (fatalities)
1	Minor	Single or minor injuries	Local equipment damage	0.01
2	Significant	Multiple or severe injuries	Non-severe ship damage	0.1
3	Severe	Single fatality or multiple severe injuries	Severe casualty	1
4	Catastrophic	Multiple fatalities	Total loss	10

The frequency index (FI)

FI	FREQUENCY	DEFINITION	F (per ship year)
7	Frequent	Likely to occur once per month on one ship	10
5	Reasonably probable	Likely to occur once per year in a fleet of 10 ships, i.e. likely to occur several times during a ship's life	0.1
3	Remote	Likely to occur once per year in a fleet of 1000 of ships, i.e. **10%** chance of occurring in the life of 4 similar ships	10 - 3
1	Extremely remote	Likely to occur once in 100 years in a fleet of **1000** ships, i.e. 1% chance of occurring in the life of 40 similar ships	10 - 5

If risk is represented by the product frequency x consequence, then an index of log(risk) can be obtained by adding the frequency and severity indices. This gives a risk index (RI) defined as:

RI = FI + SI

E.g. An event rated “remote” (FI = 3) with severity “moderate” (SI = 2) would have RI = 5 The risk matrix is as follows (risk indices in bold):

The risk matrix (from RI = FI + SI)

FI	FREQUENCY	SEVERITY (SI)			
		1	2	3	4
		Minor	Moderate	Serious	Catastrophic
7	Frequent	8	9	10	11
6		7	8	9	10
5	Reasonably probable	6	7	8	9
4		5	6	7	8
3	Remote	4	5	6	7
2		3	4	5	6
1	Extremely remote	2	3	4	5

