SCREENING PROCEDURES FOR PRESCRIBED ACTIVITIES – QUANTITATIVE RISK ASSESSMENT

1.1 INTRODUCTION

This document function as a guide for investors on the methodology for identification of major acute risks in proposed process facilities that have potential for serious impacts to onsite and off-site populations, and for prioritization of mitigating measures.

Risk assessment is essentially to identify hazard(s) associated with a particular operation and determine its risk levels in order to incorporate appropriate safety design and measures. Output from the risk assessment will be the safety zones of which public will be relatively safe from any hazard or emergencies occurrence resulting in operational failure or accidental releases which leads to fire, explosion or toxic releases. Within Malaysian standard, the tolerable safety limits is 1.0×10^{-6} fatalities/person per year and the contour must be defined for projects that are high risk potential.

Performing a full quantitative risk assessment (QRA) of each plant or process unit can involve a major allocation of company resources and can take considerable time to implement. Moreover, such a detailed study is not always necessary to identify the major areas for risk reduction at the plant level. Given an appropriate framework, experienced technical and safety personnel can locate major hazards and rank them in terms of relative risk. Reference can be made to Environmental Impact Assessment Guidelines For Risk Assessment 2004 published by the Department of Environment (DOE).

1.2 RISK ASSESSMENT TIERS

Quantitative risk assessment involves a significant commitment from the company's human resources and many companies have adopted a multi-tiered approach to risk assessment of their facilities. The risk assessment levels presented in **Figure 1**, are generally consistent with practices encountered through various assignments for medium and large chemical and petroleum companies.

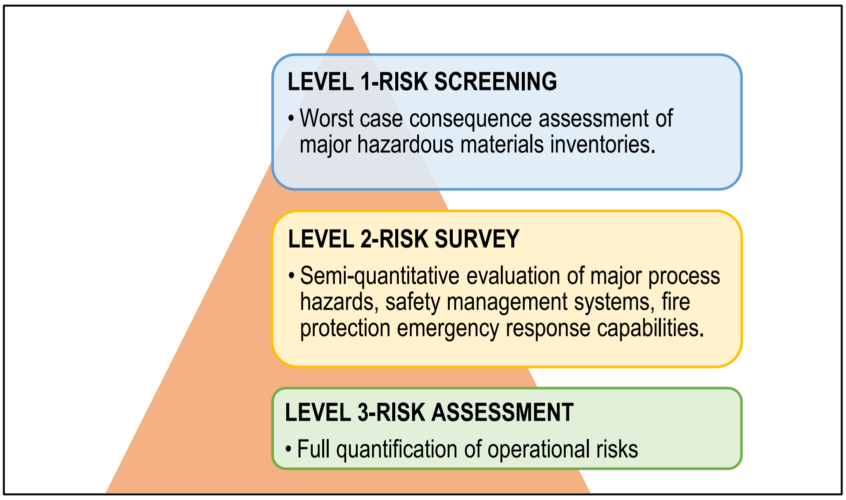

Figure 1 Risk Management Tiers

1.2.1 Level 1 - Risk Screening

This is a top-down review of worst-case potential hazards/risks, aimed primarily at prioritizing plant sites or areas within a plant, which pose the highest risk.

Factors typically considered include:
- Inventory of hazardous materials
- Hazardous material properties (e.g., toxicity, flammability)
- Storage conditions (e.g., temperature and pressure)
- Population distribution (density/distance)

The implementation relies mainly on data and information furnished by the site, with little or no site inspection. The results provide a relative indication of the extent of hazards and potential for risk exposure. More formalized programs use hazard ranking indexes (e.g., Dow Fire and Explosion or Chemical Exposure Index) to determine the need for further review or risk mitigation. Computerized indices which incorporate simplified hazard models are also utilized for Level 1 screening.

1.2.2 Level 2 - Major Risk Survey (Semi Quantitative)

This survey approach combines site inspection with established risk assessment techniques applied in a semi-quantitative fashion. The primary objective is to identify and rank major risks at a specific site and provide risk mitigation recommendations.

Aspects covered in the risk survey usually include:
- Major process hazards
- Process Safety management systems
- Fire protection/emergency response equipment and programs
- Security Vulnerability
- Impact of hazard consequences (equipment damage, business interruption, injury, fatalities)
- Qualitative risk ranking of scenarios involving hazardous materials
- Risk reduction recommendations

The ranking of major risks provides a means of prioritizing mitigative actions, and allocating resources to those areas, which pose the highest risk.

