THE GOVERNMENT OF THE
HONG KONG SPECIAL ADMINISTRATIVE REGION

GUIDANCE NOTE ON QUANTITATIVE RISK ASSESSMENT STUDY FOR HIGH PRESSURE TOWN GAS INSTALLATIONS IN HONG KONG

EMSD

April 2021

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1. Foreword and Scope

1.1 This Guidance Note (GN) covers the technical guidelines related to the Quantitative Risk Assessment (QRA) methodology for High Pressure Town Gas Installations (HPTGIs), particularly for the land-use application of any proposed development with a significant increase in working or living population in the vicinity of HPTGIs.

1.2 The following installations are defined as HPTGI:-

- High Pressure Town Gas Pipeline (HPTGP); and
- High Pressure Town Gas Regulating Station (HPTGRS), including offtake and/or pigging station with HPTGP connected.

1.3 While Tai Po Gas Production Plant (TPGPP) contains high pressure town gas installations, it is however excluded from the scope of HPTGIs. Instead, TPGPP is defined as a Potentially Hazardous Installation (PHI) in accordance with chapter 12.4 of the Hong Kong Planning Standards and Guidelines (HKPSG) [4.2]. Any proposal for development that will result in an increase in the number of persons living or working in the Consultation Zone (CZ) of a PHI have to be submitted to the Coordinating Committee on Land-use Planning and Control relating to Potentially Hazardous Installations [4.1] (CCPHI) for consideration.

1.4 This Guidance Note aims to provide technical guidelines and general requirements for conducting QRA for proposed development(s) in the vicinity of HPTGIs. **Whenever alternative methodologies and/or assumptions to be adopted, relevant justification(s) should be provided as appropriate.**

2. Definition

ALARP	– As Low As Reasonably Practicable
CBA	– Cost Benefit Analysis
CCPHI	– Coordinating Committee on Land-use Planning and Control relating to Potentially Hazardous Installations
CZ	– Consultation Zone
EGIG	– European Gas Pipeline Incident Data Group
ETA	– Event Tree Analysis
GN	– Guidance Note
HKO	– Hong Kong Observatory, HKSARG
HKPSG	– Hong Kong Planning Standards and Guidelines
HKRGs	– Hong Kong Risk Guidelines
HKSARG	– Hong Kong Special Administrative Region Government
HPTGI	– High Pressure Town Gas Installation (including HPTGP and HPTGRS, but excluding Tai Po Gas Production Plant)
HPTGP	– High Pressure Town Gas Pipeline
HPTGRS	– High Pressure Town Gas Regulating Station (including offtake and/or pigging station)
IGEM/TD/2	– Assessing the risks from high pressure natural gas pipelines, Institution of Gas Engineers & Managers
IOGP	– International Association of Oil & Gas Producers
IR	– Individual Risk
PHI	– Potentially Hazardous Installations
PLL	– Potential Loss of Life
QRA	– Quantitative Risk Assessment
RG	– Risk Guidelines
SR	– Societal Risk
SZ	– Study Zone
TPGPP	– Tai Po Gas Production Plant
Town Gas	– Any gas which is primarily a mixture of hydrogen and methane
VCE	– Vapour Cloud Explosion

3. QRA Methodology

The HPTGI(s) involved in QRA study can be categorized into two (2) cases:-

- Case 1: High Pressure Town Gas Pipeline (HPTGP) only; and
- Case 2: High Pressure Town Gas Regulating Station (HPTGRS) with HPTGP connected.

3.1 Consultation Zone (CZ)

A 150 metres Consultation Zone (CZ) is defined for HPTGIs, i.e. 150 metres from the alignment of the HPTGP and 150 metres from the boundaries of HPTGRS. For any proposal for development within CZ that will result in a significant increase in population, a QRA study is required to assess the potential risks associated with the HPTGI(s), having considered the proposed development.

3.2 Study Zone (SZ)

In QRA study, a Study Zone (SZ) should be of an area covering 200 metres from the HPTGI(s) concerned.