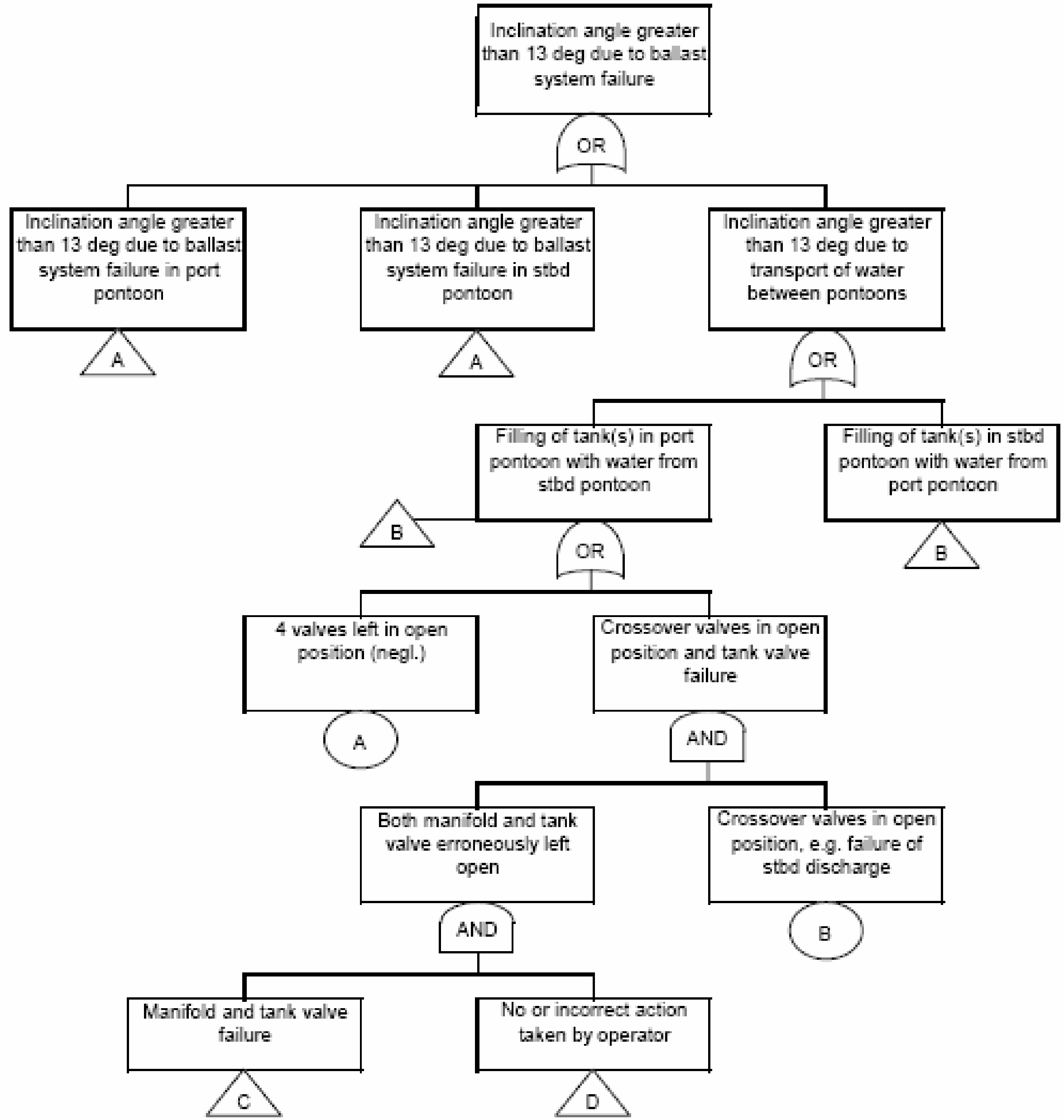
Semi-Quantitative Methods

- It uses techniques drawn from Quantified Risk Analysis (QRA)
- analysed using a modelling technique such as
  - Fault Tree Analysis (FTA)
  - Event Tree Analysis (ETA)
  - Bow Tie Analysis

Fault Tree Analysis (FTA)

Fault tree analysis (FTA) is a logical representation of the many events and component failures that may combine to cause one critical event.

Extract from Fault Tree Analysis of Ballast System Failures (Veritec 1987)