1.2.3 Level 3 - Quantitative Risk Assessment (Deterministic)

This is a rigorous analysis of the risks associated with all credible hazards that have the potential to cause an undesirable outcome such as human injury, fatality, or destruction of property. It is usually a more narrowly focused assessment of a single process unit or portion thereof (e.g., a reactor system).

The four basic elements include:

1. **Hazard Identification** utilizing a formal, systematic technique (e.g., line-by-line hazard and operability study [HAZOP]) applied to piping and instrument drawings (P&IDs).
2. **Frequency Analysis.** Based on logic diagramming for depicting failure pathways and quantifying likelihood of toxic and flammable materials releases (e.g., Fault/Event Tree Analysis).
3. **Consequence Analysis** to quantify the consequences of various hazards (fire, explosion, BLEVE, toxic vapour, etc.). Establishment of minimum values for damage criteria (e.g., IDLH, over pressure, radiation flux) to assess impacts is required.
4. **Risk Quantification.** Applying quantitative techniques which couple impact areas for each specific hazard with weather data, population data, frequency of occurrence, likelihood of ignition, etc., in order to depict the risk. For example, risk profiles can be developed which display the frequency with which consequences exceed a given magnitude for a full range of magnitudes. They are used to show the risk of injuries, fatalities, or property damage. The quantitative analysis indirectly incorporates process safety management and loss prevention through adjustment of failure rates and hazard duration. For example, instrumentation failure rates are modified depending on the frequency of testing and calibration.

QRA provides a means to determine the relative significance of each of a number of undesired events, allowing analysts and engineers to focus their risk reduction efforts where they will be most beneficial. The full quantitative risk analysis can generate information to be used in: deciding between risk mitigation alternatives; determining the tolerability of risk levels posed to workers and/or the public; deciding whether or not to issue permits for a project and what conditions to impose on that project; evaluating the adequacy of insurance, or assuring compliance to corporate standards for acceptable risk.

1.3 APPLICATION IN SITING AND ZONING OF INDUSTRY

At early stage of locating sites for the proposed development, project proponents were looking for a simple, effective, yet streamlined approach to assess major risks at their facilities without the need for extensive skills or experience in risk analysis. Utilizing QRA for this purpose would be quite time consuming and costly, particularly if applied to large, multi-plant complexes. Moreover, such a detailed study is not always necessary to identify the major areas of risk reduction at the plant level. In the process of evaluating a proposed installation for major risks, a screening approach to risk assessment was evolved – **Level 1 risk screening** methodology.

1.3.1 Risk Screening

A risk screening is performed to help orient the team to the possible type of process/loss-of-containment hazards at the facilities, and areas with the greatest potential consequences. The risk screening incorporates elements such as identification of chemical hazards through review of material safety data sheets (MSDSs), material inventories, incident reports, etc.

However, the screening also includes some consequence analysis based on worst-case incident scenarios for the more hazardous materials. This is done with the application of comprehensive consequence analysis model packages such as ALOHA^{TM}, and PHAST®. The results, in the form of hazard zones, provide a benchmark for estimating the severity of impacts during the risk-ranking step.

The risk ranking matrix encompasses both dimensions of risk, namely, probability (likelihood) and consequence (severity). To apply the risk matrix, each identified process hazard meeting a set of minimum criteria in rated based on potential impact relative to other hazards. At the same time, the likelihood of having an incident with the potential for a defined severity is also estimated. Subsequently, each incident is classified according to relative risk level using the risk ranking matrix.

As a result of the risk screening is the risk reduction recommendations provided by the review team. Risk reduction measures can take on many forms, including procedural changes, the addition/deletion/substitution of instruments, other design modifications, training, operating restrictions, facility or equipment relocation, or more detailed risk assessment. Because each potential hazard has been classified according to risk level, the appropriate priority for implementation of risk reduction measures is provided.

The risk screening methodology is not rigid, and can be modified to suit a company's particular needs. For example, the above primarily addresses acute risk concerns. However, chronic risks can be identified by incorporating an Industrial Health Assessment module.

