A Three-Decade Review of Risk Management Efforts in Hong Kong

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Hong Kong is one of the most densely populated cities in the world. With scarcity of land resources and ever increasing population, developments in the vicinity of hazardous installation are inevitable and they remain a major challenge for Hong Kong over the past few decades, necessitating specific measures to minimize such risks.

This paper provides an overview of Hong Kong's policies in the past three decades for managing the risks from hazardous installations and other activities relating to handling of hazardous materials, the statutory and administrative control frameworks, and the coordinating efforts made by the Government authorities with a view to controlling such risks to acceptable levels. The Coordinating Committee on Land-use Planning and Control Relating to Potentially Hazardous Installations (CCPHI), a Government-led administrative entity to regulate hazardous facilities storing quantities of hazardous materials in excess of specified threshold quantities, was established in 1986. CCPHI aims to require all Potentially Hazard Installations (PHIs) in Hong Kong to have their risks quantitatively assessed and to have their action plans and emergency response plans compiled and implemented. The lands in vicinity of these PHIs should also be scrutinized and be properly planned to avoid incompatible land uses and developments.

Fine points are highlighted on the significance of mandating a high-fatality cut-off in the Hong Kong Government Risk Guidelines, lessons learnt from a judicial review on a hazard assessment study under the statutory Environmental Impact Assessment regime, and the success stories in reducing risks of these hazardous installations amid plaguing land shortage. Looking ahead, the paper articulates Government's plan to replace risky operations with less hazardous options, and our employment of smart and innovative technologies in risk management and for information dissemination.

Throughout some 30 years of concerted efforts by the concerned Government departments, risks from all PHIs are now in compliance with the Hong Kong Government Risk Guidelines. The Government is committed to continuing with these good efforts to ensure the public are well protected from undue risks.

Keywords: Hong Kong, Risk Guidelines, Government's role, Requirements, EIA, public engagement.

Land Resources of Hong Kong

Hong Kong is one of the most densely populated cities around the globe. The land population density i.e. excluding marine population and area of reservoirs, as at the end of June 2019 stood at 6,880 persons per square kilometre that the land area of HK is about 1106 square kilometre (C&SD, 2019). The topography of HK is extremely rugged and there is little natural flat land, with a series of ridges making up the backbone of the territory. Owing to rugged terrains, only about one-fourth is built-up area, the remaining is being not-for-development or non-built-up area consisting mainly of country parks, wetland, reservoirs, etc. (TFLS, 2018) Scarce land resources turns into one of the key issues to the public, and feasibility of developments in the vicinity of hazardous installation have been investigated proactively by stakeholders of the society. The land use compatibility has become a major growing concern over the past few decades.

Figure 1 A board view of Hong Kong with hilly terrain (photo taken by Matthew HUNG)

Risk Management Regimes

Major Industrial Hazards

The Hong Kong Government (the Government) imposes special controls on industrial installations which use hazardous materials in quantities exceeding specified threshold quantities, such installations are designated as Potentially Hazardous

Installations (PHIs). (EPD, 2019) The threshold quantity generally follows the specification in the UK Notification of Installations Handling Hazardous Substances Regulations 1982. Some of the threshold quantities have been suitably amended in the light of local conditions and developments, and these PHI thresholds may also be amended in the future where necessary. The threshold quantities for the common types of dangerous goods (DG) in HK are as follows:

- LPG storage facilities (in oil terminals, bulk stores & substitute natural gas plant, etc.): 25 tonnes or more;
- Town gas installations: 15 tonnes or more;
- Chlorine stores (mainly at water treatment or any storage in works): 10 tonnes or more; and any one tonne drums;
- Petrol or naphtha stores (mainly at oil depots): 10 000 tonnes or more;
- Liquid oxygen storage (mainly at industrial gas facilities): 500 tonnes or more.

In addition, all explosives factories and Government explosives depots are classified as PHIs.

