Development of Corporate Risk Matrix and ALARP Concept

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Risk Matrices - Introduction

- Risk matrices have been widely promoted in risk management standards and reference books and have been widely adopted by many organisations.
- They are a practical and easy-to-use tool which can help most organisations over a range of circumstances to:
  - Promote consistency to risk assessment and prioritisation,
  - Help keep participants in facilitated risk workshops on track (by providing clear definition of consequence/likelihood),
  - Focus decision makers on the highest priority risks, and
  - Present complex risk data in a concise visual fashion.

Risk Matrices - Introduction

Within Process Safety applications a risk matrix not only defines risk in terms of consequence and frequency, but also defines the ***boundary for unacceptable (high) risk, acceptable risk and tolerable risk***.

Risk Matrices - Introduction

This presentation will discuss:

- **What is risk** and how can it be **represented quantitatively**?
- What is **tolerable risk**?
- What is **acceptable risk**?
- What is the difference between tolerable and acceptable risk?
- How can **corporations define the boundaries** for their unacceptable, acceptable and tolerable risk?

What is risk?

What is risk?

- An expectation of loss,
- Always has an element of uncertainty,
- Always refers to the future,
- Usually refers to any unwanted consequence:
  - Personnel injury or death is a risk,
  - Site downtime is also a risk.

Risk is a combination of the frequency of occurrence of harm and the severity of that harm.

Risk = Frequency x Consequence

Determining risk

How does one quantitatively assess risk?

- Risk may be quantitatively expressed by:

  The **Individual Risk Per Annum (IRPA)**, which is defined as:

$$\text{IRPA} = \Pr(\text{Individual is killed during one year's exposure})$$

$$\text{IRPA} = \frac{\text{Observed number of fatalities}}{\text{Total no. of employee-years exposed}}$$

Determining risk

- Typical IRPA for different industry sectors:

Industry sector	Annual Risk	Annual Risk
Mining and quarrying of energy	1 in 9,200	108.7 E-6
Construction	1 in 17,000	58.8 E-6
Extractive and utility supply industries	1 in 20,000	50.0 E-6
Agriculture, hunting and forestry	1 in 17,200	58.1 E-6
Manufacture of basic metals & fabricated metal products	1 in 34,000	29.4 E-6
Manufacturing industry	1 in 77,000	13.0 E-6
Manufacture of electrical optical equipment	1 in 500,000	2.00 E-6
Service industry	1 in 333, 000	3.00 E-6

Determining risk

- How can one make a decision on the acceptability of risk?

- When do we accept risk?
  - When we do not (fully) know about the risk;
  - When the risk is insignificant;
  - When the benefit is high compared to the risk (‘it is worth the risk’).

Determining risk

- Below are some common every day risks:

Hazard	IRPA
Cars	3 E-3 deaths/person-year
Falls	1 E-4 deaths/person-year
Fires	4 E-5 deaths/person-year
Drowning	4 E-5 deaths/person-year
Firearms	1 E-5 deaths/person-year
Poisoning	1 E-5 deaths/person-year
Lightning	8 E-7 deaths/person-year

Activities with a fatality risk greater than 1E-3 deaths/year to the general public are generally not acceptable.

Tolerable risk

'Tolerable risk' is the level of risk in which organisations and society will bear, but in fact the level of risk may not be as low as acceptable risk.

Tolerability does not mean acceptability!

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

To tolerate a risk means that we do not regard it as negligible, or something we might ignore, but something that we review and reduce further if possible.

