

POLLUTION CONTROL DEPARTMENT (PCD)
GUIDELINES FOR QUANTITATIVE RISK ASSESSMENT (QRA) STUDY
(For Installations Which Store, Transport Or Use Hazardous Substances)

Rev: Mar 2012

INTRODUCTION

Under Section 26 of the Environmental Protection and Management Act, PCD may require the owner/occupier of hazardous installations to conduct pollution/hazard/risk impact studies.

The purposes of the QRA are to:

- i identify and quantify hazards and risks related to the transport, use and storage of hazardous materials;
- ii determine hazards/risks due to possible accident scenarios which will lead to fire, explosion or toxic release;
- iii recommend measures to be incorporated in the design and operation of the plant to keep hazards/risks to as low a level as practical;
- iv facilitate the development of emergency response plans to deal with all possible accident scenarios.

QRA REPORT REQUIREMENTS

Introduction

- i Describe the approved/proposed industrial activity of the facility.
- ii Include a description of the hazards of the hazardous substances that will be used, stored or transported to/from the facility.
- iii Provide a labeled site map of the facility and transportation route

Hazard Identification

- i Tabulate the inventory of hazardous materials to be handled/stored on-site. (see **Annex 1**). Include MSDSs in the report.
- ii Identify all possible accident scenarios; especially those credible scenarios with off-site impacts.
- iii Highlight any hazardous materials that will be transported by road in bulk (i.e. ISO-container)

Consequence Analysis

- i For the facility, determine the hazard zones for possible accident scenarios considering proposed safety systems / mitigation measures, using well validated models

- ii For the road transport of hazardous materials in bulk, determine the worst case (rupture) 3% fatality distance for both daytime and nighttime weather conditions
- iii State clearly in the report which models are used and the basis for their selection.
- iv Key assumptions made in the calculations shall be tabulated (see **Annex 2**)
- v Estimate the distance to each of the following criteria. Tabulate the results (see **Annex 2**) and indicate the hazard zones of the worst credible scenario (WCS) on a map of the site:

Hazard	Criteria
Toxic (see Notes 2)	<ul style="list-style-type: none"> ▪ IDLH; ▪ 3% fatality (for a release duration of less than 30 minutes)
Fire (Radiation)	<ul style="list-style-type: none"> ▪ 37.5kw/m² and 4kw/m²; ▪ 3% fatality / 500 TDU (for a fire of less than 30 seconds) (see Notes 1)
Explosion (Overpressure)	<ul style="list-style-type: none"> ▪ 5psi, 1psi and 0.5psi ▪ Fireball zone

- e) Use the following meteorological conditions for the consequence analysis:

Wind Speed (m/s)	Atmospheric Stability
1	F
2	B
3	C

Frequency Analysis

- i Estimate the event frequency per year for credible accident scenarios based on relevant historical failure frequencies. Tabulate the results (see **Annex 2**)
- ii Provide references for the failure data and indicate the applicability of the historical failure data to the actual items being considered. (see **Notes 3**)
- iii The failure frequency/probability of proposed safety systems / mitigation measures shall be tabulated. (see **Annex 2**)

Individual Fatality Risk

- i Name the software package used for the risk summation and give a simple description of the basic approach the software uses for the calculation.
- ii Identify the key risk contributors
- iii Establish the following Individual Risk (IR) contours, tabulate the results (see **Annex 2**) and indicate the IR contours on a map of the site:
 - (a) 5×10^{-5} per year;
 - (b) 5×10^{-6} per year; and
 - (c) 1×10^{-6} per year

QRA REPORT CONCLUSION / CONFIRMATION

- i That the following hazard zones / IR contour for credible scenarios are within the plant site boundary:
 - a 37.5 kW/m² heat radiation hazard zone
 - b 5 psi explosion overpressure hazard zone
 - c 5x10⁻⁵ per year IR contour

- ii IR contours:
 - a that the 5x10⁻⁶ IR contour extends into industrial developments only
 - b that the 1x10⁻⁶ IR contour extends into commercial and industrial developments only.

- iii Hazard zones (IDLH, 3% fatality, 4kW/m², 500TDU, 0.5psi, fireball zone):
 - a that the hazard zones for the worst credible scenario (WCS) does not extend into residential areas
 - b no high-rise developments within the fireball zone

- iv Summarise the key findings of the study in the format at **Annex 3**.