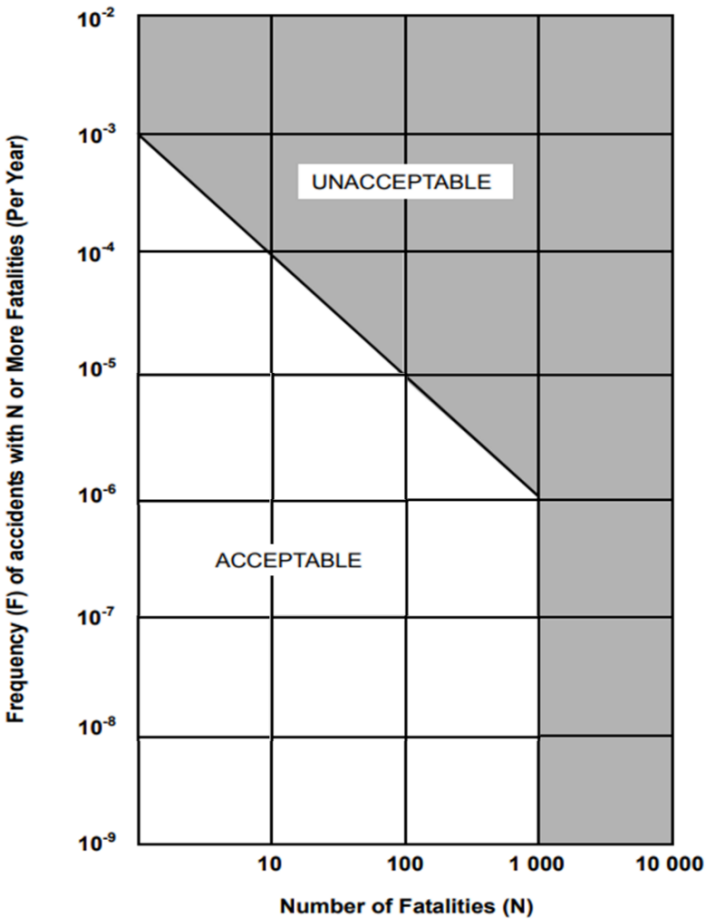
Figure 2 Locations of Existing PHI Sites as at March 2020

Risk Management Policy

The Government's policy is to minimize potential risks associated with a PHI to internationally acceptable levels by controlling the siting of PHIs and the land use in the vicinity, and by requiring the installation to be constructed and operated to specified standards. The Coordinating Committee on Land-use Planning and Control relating to Potentially Hazardous Installations (CCPHI) was established in December 1986 to coordinate Government actions in relation to HK PHIs. CCPHI is an administrative control mechanism to oversee the land-use and planning of PHIs across Hong Kong. For every PHI, Consultation Zone (CZ) is delineated, within which proposed development that will result in an increase in the number of living or working population will be referred to CCPHI for consideration, and planning restrictions may need to be imposed on future developments. (PlanD, 2019) CZ could be extended up to 1 km in radius at maximum for existing PHIs. Although PHI related control framework is administrative in nature, advice from CCPHI will play a vital role in relevant statutory framework and land administration (e.g. application for change of land use, disposal of lands, etc). It shall be noted that administrative (i.e., non-statutory) framework is essentially different from the Environmental Impact Assessment Ordinance (EIAO) regime, which will be detailed in later section of this paper.

Early in 1990, interim risk guidelines (RG) in both individual risk and societal terms were published and adopted by the Government. This set of guidelines applied to new installations, expansion of existing installations and new developments in the vicinity of existing installations only. The maximum level of involuntary off-site individual risk associated with PHIs should not exceed 1 in 100,000 per year i.e. 1 x 10^{-5}/year and societal risk guideline is illustrated in Figure 3. It can be seen that the societal RG is broadly divided into ‘acceptable’ and ‘unacceptable’ regions, and 1000 fatality must not occur at a frequency greater than 1 in a billion years. (Reed, 1992)