ALARP & Tolerable Risk

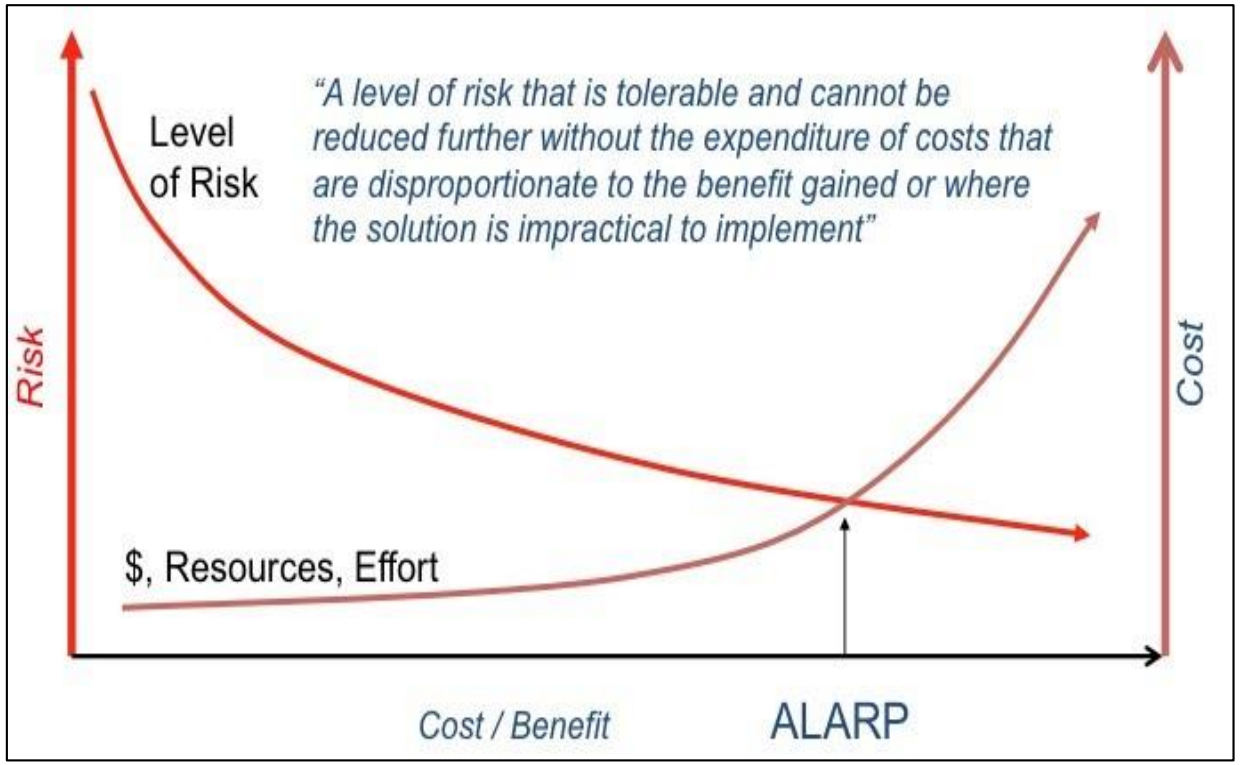
ALARP =

Any risk which has been reduced to a level

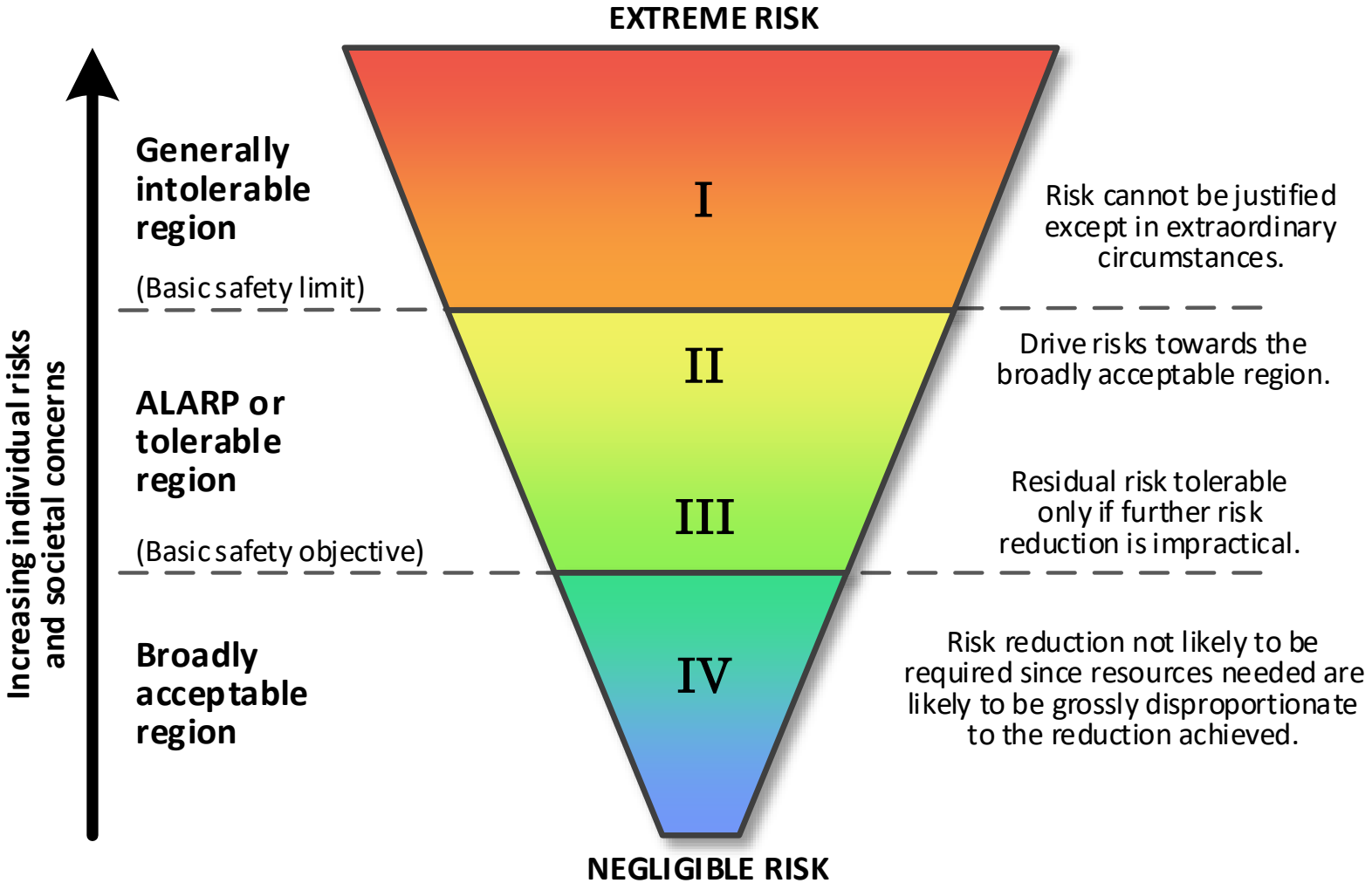
As **L**ow **A**s **R**easonably **P**racticable

ALARP & Tolerable Risk

- The concept of ALARP is one of the fundamental principles of risk management.
- Risk is typically an unavoidable product of every activity. While ideally it may be desired to manage risk to the point where it is eliminated, in practice this may not be practical.
- There comes a point where the cost and resources to reduce the risk outweigh the benefits.



Risk Classifications



ALARP & Tolerable Risk

Typically risk can be classified into three categories:

a. The risk is so great it must be refused altogether; or

b. The risk is, or has been made, so small as to be insignificant or broadly acceptable; or

c. The risk falls between the two states of ***a*** and ***b*** *and* has been reduced to the lowest practicable level, bearing in mind the benefits and taking into account costs of further reduction.

ALARP & Tolerable Risk

Tolerable risk is therefore different from acceptable.