1.3.2 Consequence Analysis Model Packages

There are a number of software packages available in the industry developed by private companies with varying degrees of sophistication and price. The most widely used consequence analysis software are ALOHA, PHAST, EFFECTS, and etc. **Table G3-1** compares some of the most common modelling packages used in consequence analysis:

Table G3-1 Common Modelling Packages Used in Consequence Analysis

Name	ALOHA™	PHAST™	EFFECTS	TEREX
Sponsor	National Oceanic and Atmospheric Administration (NOAA) U.S. Environmental protection Agency (EPA)	DNV Technica	TNO Department of Industrial Safety, Netherlands	T-SOFT, Czech
Application	➢ Rapid prediction of source strength and dispersion during emergency response ➢ Generates a variety of scenario-specific output, including threat zone pictures, threats at specific locations, and source strength graphs. ➢ Calculates how quickly chemicals are escaping from tanks, puddles, and gas pipelines – and predicts how those release rates change over time. ➢ Models many release scenarios: toxic gas clouds, BLEVEs, jet fires, vapor cloud explosions, and pool fires. ➢ Evaluates different types of hazard (depending on the release scenario): toxicity,	➢ Phast is the industry standard tool for process hazard analysis. ➢ It is used to estimate, understand and visualize the effects from loss of containment scenarios. ➢ Comprehensive hazard analysis facilities to examine the progress of a potential incident from the initial release to its far-field effects. ➢ Predict all possible complex consequences from possible release of hazardous material. ➢ PHAST includes a wide range of models for discharge and dispersion as well as flammable, explosive and toxic effects.	➢ Assess the physical effects of accidental releases of toxic or flammable chemicals. ➢ Detailed modelling and quantitative assessment of release rate pool evaporation, atmospheric dispersion, Vapour Cloud Explosion, Combustion, heat radiation effects from fires etc.	➢ Simulating concrete risk sources in industrial processes ➢ Civil crisis planning where the main threat is a terrorist attack ➢ Army modelling for an attack with hazardous substances, chemical and combat weapons for determining the area struck ➢ The rapid determination of the extent of the threat and the realization of subsequent measures for population protection, especially the area struck and the necessary evacuation. ➢ Basic modules to assess accident events:

Name	ALOHA™	PHAST™	EFFECTS	TEREX
	flammability, thermal radiation, and overpressure. ➢ Models the atmospheric dispersion of chemical spills on water.			-Dangerous chemical substances (TOXI, UVCE, FLASH FIRE) -Explosive systems (TEROR) -Toxic agents (POISON)
Limitation	➢ ALOHA's concentration estimates (Gaussian assumption) can be less accurate when any condition exists that reduces mixing in the atmosphere. ➢ Concentration patchiness, particularly near the source makes the estimate unreliable. ➢ ALOHA does not account for some effects such as: - Byproducts from fires, explosions, or chemical reactions - Particulates - Chemical mixtures - Wind shifts and terrain steering effects - Terrain - Hazardous fragments	➢ PHAST has limitations on the source term for maximum temperature and cannot deal with temperatures above 600°C.		
Input	➢ Scenario information (e.g. chemical, weather conditions, and the type of release)	➢ Basic information about storage or process conditions and material properties		
Output	➢ Graphical outputs	➢ Graphical or report outputs	➢ Graphical outputs	➢ Situation of modelling

Name	ALOHA™	PHAST™	EFFECTS	TEREX
	➢ GIS-Compatible output (ALOHA's threat zones can be displayed on maps)	➢ GIS-Compatible output	➢ Reports ➢ Contours on map (incorporated GIS tool)	➢ Characteristics of a danger ➢ Marking out a danger zone ➢ GIS-compatible
Special Feature	➢ A part of CAMEO® software suite. ➢ Large chemical library (approximately 1,000 common hazardous chemicals) ➢ Pre-accident modelling	➢ Integrated material property database containing more than 1,600 pre-defined pure component chemicals	➢ Complete and industry standard chemical database, containing over 2200 toxic and flammable values and all thermodynamic properties. ➢ Pre-accident modelling ➢ Modelling the effects of accidental release of hazardous substances	➢ Post-accident modelling

1.3.3 Risk Evaluation

Risk is evaluated based on the regulations set by Department of Environment (DOE) Malaysia. Above $1x10^{-3}$ frequency of fatality per year, risk is intolerable and necessary action is required to minimize the risk. Below $1x10^{-6}$ frequency of fatality per year, risk is generally acceptable. Between the intolerable and generally acceptable regions, there is a need to demonstrate risk as low as reasonably practicable (ALARP). Risk within ALARP region should be reduced with subject to balance in cost benefit analysis.