3.2.1 Case 1: Proposed development within the CZ of HPTGP

When the proposed development is within the CZ of HPTGP, the highest risk 1.6 km HPTGP segment should be first selected. [4.4] The SZ should be an area covering 200 metres from the HPTGP selected (as illustrated in example Figure 1). All HPTGIs within the SZ including HPTGRS, if any, should be considered in the QRA study (as illustrated in example Figure 2).

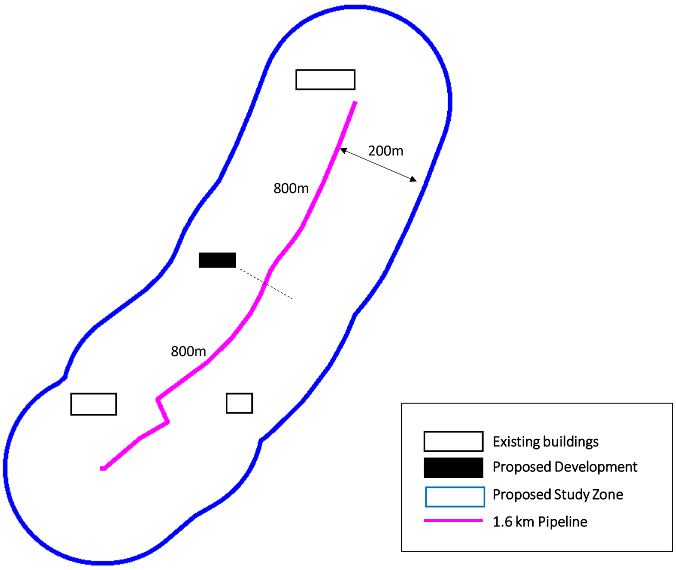

Figure 1: Recommended Study Zone for Case 1 (Continuous HPTGP)

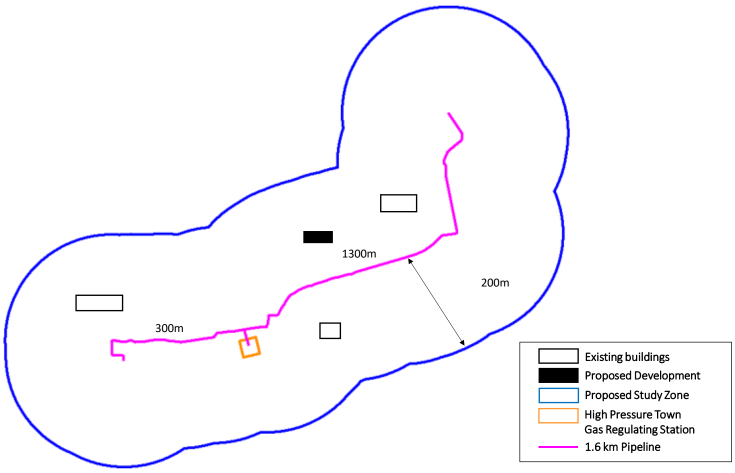

Figure 2: Recommended Study Zone for Case 1 (HPTGRS with continuous HPTGP)

3.2.2 Case 2: Proposed development within the CZ of HPTGRS

When the proposed development is within the CZ of HPTGRS, apart from the HPTGRS concerned, the highest risk 1.6 km HPTGP segment should also be selected. The SZ should be an area covering 200 metres from the HPTGRS and associated HPTGP selected (as illustrated in examples Figure 3 and 4).

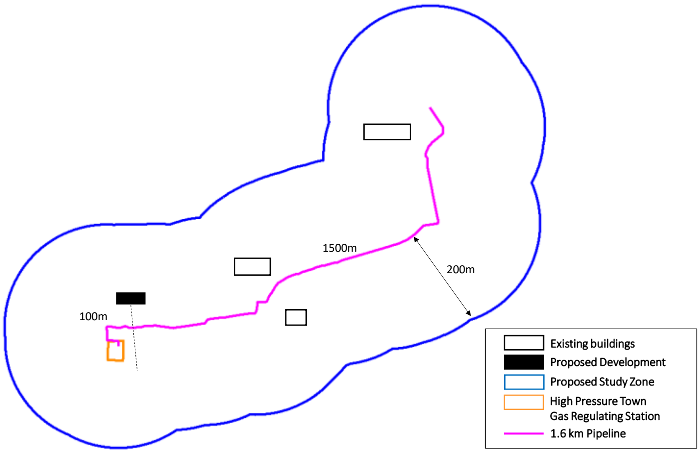

Figure 3: Recommended Study Zone for Case 2 (HPTGRS at the end of HPTGP)