One of the key challenges with ALARP is that it is inherently a subjective standard. It will always come down to personal and corporate 'values'.

Four things worth noting about ALARP:

- It is driven almost totally by values,
- It takes significant analysis to determine how to get into the ALARP range (and to tell when you are there),
- ALARP is all about trade-offs. There is no perfect 'ALARP'.
- The decision and acceptance of tolerable risk levels for on-site safety, property/production and the environment rests with a corporation.

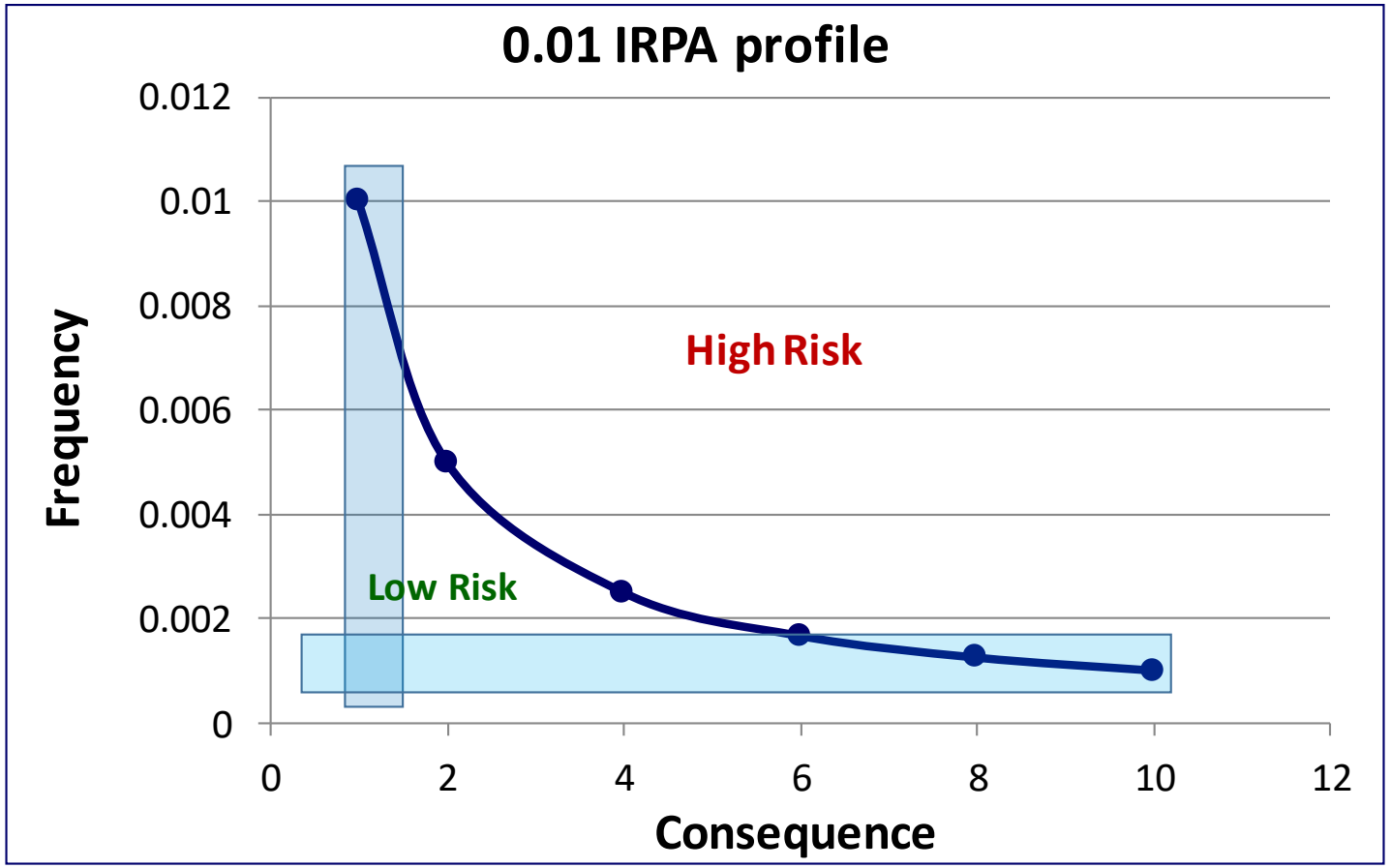
Acceptable risk

One definition for *'acceptable risk'* is:

> "The residual risk remaining after controls have been applied to associated hazards that have been identified, quantified to the maximum practicable, analysed, communicated to the proper level of management and accepted after proper evaluation."