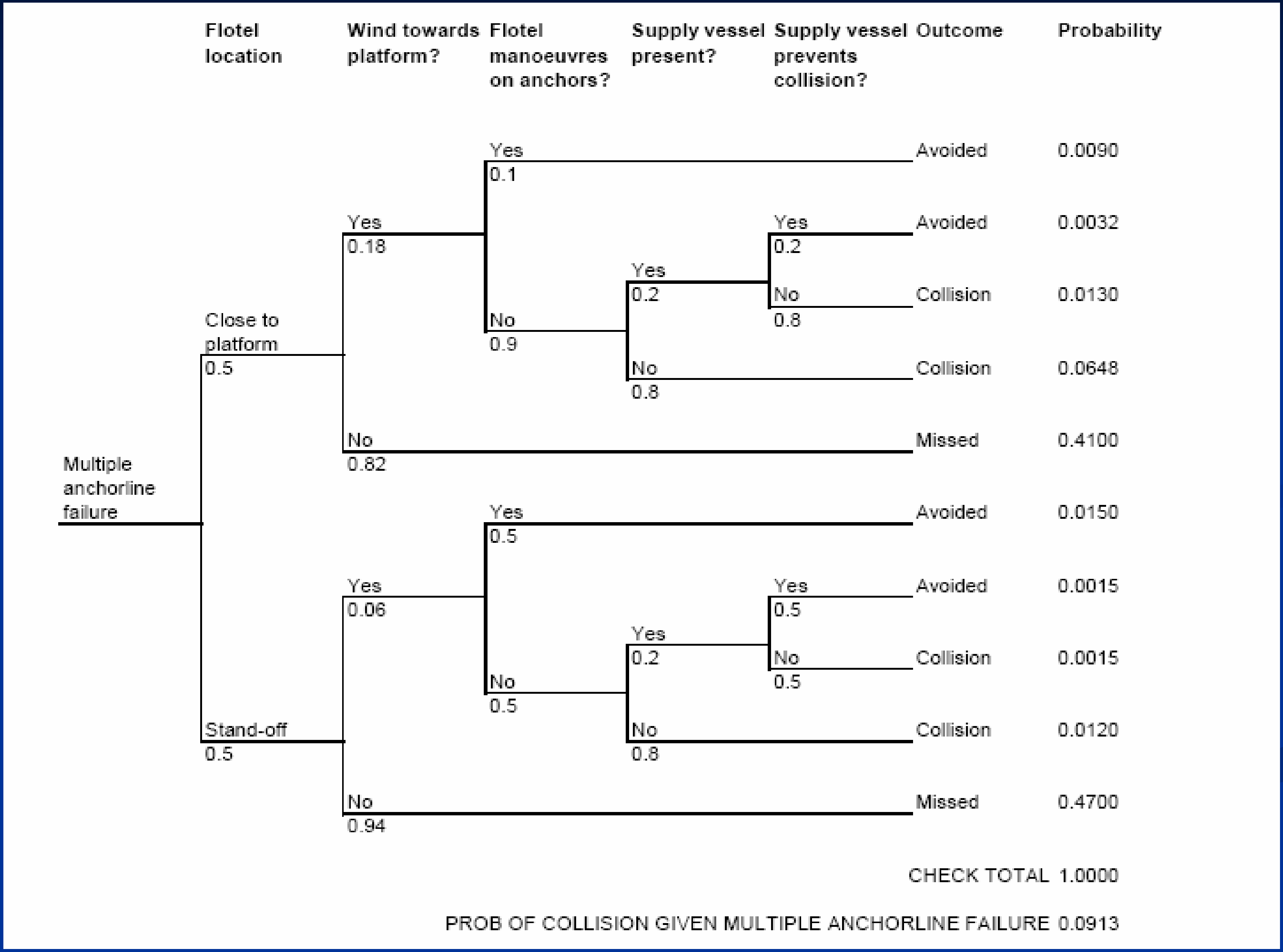


Event Tree Analysis (ETA)

Event tree analysis (ETA) is a logical representation of the various events that may follow from an initiating event (e.g. a component failure).

It uses branches to show the various possibilities that may arise at each step.

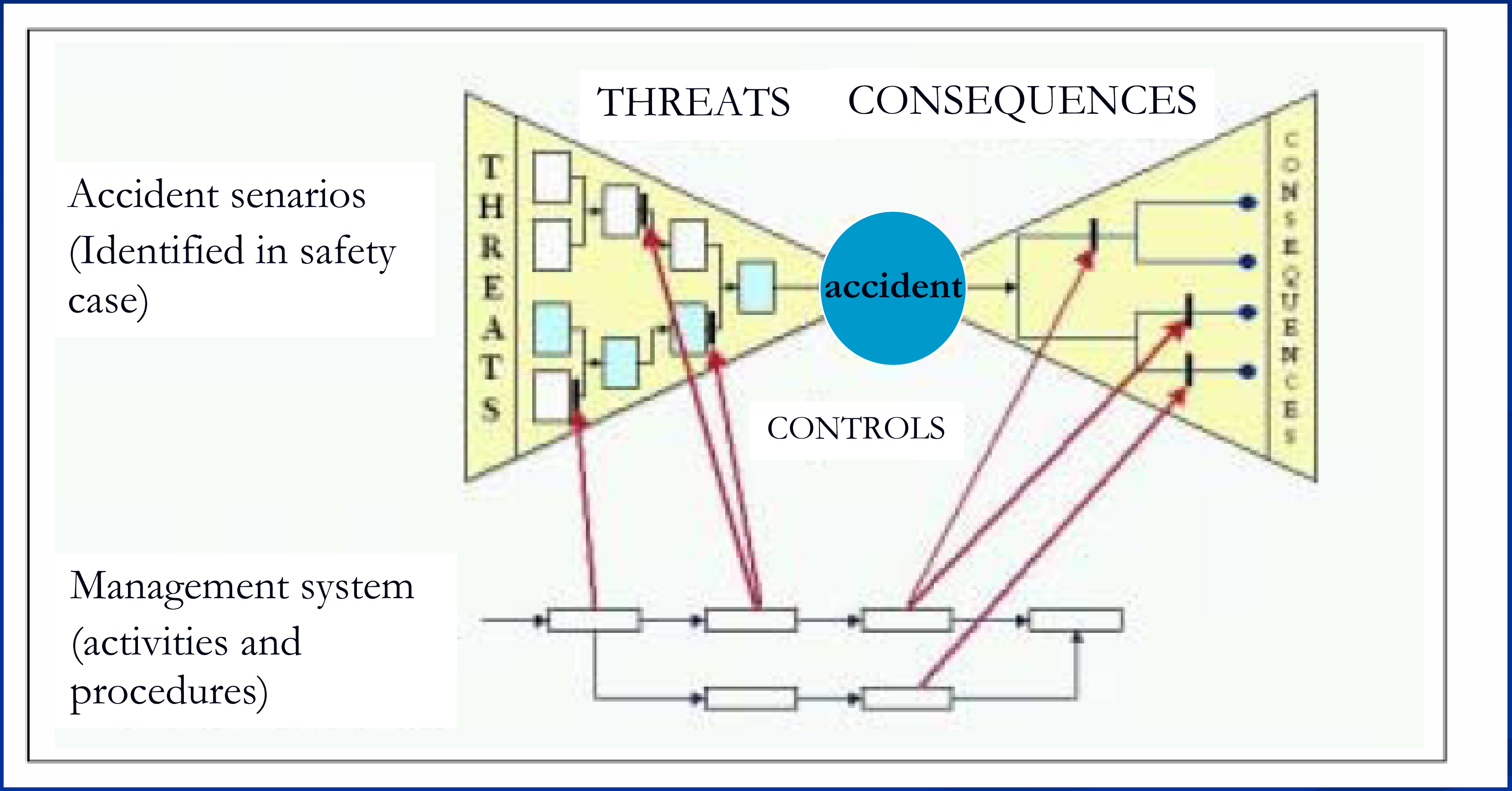
Event Tree Analysis of Flotel-Platform Collision Probability (OCB/Technica 1988)