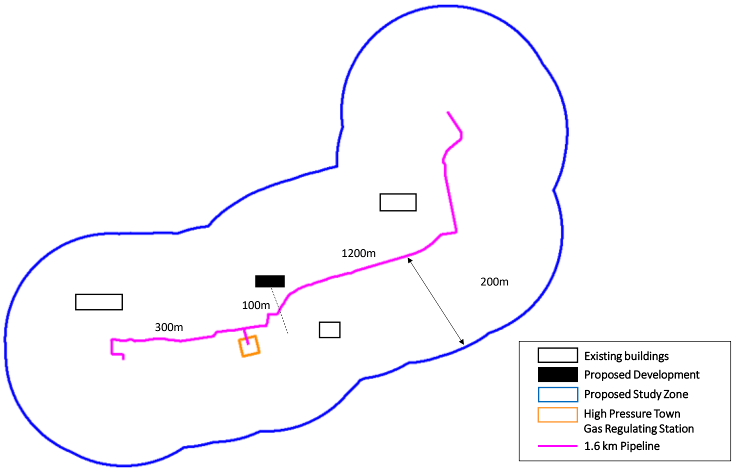

Figure 4: Recommended Study Zone for Case 2 (HPTGRS with continuous HPTGP)

3.3 Hazard Identification

3.3.1 All potential hazardous events and failure scenarios should be identified and considered. With reference to internationally recognized historical failure databases, such as EGIG, OGP, Cox, Lee, Ang, etc., identified hazardous scenarios should include but not limited to:-

- Full-bore rupture; and
- Leakages from representative hole sizes.

With flammability and toxicity of town gas in nature, the loss of containment of HPTGIs, if the dispersed town gas encounters an ignition source while its concentration lies within the flammability limits, may result in fire and/or explosion events. Hazardous events should include but not limited to:-

- Fireball;
- Jet Fire;
- Flash Fire; and
- Toxicity.

3.3.2 Vapour cloud explosion (VCE) hazardous event should be considered where applicable, as it may occur under some site specific conditions with a certain degree of confinement or congestion.

3.4 Failure Frequency

Failure frequencies of gas installations considered in the QRA study should be determined with reference to internationally recognized historical failure database(s). The failure frequencies suggested should not be less than the following GN recommended values, or other values suggested with justification(s) provided:-

Type of HPTGI		Recommended value
High Pressure Town Gas Pipeline (HPTGI)	Underground[4.6, 4.7]	10^{-5} per km-year
	Aboveground[4.9]	2.67×10^{-7} per m-year
High Pressure Town Gas Regulating Station (HPTGRS)	Valve[4.8]	1.1×10^{-3} per valve-year
	Flange[4.8]	10^{-3} per flange-year
	Connection[4.10]	5.7×10^{-4} per connection-year

Table 1: Recommended values of failure frequency for HPTGI

3.5 Event Tree Analysis

An event tree analysis should be performed to model the development of each hazardous event from the initial release to final outcomes. The analysis should take into consideration of hole sizes of release, orientations of release, presence of ignition sources and types of ignition. Possible outcomes include but are not limited to fire balls, jet fires, flash fires and toxic releases. Event tree examples for aboveground HPTGIs and underground HPTGP are presented as below:-.