Figure 3 Interim Societal Risk Guidelines for Acceptable Risk Levels



Following the interim RG, a new set of RG have been developed and promulgated in 1993 by the Government for assessing the off-site risk levels of PHIs (i.e., not applied to personnel at the PHI) in terms of individual and societal risks which are currently applied, with details as below:

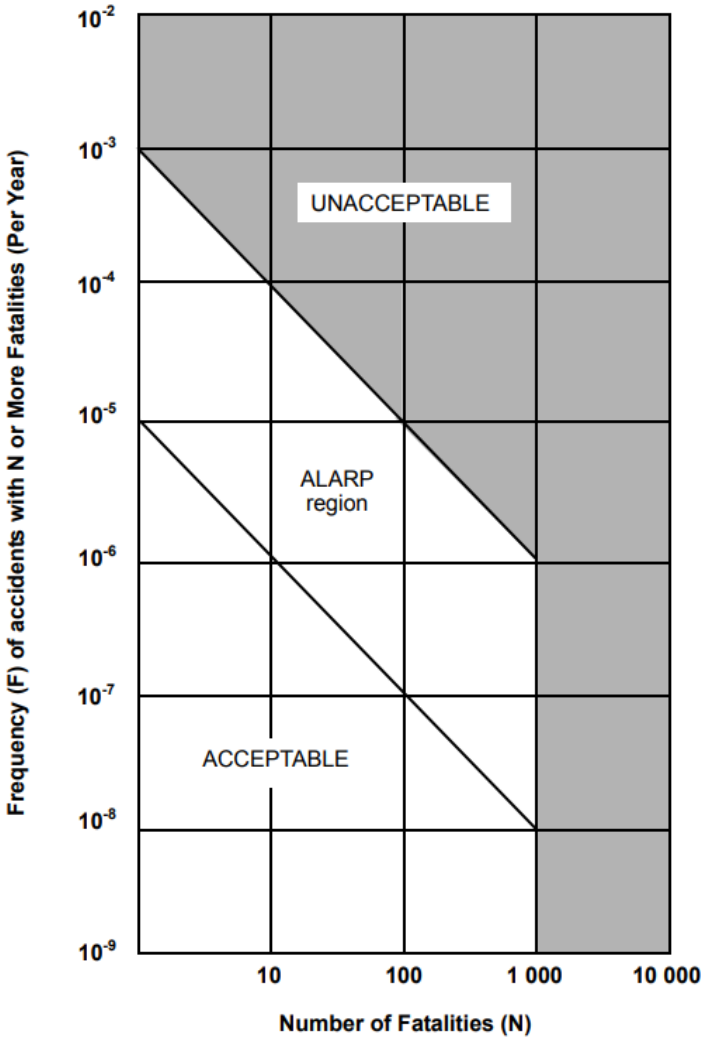
Individual risk is the predicted increase in the chance of death per year to an individual who lives or works near to a PHI. As individual risk varies with location, it is often shown on a map of the area surrounding a PHI as contours of equal risk which decrease according to distance from the PHI. Moreover, realistic occupation factors or presence factors in relation to exposure of a person to the PHI should also be taken into consideration to determine the individual risk for comparison with the RG (also known as Personal Individual Risk). The individual RG requires that the maximum level of involuntary off-site individual risk associated with PHIs should not exceed 1 in 100,000 per year i.e. 1×10^{-5}/year.

Societal risk expresses the risks to the whole population living near a PHI. The current societal RG is presented graphically in Figure 4. The acceptability of societal risk is judged against the frequency and number of deaths of potential incidents at the PHI. The societal RG is expressed in terms of lines plotting the frequency (F) of N or more deaths in the population from incidents at the PHI. Two FN risk lines are used in the societal RG to determine 'acceptable' or 'unacceptable' societal risks. Given the notably high population density, the Government gives special attention to the high consequence events. In order to avoid major disasters resulting in more than 1000 deaths, there is a vertical cut-off line at the 1000 fatality level extending down to a frequency of 1 in a billion years, in a fashion similar to the interim RG. This cut-off limit is particularly important to Hong Kong to prohibit PHIs from building close to populated areas, and vice versa. The very low probability of scenarios causing more than 1000 people fatalities implies that it does not never occur, unless the cumulative frequency for the severity of accident on the F-N curve is less than 1×10^{-9} per year, which is considered to be such a low frequency that it is effectively non-credible. The Government aims at using this set of risk guidelines to avoid major disasters whenever possible.