Bow Tie Analysis

- The Bow-Tie approach is a structured for risk analysis within safety cases where quantification is not possible or desirable. The idea is simple, to combine the cause and consequence analyses into a single diagram.

Example Bow Tie Analysis



Quantitative Risk Assessment

- Next level up from Semi-Quantitative + Qualitative
- QRA as an engineering tool provides good understanding of the mechanisms of accidents and the role of safeguards in terminating accident sequences.

QRA methods

- Frequencies and Consequences method
  - Historical Data Analysis
- Modelling prediction
  - Fault Tree Analysis
  - Event Tree Analysis
- Human element

Human Element

- Human Factors
- Human Errors
- Training and Competence
- Safety Management Systems

Human Factors

"Human factors" refer to environmental, organisational and job factors, and human and individual characteristics that influence behaviour at work in a way that can affect health and safety (HSE 1999b).

It includes consideration of:

- The job
- The individual
- The organisation

Human Errors

Nearly all accidents are initiated or exacerbated by human error. These errors include:

- Slips
- Lapses
- Mistakes
- Violations

Decision making

- The purpose is to support some form of decision making on safety matters.
  - Whether or not an activity should be permitted.
  - Whether measures are necessary to reduce its risks.
  - Which of various options, involving different combinations of safety and expenditure, should be selected.
  - How much should be invested in enhancing the safety of an installation.
- The decision-maker must decide when the activity or the installation is **"safe enough"**

The ALARP Principle

- as low as reasonably practicable
- The ALARP principle originated as part of the philosophy of the UK Health and Safety at Work. (Act 1974)
- "every employer to ensure, so far as is reasonably practicable, the health, safety and welfare of all his employees"

Tolerability and Acceptability

"Tolerability" does not mean "acceptability".

It refers to a willingness to live with a risk so as to secure certain benefits and in the confidence that it is being properly controlled.

Risk Quotient (R.Q.)

- Risk quotient is the ratio between the exposure and the effect of all hazards in the system, it was defined as :

$$R.Q. = \frac{\sum[\text{ exposure }]}{\sum[\text{effect}]}$$

$$= \frac{[\text{ hazard}_{in} - \text{hazard}_{out}\text{ }]}{\text{conc. Hazard at no effect}}$$

Risk Quotient (R.Q.)