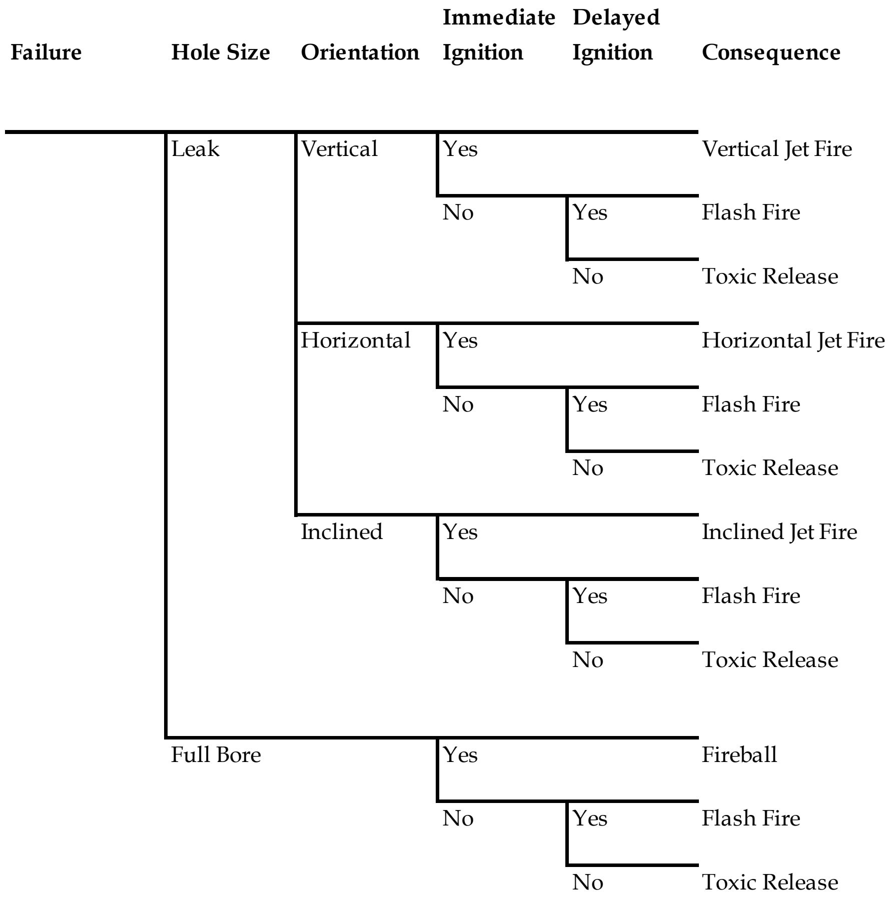

Figure 5: Event tree example for aboveground HPTGIs

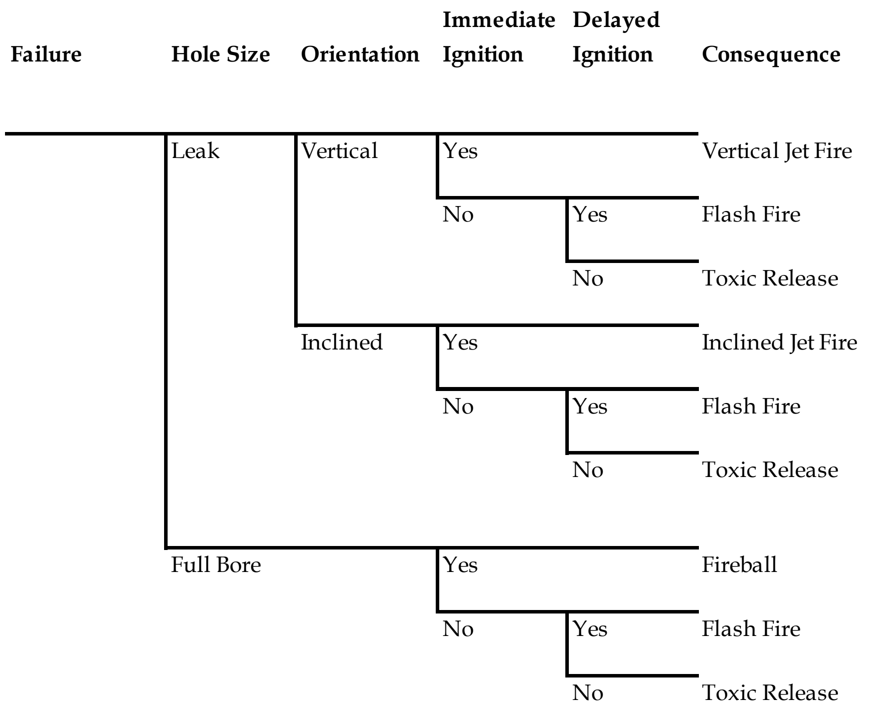

Figure 6: Event tree example for underground HPTGP

3.5.1 Hole size distribution

The recommended hole size distributions for underground HPTGP, aboveground HPTGP, and equipment at HPTGRS are tabled as below:-