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.

The RG apply to both new and existing installations, as well as expansion of existing installations and new development in the vicinity of existing installations.

Figure 4 Current Societal Risk Guidelines for Acceptable Risk Levels



Under the CCPHI framework for controlling PHI, a document called the HA-PS-AP is required to be compiled by PHI operators and relevant Government authorities, and be endorsed by the CCPHI before the PHIs can be put to operation.

Hazard Assessment (HA) is a technical study on the levels of individual and societal risks associated with a PHI. It is required to identify potential incidents at the PHI and calculate the frequency and consequences of each incident. The HA shall assess the risks posed by the PHI on the present and future population in its vicinity, and to determine what actions can be taken to reduce such risks. Depending on the findings and recommendations of the HA, practicable and cost-effective measures will be taken to reduce risk or contain risk at its present level.

Planning Study (PS) is a study to examine the present and future land use and development proposals in the neighbourhood of each PHI, and to advise on the necessary planning considerations and development control within the CZ of the PHI, to ensure that the existing and future developments can be protected from being exposed to unacceptable risk caused by the respective PHI

After the completion of the HA and PS, Action Plan (AP) will be prepared by the Government setting out the actions required to bring the risk to as low as reasonably practicable level. The AP will set out various measures to implement the recommendations of the PHI studies, typical measures include physical and operational improvements to the installation, special planning and development control, and immediate administrative and emergency measures.

This requirement brought the implementation of cost-effective risk mitigation strategies into effect including:

- provision of plant safety systems, for example, containment and absorption systems have been installed in chlorine stores at water treatment works;
- control of residential development near PHIs; and
- PHI relocation from urban sites to sites in less populated areas.

Figure 5 One of the LPG/Oil terminals on Tsing Yi Island, Hong Kong (photo courtesy of Edmund TSUI, Highways Department of HKSAR)

Another Framework for Hazard Assessment

The HK Environmental Impact Assessment Ordinance (EIAO) was enacted in 1997 and came into operation in 1998. As stipulated in the Technical Memorandum of EIAO, a Hazard to Life Assessment, also known as Hazard Assessment (HA), is required to be conducted for designated projects under EIAO. In contrary to the administrative CCPHI framework, HA required under EIAO is a statutory requirement. If facilities manufacturing, storing, using, or transporting of dangerous goods (DGs) i.e., not limited to PHI, and risk to life is a key issue with respect to the RG, HA shall be conducted. The objective of the assessment is to evaluate the residual risks posed to the public. Residual impacts refer to the net impacts after mitigation, taking into account the background conditions and the impacts from existing, committed and planned projects. When the residual impacts pose an unacceptable risk to life, they are considered as key concerns. The HA shall consider the occurrence frequency of hazardous events, as well as the severity of the respective consequences. Any practicable and cost-effective risk mitigation measures should also be identified and assessed to mitigate the risk to As Low As Reasonably Practicable (ALARP) if required.

It should be noted that HA requirements under the EIAO may differ from CCPHI requirements. For example, HA for dangerous goods stores with inventory below CCPHI thresholds may still be required under the EIAO. Besides, risk associated with existing dangerous goods facilities/ operations (i.e. items exempted from EIAO) would not be required to be re-assessed unless they are involved in EIA studies under the EIAO. It shall be noted that onsite transport activities of DGs related to PHI should be considered in the assessment for comparison against the RG.