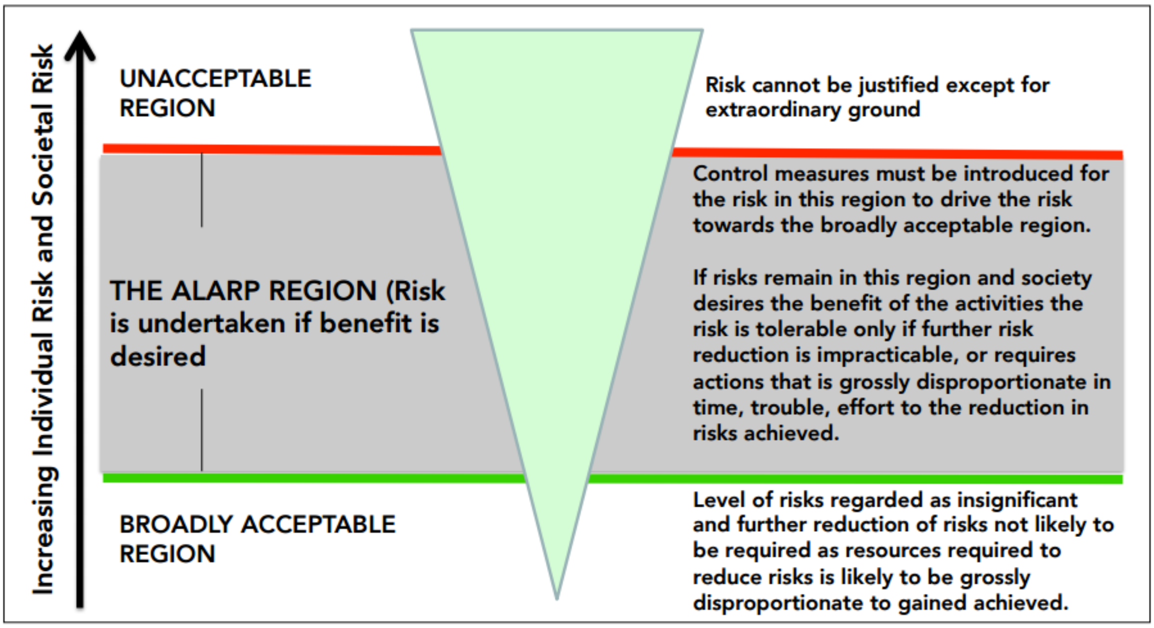

Figure 2 ALARP Criteria

Individual Risk

Individual risk can be thought of as the risk to a person being at a specific location all the time. The population is not taken into account in the individual risk calculation. The risk is measured as a probability of fatality in a year. Risk Contours connect points of equal risk around the source of hazard, and are usually represented in orders of magnitude.

Figure 3 Example of Individual Risk Contours

Societal Risk

Societal Risk provides a technique to measure actual risk to a given population at or near a source of hazard. A common measure of societal risk is the FN Curve. FN Curve provides a result of Likelihood or Frequency (F) of fatal events occurring causing a certain Number of Fatalities (N), within a given period of time, usually set for 1 year. The Societal Risk F-N curve is a plot of cumulative frequency versus consequences which is expressed as number of fatalities. Normally a logarithmic plot is used, because of the frequency and number of fatalities range over several orders of magnitude.

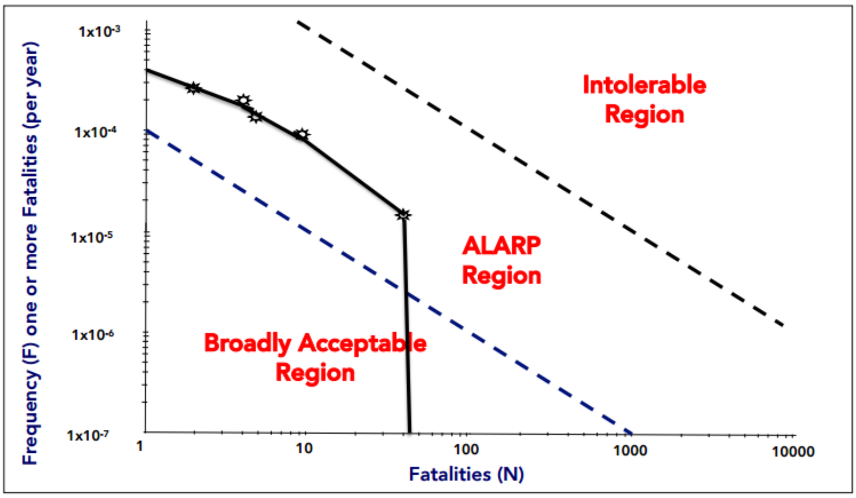

Figure 4 Example of Societal Risk F-N Curve

Tolerability Criteria in Malaysia

Location Specific Individual Risk (LSIR) is used as a measure of individual risk. This means that the risk is not influenced by population. The upper limits for LSIR are as follows:

Residential receptors	$1x10^{-6}$ fatalities per year
Industrial receptors	$1x10^{-5}$ fatalities per year
Voluntary risks (workers on site)	$1x10^{-3}$ fatalities per year

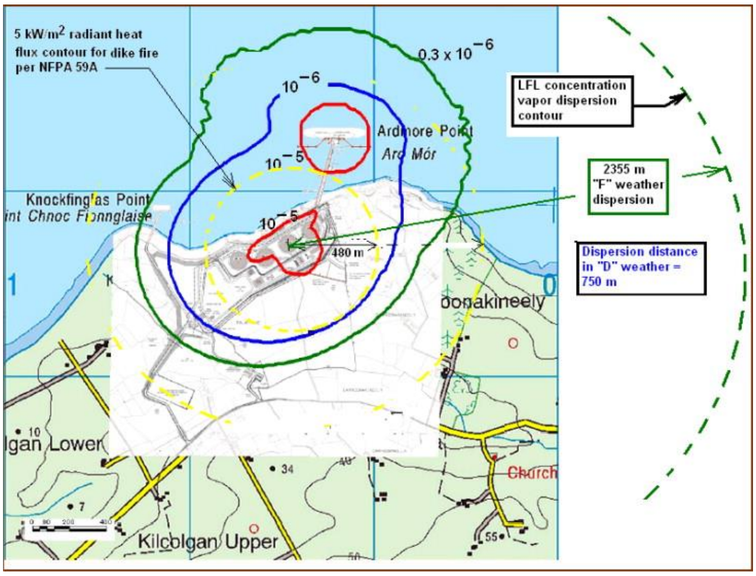

Figure 5 Risk Tolerability (Illustration)

References

DNV GL. (2014). Process hazard analysis/consequence analysis - *Phast software*. [Brochure]. Accessed on June 6, 2017 at: https://www.dnvgl.com/services/process-hazard-analysis-phast-1675

Witlox, H. W. (2010). *Overview of Consequence Modelling In the Hazard Assessment Package Phast.* American Meteorological Society.

Stickles, R.P. and Ozog, H. (2002). *Facility Major Risk Survey*. ioMosaic Corporation. Accessed on June 5, 2017 at: https://www.chemicalprocessing.com/assets/Media/MediaManager/Facility_Major_Risk_Survey.pdf

TNO. (2005). *EFFECTS 9* [Brochure]. Retrieved June 8, 2017, from https://www.tno.nl/media/1548/effects-9-brochure2.pdf

Jakub, R., Lucie, J., David, S., & Adamek, M. (2013). *Utilization of GIS for needs of Environmental Risks Presentation from the Perspective of Industrial Accidents.* In Nakov, O., Voznak, M., Vasek, V., & Naaji, A. (Eds.), Recent Advances in Computer Science. Greece: WSEAS Press.

Bhattacharya, R. and Kumar, V.G. (2015). *Consequence Analysis for Simulation of Hazardous Chemicals Release using ALOHA Software.* International Journal of ChemTech Research. 8(4), pp 2038-2046.

Ristvej, J. and Lovecek, T. (2011). *Software Products for Risk Assessment.* In Demiralp, M., Bojkovic, Z., & Repanovici, A. (Eds.), Mathematical Methods and Techniques in Engineering and Environmental Science. Greece: WSEAS Press.

Abidin, N. A. Z., Ariffin, M. A. and Rusli, R., (2011). *Preliminary risk assessment for the bench-scale of biomass gasification system*, National Postgraduate Conference, Kuala Lumpur, 2011, pp. 1-6. DOI: 10.1109/NatPC.2011.6136262

EPA. (2016). *ALOHA Software – ALOHA fact sheet*. Accessed on June 2, 2017 at: https://www.epa.gov/cameo/aloha-software.

Sliacka, B., Majlingova, A., & Markova, I. (2015). *Results of Major Industrial Accidents Modelling Tools Comparison.* Advances in Fire, Safety and Security Research 2015.