Category	Hole Size (mm)	Proportion
Pipeline	Full bore	1%
	100 mm	19%
	50 mm	30%
	25 mm	30%
	10 mm	20%

Table 2: Recommended hole size distribution for underground HPTGP

Category	Hole Size (mm)	Proportion
Pipeline	Full bore	2%
	100 mm	12%
	50 mm	25%
	25 mm	30%
	10 mm	30%

Table 3: Recommended hole size distribution for aboveground HPTGP

Category	Hole Size (mm)	Proportion
Valve	10 mm	100%
Flange	50 mm	1%
	25 mm	9%
	10 mm	90%
Instrument Connection	25 mm	11.5%
	10 mm	88.5%

Table 4: Recommended hole size distribution for equipment at HPTGRS

3.5.2 Release orientation

Recommended release orientations for various HPTGIs are listed as below:-

Gas installation	Vertical	Horizontal	Inclined (45°)
Aboveground HPTGIs (Aboveground HPTGP, Valves, Flanges, Instrument Connections)	0.5	0.25	0.25
Underground HPTGP	0.5	-	0.5

Table 5: Recommended release orientation

3.5.3 Ignition probability

Both immediate and delayed ignitions should be considered. For immediate ignition, gas release rate [4.8] should be taken into consideration for the immediate ignition probability.

Leak Size	Immediate ignition probability
Minor (<1 kg/s)	0.01
Major (1 to 50 kg/s)	0.07
Massive (>50 kg/s)	0.30

Table 6: Recommended immediate ignition probability

For delayed ignition, the delayed ignition probability should be at least 40% of immediate unignited probability [4.3]:-

Minimum delayed ignition probability = 0.4 * (1 – immediate ignition probability)

3.6 Meteorological Data

At least six (6) representative weather classes should be proposed, covering the stability conditions of stable, neutral and unstable, and wind speeds of low, medium and high[4.3]. The allocation of six (6) representative weather classes is recommended in the following table:

<table>
<tr><th>Wind speed</th><th>A</th><th>B</th><th>B/C</th><th>C</th><th>C/D</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td>< 2.5 m/s</td><td colspan="3" rowspan="3">B medium</td><td colspan="3">D low</td><td colspan="2">F low</td></tr>
<tr><td>2.5 - 6 m/s</td><td colspan="3">D medium</td><td colspan="2" rowspan="2">E medium</td></tr>
<tr><td>> 6 m/s</td><td colspan="3">D high</td></tr>
</table>

Note: Low wind speed corresponding to < 2.5 m s^{-1}
Medium wind speed corresponding to 2.5 – 6 m s^{-1}
High wind speed corresponding to > 6 m s^{-1}

Wind speeds are in units of metres per second (m s^{-1}) while the atmospheric stability classes are referred to the following definition:-

A – Turbulent
B – Very Unstable
C – Unstable
D – Neutral
E – Stable
F – Very Stable

3.7 Ignition Source

When loss of containment of a gas installation occurs, the flammable gas would disperse and may be ignited subject to a number of factors:-

- Location of ignition source
  This allows positioning of the ignition source relative to the location of the flammable release to be evaluated. Dispersion modelling would then able to determine the size and mass of flammable gas when it reaches the ignition source;

- Presence factor
  The probability that an ignition source is being active; and

- Ignition factor
  The strength of an ignition source should be defined, which is derived from the probability that an ignition source would ignite the flammable gas cloud when it presents over the ignition source for a particular length of time.

Consideration of typical ignition sources in Hong Kong including but not limited to (1) road vehicles; and (2) surrounding population are required. Minimum ignition probabilities of 0.4 per vehicle and 0.01 per person are recommended [4.3].

3.8 Population

At least two (2) following major types of population within the proposed study zone should be considered.

- Building population
  Building population includes residual, commercial, industrial, etc. as well as the additional population introduced from the proposed development; and

- Transient population
  Transient population includes road traffic population and pedestrian population.

The interactive effect of the development leading to significant transient population to the proposed study zone should be considered as per case by case basis.