Responsibilities of Government Departments for Hazard Assessment under the EIAO

Annex 22 of the Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM) defines the authorities for hazard assessment under the EIAO. Director of Electrical and Mechanical Services (DEMS) is the authority for hazard assessment of "fuel gas" dangerous goods defined in the Gas Safety Ordinance (GSO), namely town gas, liquefied petroleum gas (LPG), natural gas or any mixture of such gases whether in the form of a liquid or vapour. Director of Environmental Protection (DEP) is the authority for hazard assessment of "other dangerous goods", i.e. all dangerous goods defined in the Dangerous Goods Ordinance (DGO) but not covered by the GSO. These "other dangerous goods" are also referred to as "non-fuel gas" dangerous goods.

Table 1 Relevant Authorities for Hazard Assessment

Source of Risk	Authority
The manufacture, storage, use, or transport of dangerous goods (DGs):	
- Fuel gas DGs (Note 1)	DEMS
- Other DGs (Note 2)	DEP

Note:

1. Defined in the Gas Safety Ordinance (Cap. 51).
2. Defined in the Dangerous Goods Ordinance (Cap. 295), but not covered by the Gas Safety Ordinance (Cap. 51).

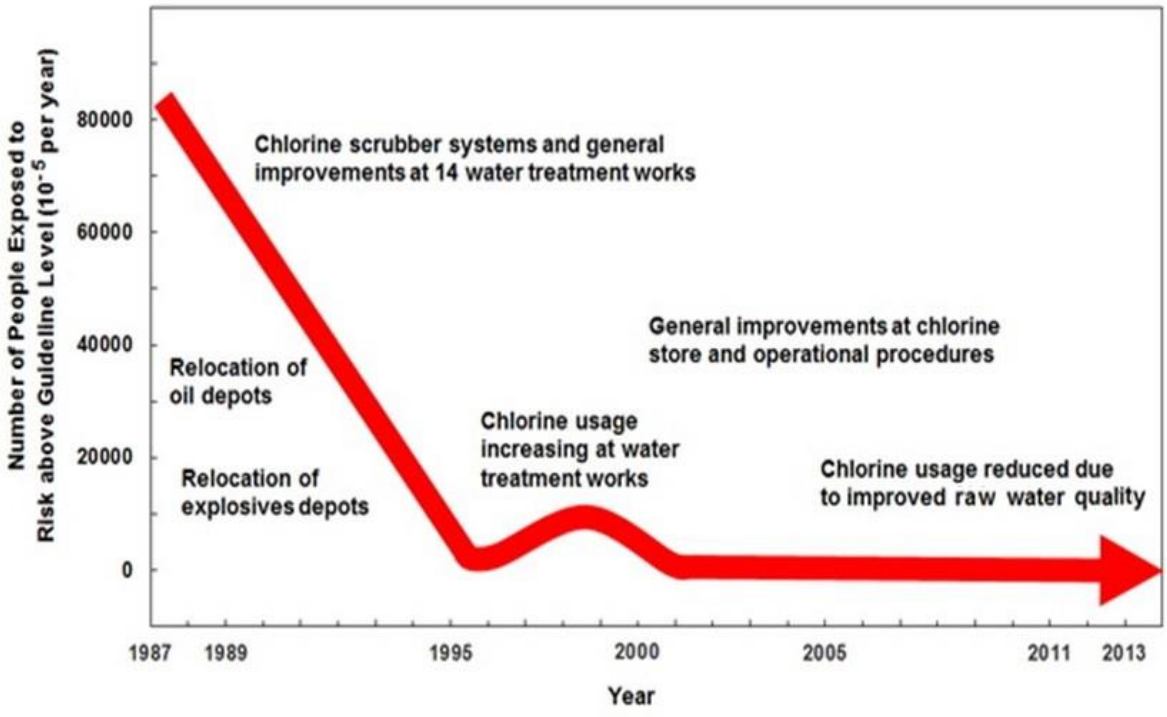
It is important to note that DEP shall take advice from relevant authorities during the EIAO process, including Mines Division of Civil Engineering and Development Department (CEDD), the licensing authority for category 1 dangerous goods (explosives and blasting agents defined under DGO), as well as Marine Department on "marine matters" which may involve marine transport of dangerous goods. The Government is dedicated to coordinate the efforts from all relevant authorities with a view to controlling potential risks to acceptable levels.