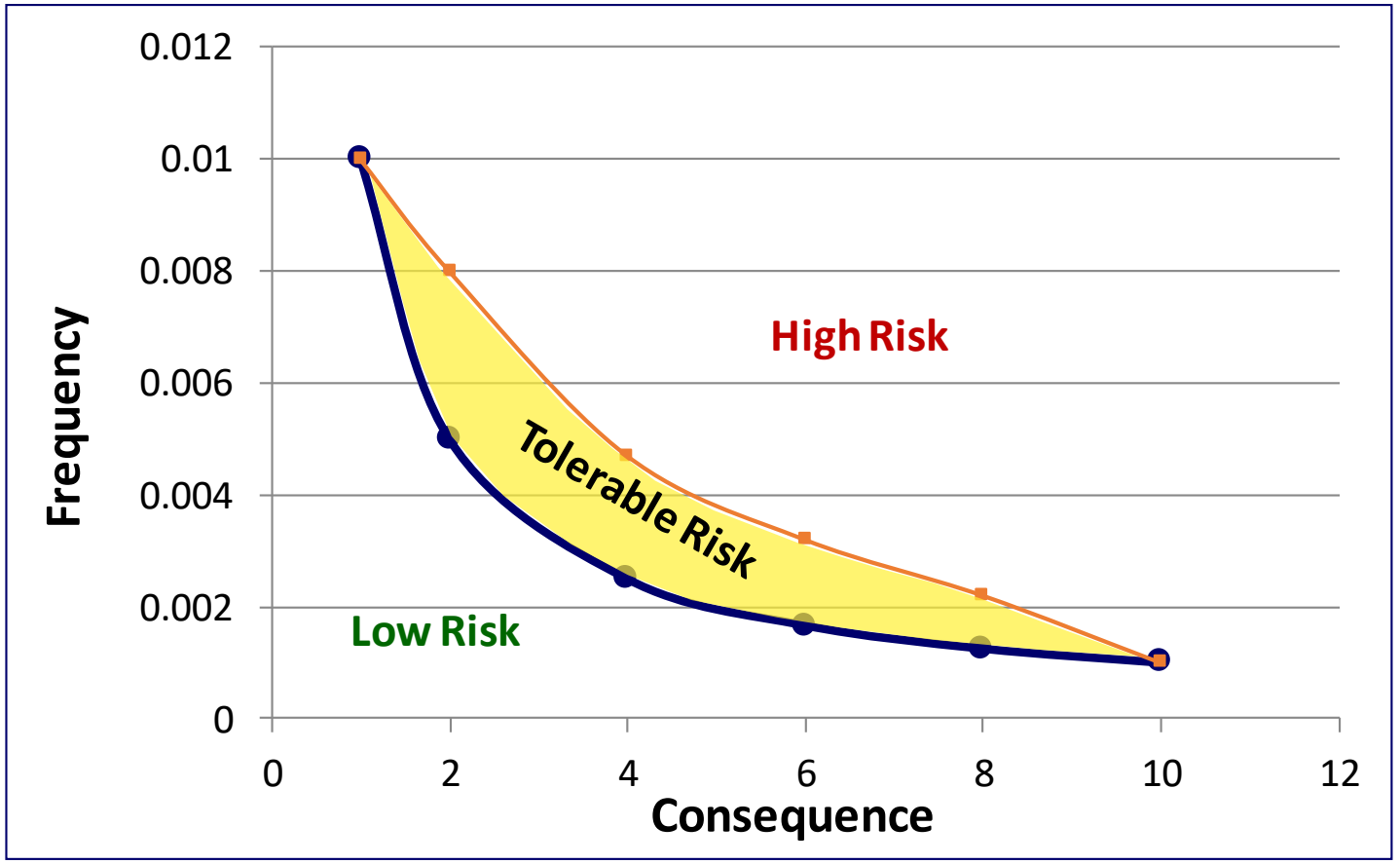
Determining Risk

- How can one make a decision on the acceptability, or tolerability, of a given risk?



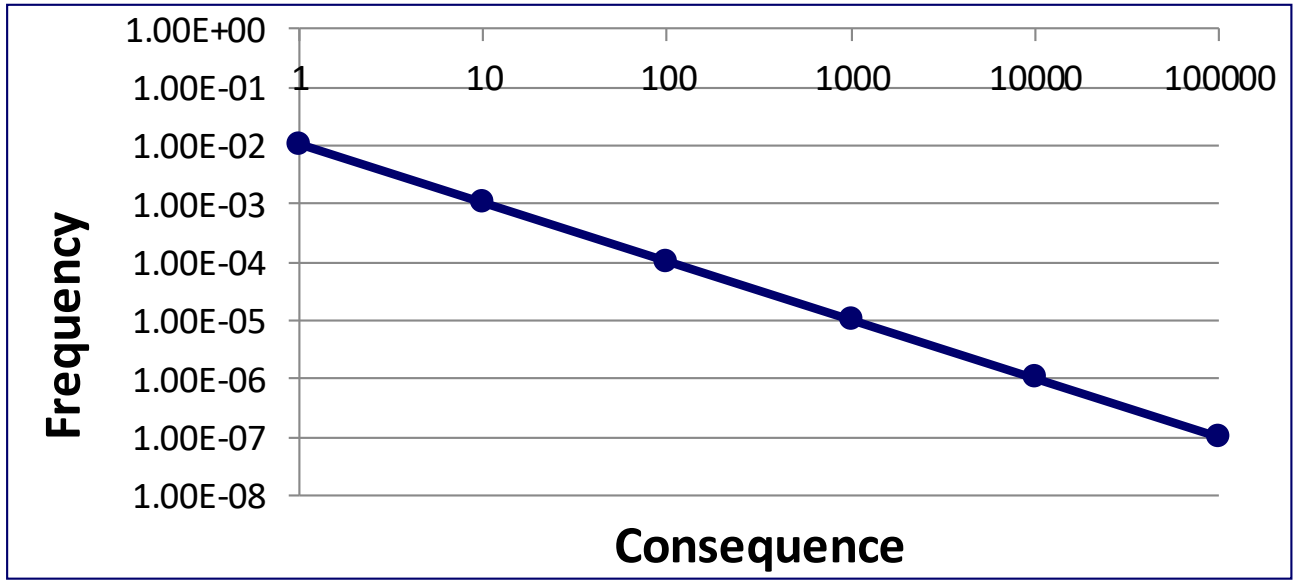
Determining Risk

- How can one make a decision on the acceptability, or tolerability, of a given risk?