The typical indoor factor as 0.95 should be considered for typical building such as residential building, while the indoor factor for other types of buildings should be case by case to considered in the QRA Study.

3.9 Consequence Modelling

Consequence modelling (including source term and physical effect modelling) should be conducted by industrially recognized and validated software, such as DNV GL PHAST [4.11], etc. With the consequence modelling, hazardous impact distance and the associated impacts for all identified hazardous events can be evaluated.

3.9.1 Source term modelling

For every failure scenario, gas release rates under various sizes of leak should be evaluated by the gas dispersion modelling, and thus determine the associated probabilities of immediate ignition.

3.9.2 Physical effects modelling

All possible final outcomes of every hazardous event should be modelled. Final outcomes can be fireball, jet fire or flash fire if dispersion is ignited, and toxic effect is unignited otherwise.

The typical town gas composition used for consequence modelling is summarized as follows:

Gas Composition of Town Gas	Volume Percentage (%)
Hydrogen	49.0
Methane	28.5
Carbon Dioxide	19.5
Carbon Monoxide	3.0

3.9.3 Effects to human

(a) Fireball, Jet Fire and Toxic

The probit equations derived from TNO Purple Book [4.3] are recommended to calculate the fatality rates due to thermal radiation effect posed by jet fire and fireball events when dispersion is ignited; and toxicity effect to persons without protective clothing when dispersion is unignited otherwise.

(b) Fireball

Fatality rates of 100% and 50% should be assumed for outdoor and indoor population within the fireball radius respectively [4.12].

(c) Thermal Radiation from Jet Fire and Fireball

Impact distance of thermal radiation should be considered for jet fire and fireball. Fatality rates of 10% should be assumed for indoor population as per probit equation [4.12].

(d) Flash Fire

Impact distance of lower flammability limit (LFL) from flash fire should be considered as the flash fire envelope. Fatality rates of 100% and 10% should be assumed for outdoor and indoor population within the flash fire envelope [4.12].

(e) Height Protection

The impacted areas of jet fire and flash fire are limited and do not cover the entire building for high rise, a height protection factor should be considered to exclude the population residing on higher floors of a building [4.12].

3.10 Risk summation

Risk summation should be conducted by industrially recognized and validated risk summation software, such as DNV GL SAFETI [4.11], etc. to generate the risk levels associated with the HPTGIs in terms of Individual risk (IR) and Societal Risk (SR), taking into account of the following parameters:

- Release cases of all identified hazardous events with the associated likelihood;
- Release locations of all identified hazardous events;
- Meteorological data including the wind direction and the associated wind speed and stability; and
- Population data (Building population, road traffic population and pedestrian population) with the location as well as the indoor fraction.

Apart from the IR and SR, a summary of Potential Loss of Life (PLL) with breakdown of major risk contributors should be presented.

3.11 Risk Criteria

The Risk Guidelines (RG) adopted by CCPHI in assessing the off-site risk levels of PHIs as stipulated in Chapter 12 of HKPSG is referred. The acceptability of the risks is evaluated in terms of IR and SR.

3.11.1 Individual Risk (IR)

IR is the predicted increase in the chance of death per year to an individual who lives or works near to the HPTGI. IR be presented as iso-risk contours which decrease according to distance from the HPTGI.

The maximum level of off-site individual risk associated should not exceed 1 in 100,000 per year i.e. 10^{-5}/year.

3.11.2 Societal Risk (SR)

SR expresses the risks to the whole population living near the HPTGI, which should be expressed in terms of lines plotting the frequency (F) of N or more deaths in the population from incidents at the HPTGI. The societal RG is presented graphically in Figure 7.

Two FN risk lines are used in the societal RG to determine “Acceptable” or “Unacceptable” societal risks. An intermediate region is also incorporated in the societal RG in which the acceptability of societal risk is borderline and should be reduced to a level which is “as low as reasonably practicable” (ALARP). It seeks to ensure that all practicable and cost-effective measures which can reduce risks will be considered.