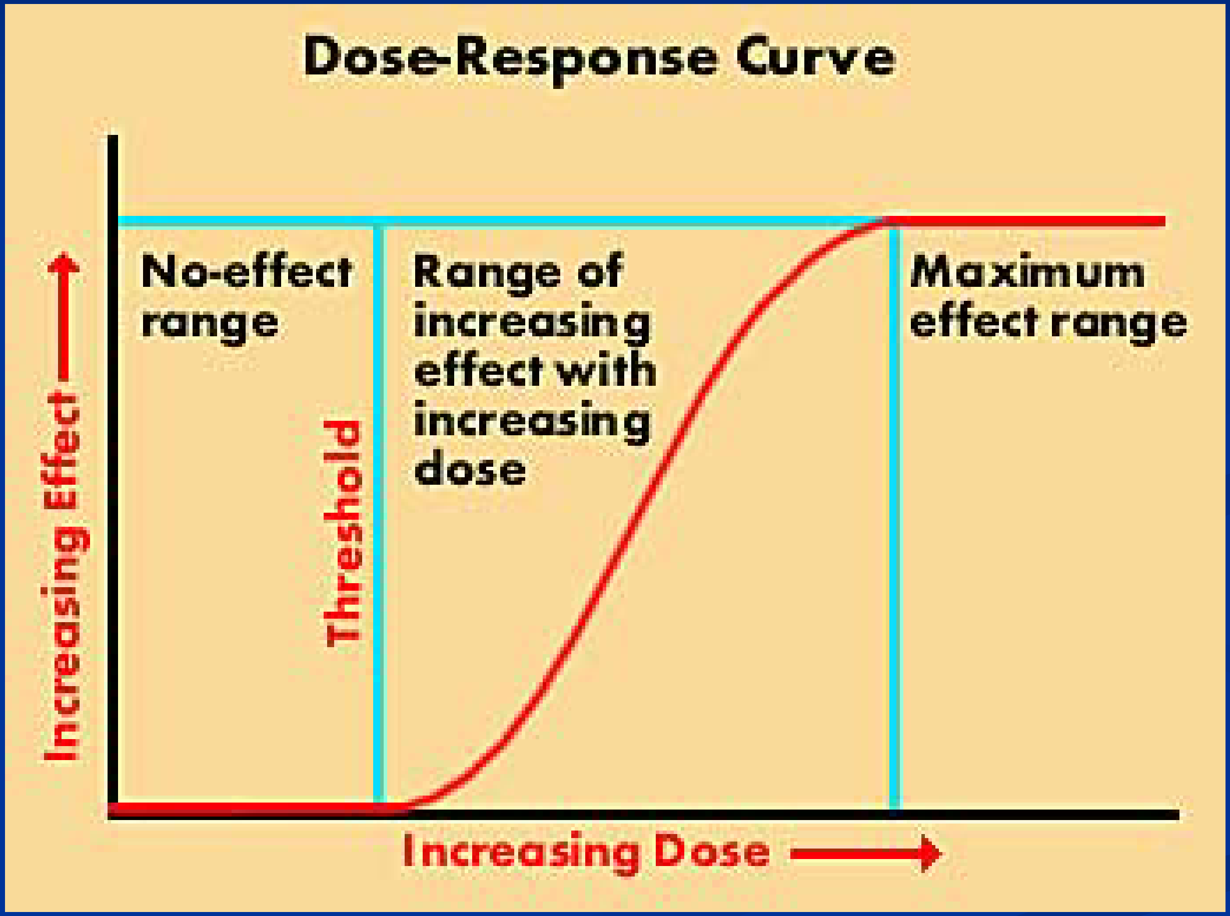
If hazard is the pollutant ; P

$$R.Q. = \frac{[\,P_{in} + P_{resuspension}\,] - [\,P_{out} + P_{sedimetation}\,]}{conc._{no\ effect}}$$

Concentration of Hazard at no effect

- Obtained from
  - Stressor – response profile (Dose – response profile)
  - toxicity test

Stressor – response profile



Toxicity test

- A test of toxic of substance on the animal at the level of 50% population resistance, LD_{50} (lethal dose) or LC_{50} (lethal concentration)

Lethal Dose (LD) Toxicity Classifications

Oral exposure (Worksafe Australia, 1994)

- **VERY TOXIC**

  LD_{50} (oral, rat) is ≤ 25 mg/kg (body weight)

- **TOXIC**

  LD_{50} (oral, rat) 25 - 200 mg/kg (body weight)

- **HARMFUL**

  LD_{50} (oral, rat) is 200 – 2000 mg/kg (body weight)

Arsenic risk assessment

Hazard identification

↓

Effect assessment

↓

Exposure assessment

↓

Risk characterization

Suggestion of solution

- Test the toxicity before release to the environment
- Disease tracking
- Research to increase knowledge
- Training of the health care