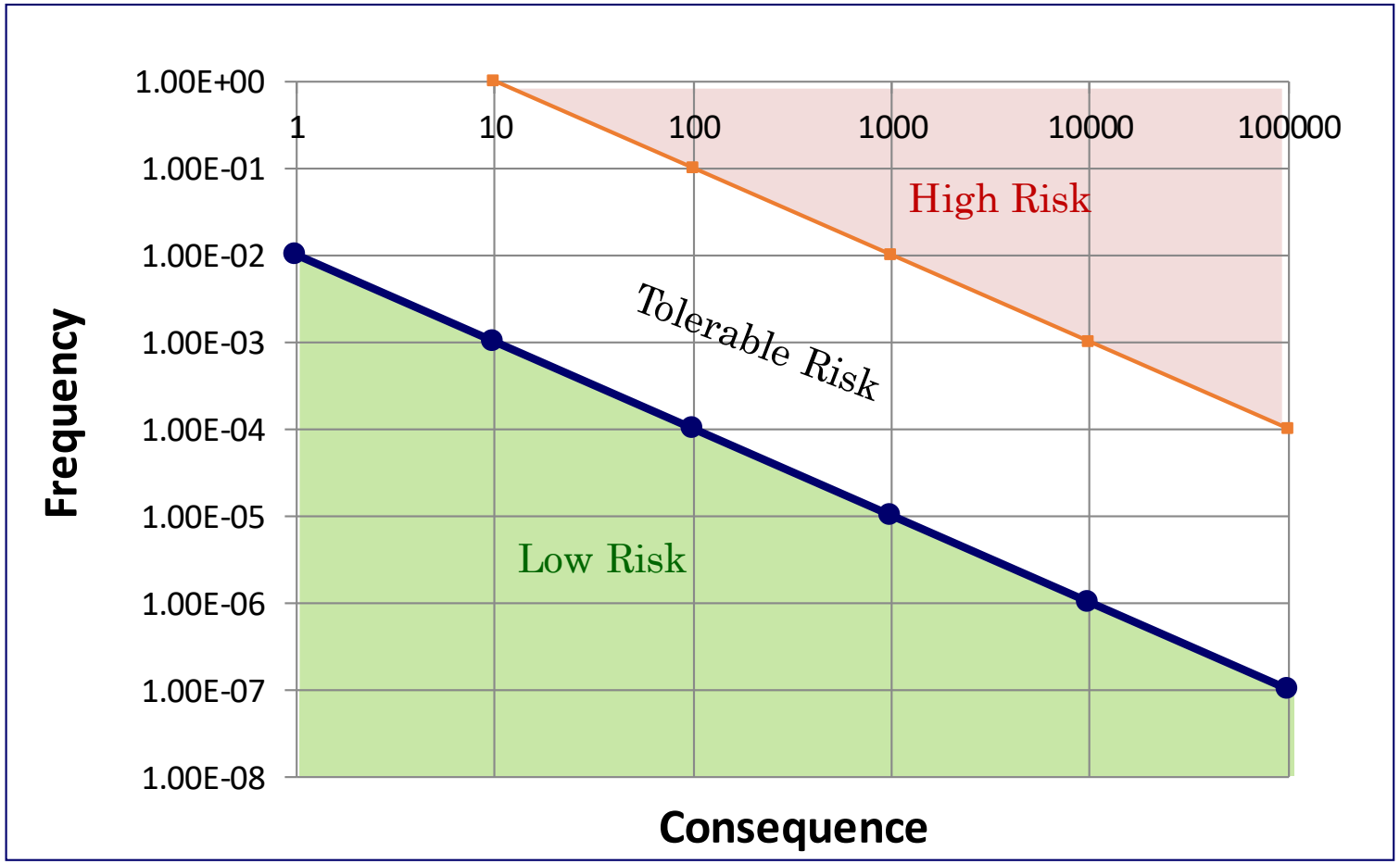
Determining Risk

- Frequency and consequence have wide scales, for this reason risk profiles typically use ***logarithmic scales***.
  - Log(risk) = log(F x Q) = Log(F) + Log(Q)
- Therefore the risk curve will change from parabolic to a straight line:



Determining Risk

- The boundaries for tolerable risk could then be:



Risk Matrix

Typical Risk Assessment Matrix

Likelihood	Potential Consequences					
	Notable	Significant	Highly Significant	Serious	Extremely Serious	Catastrophic
Almost Certain 1 to 10 /yr.	Level II 2M	Level II 1M	Level I 1M	Level I 1W	Level I 1D	Level I 1D
Very Likely <1 & >0.1 /yr	Level III 9M	Level II 6M	Level II 3M	Level I 1M	Level I 1D	Level I 1D
Likely <0.1 & >10^{-2} /yr	Level III 2Y	Level III 1Y	Level II 9M	Level II 1M	Level I 1W	Level I 1W
Unlikely <10^{-2} & >10^{-4} /yr	Level IV	Level IV	Level III 5Y	Level III 5Y	Level II 1Y	Level I 1M
Very Unlikely <10^{-4} & >10^{-6} /yr	Level IV	Level IV	Level IV	Level IV	Level III 5Y	Level II 1Y
Extremely Unlikely << 10^{-6} /yr	Level IV	Level IV	Level IV	Level IV	Level IV	Level III 5Y

Expressing Tolerable Risk

- Expressing the tolerable level of risk is one of the most difficult tasks facing any organisation as it requires the evaluation of the cost required to save lives.
- The corporate approach on their risk decision-making criteria may be based on the following:
  - Quantitative assessment based on “Value to Prevent Fatality (VPF)”.
  - Quantitative assessment of what is fair and reasonable.
  - Quantitative assessment based in statistical studies provided internally or by the regulator.

Quantitative Assessment based on Value to Prevent Fatality (VPF)

There are some general issues that companies normally face in defining risk:

- There is no practical definition,
- Its perception varies among industries,
- It is very hazard specific,
- Even government agencies are not consistent,
- There are contemporary comparisons that can be made.