Success Stories, Lessons Learnt and Future Endeavours

Risk Reduced for Thousands of People

Back in 1987, the year right after CCPHI established, the number of people exposed to risk above the level of 1 x 10^{-5} per year due to PHI was about 83000. With the risk management policy support, the Government took significant steps towards implementing practicable measures both in administrative and statutory framework such as installation of scrubber system at water treatment works, relocation of oil and explosives depots. There was a sharp decline in risk exposure in eight years, the people at risk was reduced to about 1500 in 1995, about 98% reduction. Owning to natural population growth, water usage was increased and so for the chlorine usage at water treatment works for drinking water disinfection, the number of people at risk slightly went up to 8000 around 1998-1999. Through constant efforts in risk control and monitoring, and improved raw water quality and operational procedures in disinfection, the people exposed to risk of 1 x 10^{-5} per year or higher has been reduced down to zero in 2000. (EPD, 2019) It can be concluded that all PHIs are in compliance with the Hong Kong Government Risk Guidelines at present. The Government is committed to continuing the efforts to ensure the public are well protected from undue risks.

Figure 6 Risk Reduced for Thousands of People



Replacing Risky Operations

Explosives are commonly used in tunnel construction and cavern formation in Hong Kong, and explosives are normally stored in Government-managed storage facilities for on-demand distribution to project uses. One of the former Government explosives depot that was a PHI was located on Stonecutters Island where was closer to urban areas. In consideration of safety and land use development potentials, the Government decided to construct a new Government explosives depot in a remote site and replace the one on Stonecutters Island. The new depot at Kau Shat Wan was commissioned in 1997, located in a bay between Discovery Bay and Mui Wo on Lantau Island not accessible by land. (ISD, 1998) The depot is located inside caverns, with blast walls embedded into rock mass, so as to prevent sympathetic detonation in neighbouring caverns. It achieves to

further reduce the risk to the public due to the storage of explosives. A separate paper by EPD (Reed, 1992) outlines of details on relocation of other PHIs (e.g. oil terminals) in Hong Kong in the 1980s and early 1990s.

Currently in Hong Kong, drinking water disinfection process relies on liquid chlorine which is transported and stored in 1 tonne liquid chlorine drums or 50 kg liquid chlorine cylinders. To endeavour eliminating the risk from transport and storage of liquid chlorine at water treatment works (WTW), the Government has made joint efforts to explore alternatives in drinking water disinfection recently. Thanks to advancement of membrane electrolysis technology, chlorine generation facilities are now more efficient, compact in design and financially viable. Water Supplies Department (WSD) carried out a study on generation of chlorine using membrane electrolysis, and revealed the feasibility to install chlorine generation facilities in water treatment works to replace the liquid chlorine operations. (WSD, 2019a) In gist, the chlorine generation process proposed is to generate chlorine gas by electrolyzing synthetic brine through electrodes separated by membranes. Chlorine gas will be generated according to actual demand e.g., water quality and quantity, and will then be consumed immediately upon generation. Undoubtedly, storage of liquid and gas chlorine is no longer required after the replacement of disinfection facilities (including testing and commissioning), the chlorine transport and storage hazards could be eliminated.