QRA SUBMISSION

A copy of the QRA report shall be submitted to each of the following agencies for their information and comments:

National Environment Agency (NEA) Central Building Plan Dept 40 Scotts Road #12-00, S(228231) Attn: Mr Chow Chee Kiong / Mr Chen Fu Yi Tel: 67319919 Fax: 67319725	National Environment Agency (NEA) Pollution Control Dept Chemical Control Section 40 Scotts Road #12-00, S(228231) Attn: Ms Fareena Abdul Rahim Tel: 67319642 Fax: 67319651
Singapore Civil Defense Force (SCDF) Fire Safety & Shelter Dept (FSSD) 91 Ubi Ave 4, S(408827) Attn: MAJ Han Fook Kuang Tel: 68481467 Fax: 68481494	Singapore Civil Defence Force (SCDF) Hazmat Department 91 Ubi Ave 4, S(408827) Attn: CPT Ng Boon Tiong Tel: 68483372 Fax: 68483318

Ministry of Manpower (MOM) Occupational Safety and Health Division (OSHD) OSH Specialist Dept 18 Havelock Rd, #03-02, S(059764) Attn: Ms Jaime Lim Tel: 63171119, 63171118 Fax: 63171140	Singapore Police Force (SPF) Protective & Maritime Security Security & Counter Terrorism Division, Operations Dept Police Headquarters Attn: ASP Isaac Chua Tel: 6478 4078 Fax: 6250 6306
*Jurong Town Corporation (JTC) Land Resource Planning Dept 8 Jurong Town Hall Rd, S(609434) Attn: Ms Lillian Lee Jiaxian Tel: 68833129 Fax: 68855880	Urban Redevelopment Authority Physical Planning Group 45 Maxwell Road, The URA Centre, Singapore 069118 Attn: Ms Mavis Tsoi Tel: 6329 3390 Fax: 63203546

Remark

*For proposed development on JTC's land only.

OTHER REQUIREMENTS

- i After QRA clearance, the owner/occupier shall develop an emergency response plan (ERP) to mitigate all accident scenarios identified in the QRA study. The ERP shall be submitted to PCD for information and to SCDF (HazMat Branch) for clearance.
- ii After QRA clearance, the owner/occupier may be required to conduct a
 - a safety review (HAZOP) to identify all feasible and practical safety/mitigation measures that should be incorporated into the detailed design. The HAZOP study shall be submitted to MOM (OSD).
 - b fire safety study to identify fire prevention/detection/protection strategies and measures that should be incorporated into the detailed design. The fire safety study shall be submitted to FSB.
 - c pollution impact study to (1) identify the sources of emission of air pollutants, discharge of trade effluent, generation of wastes and emission of noise and (2) to propose measures to reduce pollution and to mitigate adverse pollution impact on surrounding land use. The pollution impact study shall be submitted to PCD.

CONSULTANTS

- i A list of consultants with expertise in conducting QRAs is provided in **Annex 4**
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Notes

- 1 “TDU” denotes “Thermal Dose Units”;
where $\text{TDU} = \text{exposure time (s)} \times \text{heat load (kW/m}^2)^{4/3}$.
Use probit functions derived by TNO (1989) or equivalent.
- 2 For the purpose of emergency response planing, the consequence distances to TLV and ERPG-2 shall also be determined under section 2.3 for all toxic gases.
- 3 Statistics and frequency estimates used shall be characteristic / representative of the conditions in Singapore and specific to the accident scenario/s to which they are applied.

CHEMICAL INVENTORYTable 1: Storage

Chemical	Storage Location	UN / IMO Hazard Class	Major Hazards ¹	Physical Form ²	Type of Container ³	Unit Capacity of Container ⁴	Max Qty Stored On-Site ⁴

Table 2: Transportation

Chemical	From	To	Type of Container ³	Unit Capacity of Container ⁴	Max Qty Transported per trip ⁴	No. of Unit Containers Transported per trip	No. of Trips per year

¹ Toxic by inhalation / Highly flammable / Pyrophoric / Explosive / Emits toxic fumes in a fire or in contact with water / Low SADT...etc

² Solid / Liquid / Gas

³ Drum/Cylinder/ISO Container...etc

⁴ Convert all units to kilograms (kg) or metric tons (MT)

TABULATION OF CONSEQUENCE, FREQUENCY & RISK RESULTS FOR ALL POSSIBLE ACCIDENT SCENARIOS

Accident Scenario ¹	Release Rate & Duration	Mass Released	Event ¹		Consequence Distance ²			Event Frequency	<ul style="list-style-type: none"> ▪ Key Assumptions ▪ Safety/Mitigation Measures³
					1F	2B	3C		
(Description in words)	(in the largest applicable unit)		Toxic	IDLH 3% Fatality	-	-	-	-	
			Fire	37.5 kW/m ² 4 kW/m ² 3% fatality	-	-	-	-	
			(flash fire, jetfire..etc)		-	-	-	-	
			Explosion	5psi 1psi (BLEVE, VCE..etc) 3% fatality	-	-	-	-	

¹ all outcomes/events for each accident scenario for both storage and transport.