However, in many countries the principle of ALARP describes the way in which risk is considered legally. The difficulties for most corporations arises here in the requirement to define the 'cost per life saved' which could be regarded as being grossly disproportionate to reduce the risk.

- **'Cost per life saved' is also called 'Value to Prevent Fatality'**

Value to Prevent Fatality (VPF)

Most corporations often misunderstand the meaning of VPF as the value being placed on a life. This is not the case. It is simply another way of saying what people are prepared to pay to secure a certain average risk reduction.

For example, the UK operates with a VPF of 1,826 million pounds for ordinary workplace risks. The US uses a figure of around 6 million dollars. In New Zealand the VPF is updated annually and was $3,352,400 at June 2008.

Value to Prevent Fatality (VPF)

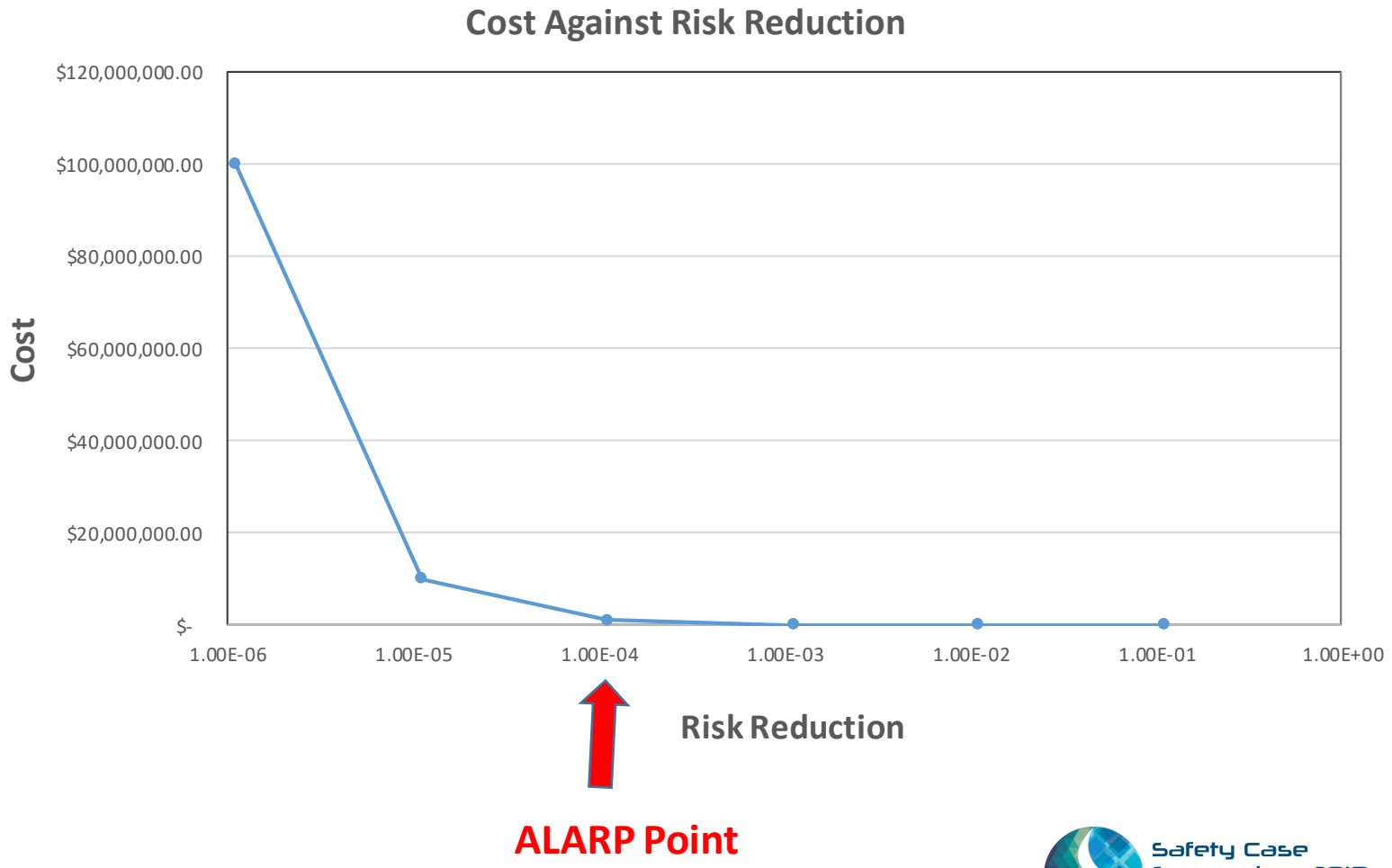
$$VPF = \frac{Cost\ of\ Risk\ Reduction}{(Risk\ Reduction) \times (No.\ of\ expected\ fatalities) \times (Life\ time\ of\ plant)}$$

Where:

- Cost of risk reduction = Estimated cost for implementing risk reduction measures, including SIS and non-SIS, including design, install, maintenance, etc.
- Risk reduction = Amount of risk reduction required achieve the specified VPF (frequency, 1/years);
- No. of expected fatalities = Number of fatalities expected per specified event;
- Life time of the plant = design life of the plant (years)