- Acceptable region
  The risk is broadly acceptable

- ALARP region
  Risk is tolerable provided that all practicable and cost-effective measures which can reduce risks have been considered

- Unacceptable region
  The risk is NOT in compliance with HKRGs

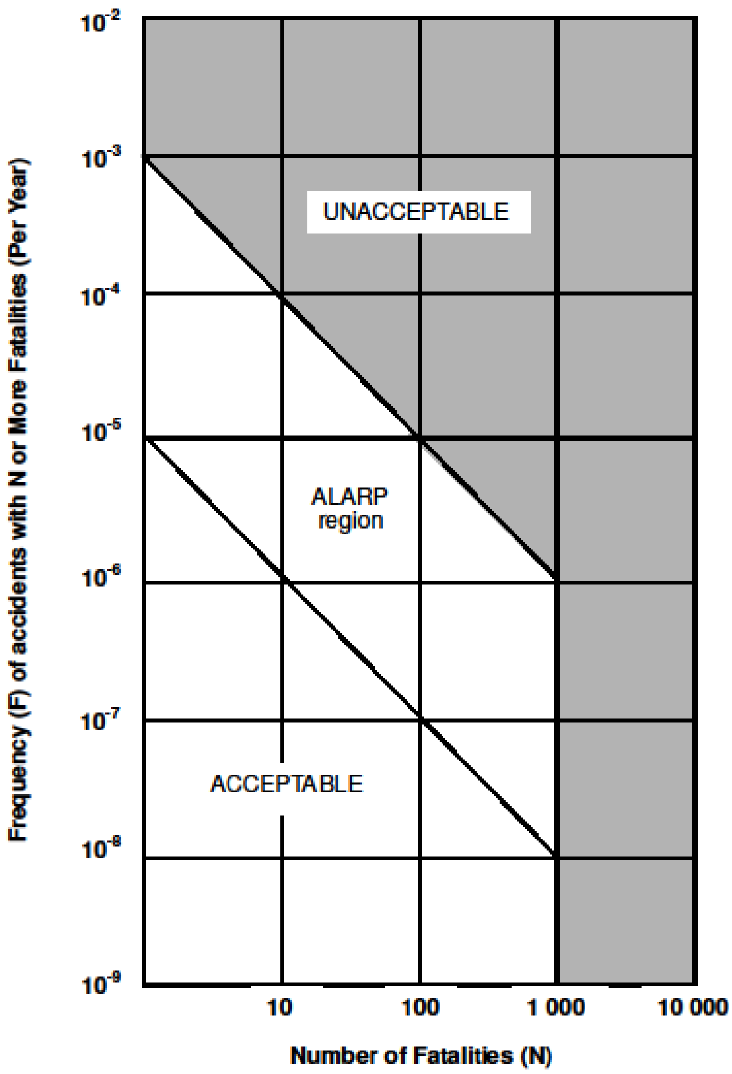

Figure 7: Societal Risk Guidelines

3.12 Study findings

HPTGIs QRA Study should summarize the gas risks in terms of both IR and SR with precise and concise descriptions of the overall QRA study. Apart from IR and SR, PLL should also be incorporated to present the top risk contributors in order to propose practical and cost-effective mitigation measures, where necessary.

3.12.1 Mitigation measures

If SR result falls into ALARP region, all practicable and cost-effective mitigation measures should be considered. The feasibility of the proposed mitigation measures should be evaluated and justified by Cost Benefit Analysis (CBA) [1.1].

If IR/SR result falls into Unacceptable region, all practicable mitigation measures should be implemented regardless of cost of construction or fulfilment.

3.12.2 Conclusion and recommendations

Conclusion should summarizes the background of the QRA study, key study findings and QRA results to indicate whether the associated risks posed from HPTGI(s) within the SZ are in compliance with HKRGs in terms of IR and SR.

The QRA study should provide recommendations in an interest of gas safety where applicable. Recommendations include but not limited to the proposed mitigation measures.

4. Reference

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4.11 DNV PHAST and SAFETI Guide.

4.12 Reeves, A.B., Minah, F.C. and Chow, V.H.K., Quantitative Risk Assessment Methodology for LPG Installations, Electrical & Mechanical Services Department, Hong Kong Government, 1997.

4.13 UK HSE "Cost Benefit Analysis", https://www.hse.gov.uk/risk/theory/alarpcheck.htm