² credible scenarios with off-site impacts shall be in bold font. The worst credible scenario shall be identified with the text "(WCS)"

³ including failure frequency/probability of proposed safety/mitigation measures and frequency/probability of human error

Individual Fatality Risk (IR) Contours	Maximum Distance to IR Contour	Confirmation
5x10 ⁻⁵ per year		That this contour remains on-site
5x10 ⁻⁶ per year		That this contour extends into industrial developments only
1x10 ⁻⁶ per year		That this contour extends into commercial and industrial developments only.

ANNEX 3

SALIENT FINDINGS OF THE QRA STUDY

1 STORAGE OF HAZARDOUS MATERIALS

Worst Case Scenario ¹	Event Frequency (per year)	Absolute Hazard Distance (m)	Offsite Hazard Distance ³ (m)	Remarks / Land Use
FIRE <i>Description.....</i>	xE-y	x (37.5kW/m ²) y (4kW/m ²)	x (37.5kW/m ²) y (4kW/m ²)	na
TOXIC RELEASE <i>Description.....</i>	xE-y	x (IDLH)	x (IDLH)	na
EXPLOSION <i>Description.....</i>	xE-y	x (5psi) y (1psi) z (0.5psi)	x (5psi) y (1psi) z (0.5psi)	na
Worst Credible Scenario ²	Event Frequency (per year)		Offsite Hazard Distance ³ (m)	Remarks / Land Use Constraints
FIRE <i>No credible scenarios</i>	Non-credible	-	-	37.5 kW hazard zone confined onsite 4kW hazard zone confined to industrial areas – does not encroach into residential areas or workers' dormitories
TOXIC RELEASE <i>Description.....</i>	xE-y	x (3% fatality)	x (3% fatality)	Hazard zone confined to industrial areas – does not encroach into residential areas or workers' dormitories
EXPLOSION <i>Description.....</i>	xE-y	x (5psi) y (1psi) z (0.5psi)	x (5psi) y (1psi) z (0.5psi)	5psi hazard zone confined onsite 1 psi and 0.5psi hazard zone confined to industrial areas – does not encroach into residential areas or workers' dormitories
Individual Risk				
INDIVIDUAL RISK CONTOURS	<ul style="list-style-type: none"> ▪ 5E-5 IR is confined on-site ▪ 5E-6 IR extends off-site by x m – only industrial developments are within this IR ▪ 1E-6 IR extends off-site by y m – only industrial, commercial and park developments are between this IR and 5E-6 IR. 			

1 – scenario with largest offsite hazard distance (independent of frequency) – e.g. rupture

2 – scenario with frequency greater than 1E-6 per year and the largest offsite hazard distance

3 – measured from the plant's fence line and using the most prevalent **night-time** weather condition

2 TRANSPORT OF HAZARDOUS MATERIALS

Worst Case Scenario (for Transport in ISO-container / tube-trailer only)	Event Frequency (per year)	Hazard Distance² (m)	Remarks / Land Use
FIRE <i>Description.....</i>	xE-y	x (3% fatality) y (4kW/m ²)	Does not encroach into residential areas or existing workers' dormitories
TOXIC RELEASE <i>Description.....</i>	xE-y	x (3% fatality)	Does not encroach into residential areas or existing workers' dormitories
EXPLOSION <i>Description.....</i>	xE-y	x (3% fatality)	Does not encroach into residential areas or existing workers' dormitories
Worst Credible Scenario¹	Event Frequency (per year)	Hazard Distance³ (m)	Remarks / Land Use Constraints
FIRE <i>Description.....</i>	xE-y	x (3% fatality) y (37.5kW/m ²) z (4kW/m ²)	37.5 kW hazard zone does not encroach into industrial buildings / facilities 4kW hazard zone confined to industrial areas – does not encroach into residential areas or workers' dormitories
TOXIC RELEASE <i>Description.....</i>	xE-y	x (3% fatality)	Hazard zone confined to industrial areas – does not encroach into residential areas or workers' dormitories
EXPLOSION <i>Description.....</i>	xE-y	x (3% fatality) y (1 psi) z (0.5 psi)	5psi hazard zone does not encroach into industrial buildings / facilities 1 psi and 0.5psi hazard zone confined to industrial areas – does not encroach into residential areas or workers' dormitories

1 – scenario with frequency greater than 1E-6 per year and the largest hazard distance

2 – measured from the edge of the road using most prevalent **daytime and nighttime** weather condition

3 – using most prevalent daytime conditions (i.e. 2B or 3C)

LIST OF QRA CONSULTANTS

The updated list of QRA consultants can be found at our NEA website
http://app2.nea.gov.sg/env_plan_cbpu.aspx

SCHEMATIC OF QUANTITATIVE RISK ANALYSIS