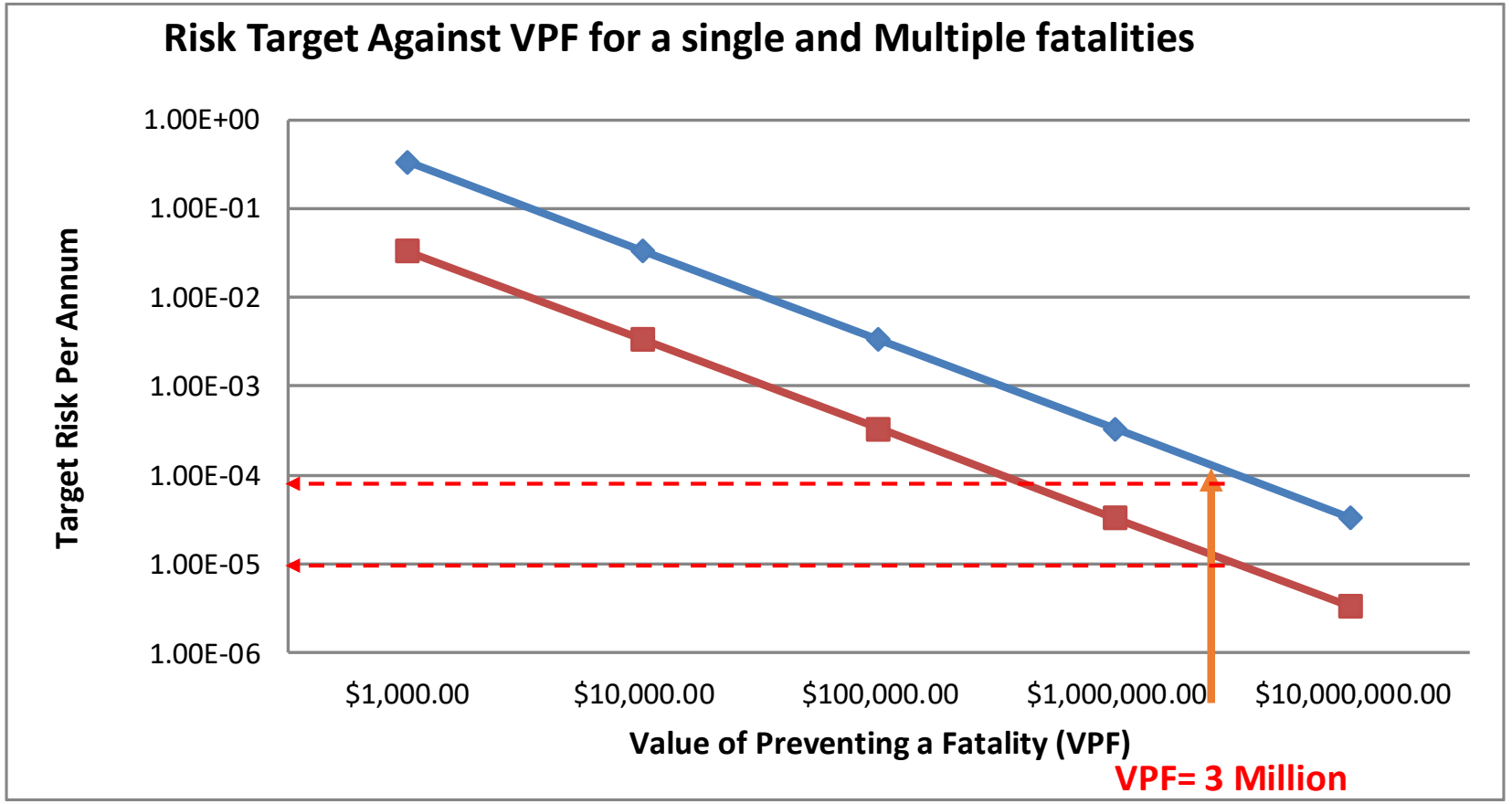
ALARP Point

From Equation 1 the cost reduction against risk reduction relation could be drawn to get the ALARP point



Corporate Risk Target

From this equation, if the of VPF = 3 Million
the target risk for single and multiple fatalities would be E-4 and E-5



Corporate Risk Target

Another approach to define tolerable risk is to ask what is the minimum average frequency for a fatality would need to be for a plant to be considered safe.

It is not at all uncommon for people to pick once every 100 years.

If then it is assumed that at certain corporate the workforce includes 500 workers who would be exposed to process risks:

$$IRPA_{total} = \left(\frac{1\ year}{500\ man{-}years}\right)\left(\frac{1\ fatality}{100\ years}\right) = \frac{1\ fatality}{50{,}000\ man{-}years}$$

Corporate Risk Target

If we assume that 50% of this risk is a process risk then the tolerable risk for single fatality is:

$$IRPA_{process} = 2.0E^{-5} \times 0.5 = 1.0E^{-5}$$

The remaining causes for fatality are not related to process risk such as general work site incidents such as falls, falling items, confined spaces, electrocution, etc.

Regulator Advised Target Risk

In some circumstances a regulatory body could advise or mandate certain target risk based on statistical studies on the number/causes of fatalities.

For example, the following table shows the number of fatalities in the mining industry in Australia.

The average number of fatalities is 6.6E-5. The regulator advice for mining companies is that target risk should be at least one order of magnitude less than 6.6E-5 (i.e. less than E-6).

Regular Advised Target Risk

Industry of employer	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11
	Fatality rate (deaths per 100 000 workers)							
Agriculture, forestry & fishing	21.54	18.20	16.66	13.41	16.17	19.57	11.38	17.64
Agriculture	*19.90*	*14.01*	*14.64*	*11.10*	*14.29*	*12.28*	*11.08*	*15.65*
Transport, postal & warehousing	13.79	10.04	11.91	14.44	14.35	11.02	8.81	7.20
Road freight transport	*29.69*	*28.71*	*32.92*	*40.20*	*38.11*	*27.83*	*23.38*	*20.50*
Construction	4.91	3.36	4.90	5.31	4.04	4.45	4.08	3.77
Manufacturing	1.65	2.19	2.24	2.93	2.56	2.46	2.39	2.02
Administrative & support services	1.73	2.85	3.38	3.37	3.15	2.62	2.41	2.75
Arts & recreation services	1.95	4.91	1.69	2.76	3.10	1.00	1.01	3.96
Public administration & safety	1.10	2.44	1.80	2.46	0.88	1.94	0.59	1.13
Mining	5.22	7.60	11.64	8.13	6.21	7.18	3.47	3.41

Health & Safety Risk Severity and Target Frequency Definition

Descriptor	Target Frequency	Consequence Description
S1 – Minor	1.0E-1 /year	Injury / illness requiring medical treatment (first aid, no lost time injury)
S2 – Moderate	1.0E-2 /year	Serious reversible / temporary injury / illness (lost time injury for less than one week)
S3 – Serious	1.0E-3 /year	Serious reversible / temporary injury / illness (lost time injury for more than one week)
S4 – Major	1.0E-4 /year	Serious permanent injury / illness or moderate irreversible disability (<30%) to one or more persons
S5 – Critical	1.0E-5 /year	1-3 fatalities or severe irreversible disability for less than 10 persons
S6 - Catastrophic	1.0E-6 /year	Multiple fatalities ≥ 4 or severe irreversible disability to more than 10 persons

Economic Risk Severity and Target Frequency Definition

Descriptor	Target Frequency	Consequence Description
S1 – Minor	1.0E-1 /year	Equipment damage and loss of production costing less than USD 30k
S2 – Moderate	1.0E-2 /year	Equipment damage and loss of production costing more than USD 30K but less than USD 300k
S3 – Serious	1.0E-3 /year	Equipment damage and loss of production costing more than USD 300k but less than USD 3M
S4 – Major	1.0E-4 /year	Equipment damage and loss of production costing more than USD 3M but less than USD 30M
S5 – Critical	1.0E-5 /year	Equipment damage and loss of production costing more than USD 30M but less than USD 100M
S6 - Catastrophic	1.0E-6 /year	Equipment damage and loss of production costing more than USD 100M

Environmental Risk Severity and Target Frequency Definition

Descriptor	Target Frequency	Consequence Description
S1 – Minor	1.0E-1 /year	Limited impact to biological/physical environment of immediate area of limited significance
S2 – Moderate	1.0E-2 /year	Minor short-term (<1 year) reversible impact to biological/physical environment of very localised area (<0.1ha) of limited significance
S3 – Serious	1.0E-3 /year	Moderate or medium-term (1 - 2 years) reversible impact to biological/physical environment of localised area (<1ha)
S4 – Major	1.0E-4 /year	Serious or prolonged (2 - 5 years) reversible impact to biological/physical environment to widespread area
S5 – Critical	1.0E-5 /year	Significant or long-term (>5 years) reversible impact to biological/physical environment to widespread area.
S6 - Catastrophic	1.0E-6 /year	Uncontained, long-term serious environmental degradation OR permanent impairment to ecosystem function or habitat.

Example Corporate Risk Matrix

Notes & utilisation:

- Risk is the product of the **LIKELIHOOD** that a particular risk event will occur and the resultant **CONSEQUENCE** of the risk. In order to classify the level of risk both the likelihood (frequency) and the consequence need to be identified.
- Likelihood is the product of the **probability that an incident** will occur and the **frequency of the operation** at which the incident could occur.

		RISK CATEGORY			Target Risk for LOPA (per year)	LIKELIHOOD					
		Health & Safety	Environment	Commercial / Financial		Remote	Rare	Unlikely	Possible	Likely	Frequent
						1/10,000 to 1/100,000 events per year	1/1,000 to 1/10,000 events per year	1/100 to 1/1,000 events per year	1/10 to 1/100 events per year	1 to 1/10 events per year	≥1 events per year
						Could theoretically occur but not aware of any instances	Has occurred somewhere in the world in ALL industries	Known to have happened within the industry	Potential to occurred at least once during the operating life of the refinery	Very likely to occur at least once during a 10 year period of operation of the refinery	Is expected to occur on a regular and repeating basis
CONSEQUENCE	Catastrophic	Multiple fatalities ≥ 4 or severe irreversible disability to more than 10 persons	Uncontained, long-term serious environmental degradation OR permanent impairment to ecosystem function or habitat.	Equipment damage and loss of production costing more than USD 100M	$1x10^{-6}$	H	H	S	S	E	E
	Critical	1-3 fatalities or severe irreversible disability for less than 10 persons	Significant or long-term (>5 years) reversible impact to biological/physical environment to widespread area.	Equipment damage and loss of production costing more than USD 30M but less than < USD 100M	$1x10^{-5}$	M	M	H	S	S	E
	Major	Serious permanent injury / illness or moderate irreversible disability (<30%) to one or more persons	Serious or prolonged (2 - 5 years) reversible impact to biological/physical environment to widespread area	Equipment damage and loss of production costing more than USD 3M but less than USD 30M	$1x10^{-4}$	L	M	M	H	S	S
	Serious	Serious reversible / temporary injury / illness (lost time injury for more than one week)	Moderate or medium-term (1 - 2 years) reversible impact to biological/physical environment of localised area (<1ha)	Equipment damage and loss of production costing more than USD 300k but less than USD 3M	$1x10^{-3}$	L	L	M	M	H	S
	Moderate	Serious reversible / temporary injury / illness (lost time injury for less than one week)	Minor short-term (<1 year) reversible impact to biological/physical environment of very localised area (<0.1ha) of limited significance	Equipment damage and loss of production costing more than USD 30K but less than USD 300k	$1x10^{-2}$	L	L	L	M	M	H
	Minor	Injury / illness requiring medical treatment (first aid, no lost time injury)	Limited impact to biological/physical environment of immediate area of limited significance	Equipment damage and loss of production costing less than USD 30k	$1x10^{-1}$	L	L	L	L	M	M

QUESTIONS

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