Other water disinfection technologies include ozonation and biological filtration in Tai Po and Ngau Tam Mei Water Treatment Works. Likewise, ozonation, deep bed biological filtration and ultra-violet (UV) would be adopted in Sha Tin Water Treatment Works after the renovation. These measures can reduce the amount of chlorine required and hence potential hazard to life impacts. (WSD, 2018)

Figure 7 Typical chlorine drums used in Hong Kong (WSD, 2015)

Lessons Learnt from Judicial Review of HA under EIAO

In 2002, it was the fourth year since the EIAO took effect, the decisions of the Director of Environmental Protection (DEP) under the EIAO were subject to judicial review (JR) in relation to a hazard assessment for a Permanent Aviation Fuel Facility (PAFF) for the Hong Kong Airport. The Hong Kong Airport Authority (HKAA, the project proponent) proposed to construct the PAFF which was confirmed to be a non-PHI facility, and an Environmental Impact Assessment report (the EIA report) was prepared and submitted for DEP's approval. The proponent was informed in June 2002 of the suitability of the report for public comment and for comment by Advisory Council Environment (ACE), an official views gauging entity to advise the Government on environmental matters, between 14 June and 14 July 2002. During the period, a private steel mill company, operating a steel mill sited in some distance to the proposed PAFF site, wrote its letter of complaint on 13 July 2002 to DEP. ACE met to consider the EIA report and all public comments and declared that it was satisfied that the risk was within

acceptable levels and endorsed the EIA report, then the EIA was approved and an environmental permit was granted by the DEP in August 2002.

The major issue of grievance by the private company was about dismissal of one hazardous scenario in the HA report, which is the catastrophic failure of one of aviation fuel storage tanks with an instantaneous or almost instantaneous loss of 100% of the tank's fuel (100% loss scenario) that may result in significant overtopping of the bund and fatalities in the steel mill in the vicinity of the proposed PAFF site. This hazardous scenario was identified in the EIA report, but its likelihood was considered to be extremely low and the scenario was not required to be quantitatively assessed in the HA report by proper exercise of professional judgment.

On the contrary, the private company challenged the EIA report did not meet the requirements of the EIA Study Brief (SB) and TM to "(i) identification of all hazardous scenarios associated with the marine transport, jetty transfer, tank farm storage and pipeline transfer of aviation fuel, which may cause fatalities; (ii) execution of a QRA expressing population risks in both individual and societal term.", because the 100% loss scenario was not assessed in the QRA. The private company applied to challenge the decisions of the DEP to approve the report and grant the permit through judicial review applications. There were altogether three applications: the first two were dismissed by the Court of First Instance and Court of Appeal in 2003 and 2005 respectively; but the last one was upheld by the Court of Final Appeal in 2006. In accordance with the Court of Final Appeal order, the granting of environmental permit with conditions to the HKAA was quashed.

After the Court of Final Appeal (CFA) judgement, hazardous scenarios identification will need to be rigorously considered in all HA. The argument that an accident is thought to be unlikely no longer stands, instead, hazard assessment needs to assess accidents within the credible frequency range in the risk guidelines (i.e. greater than 1×10^{-9} per year). Any events that were found to have a frequency lower than 1×10^{-9} per year may nevertheless be excluded from further analysis. It may be noted that the same cut-off frequency of 1×10^{-9} per year is also adopted in the Netherlands. In case there are multiples of such low frequency events, the aggregate frequency of these events shall further be evaluated and confirmed their applicability in the assessment. This approach has been stringently followed in the subsequent EIA studies such as in the assessment of use of explosives, handling of liquid chlorine containers, and operations in oil terminals, etc.

Figure 8 Hong Kong's Permanent Aviation Fuel Facility (PAFF) (photo courtesy of Hong Kong & China Gas Company Limited)

Smart and Innovative Technologies

Three-dimensional (3D) environmental impact assessment was introduced in early 2000s as public engagement tools, so as to engage individual on major proposals and assist in understanding the project and potential issues through the use of 3D interface. The tool in 3D models are provided with various coloured illustrations, graphics or multimedia images or videos, the public can readily visualise and compare the advantages and disadvantages of different situations including baseline conditions, alternative options, possible impacts and feasible mitigation measures.

Recent advances in information technology bring about new perspective in the 3D EIA, particularly the 5G technologies which realise the potential to interact and to connect to multiple devices. EPD is now exploring the possibility to make use of these new IT technologies in connecting the public and the assessment scenarios seamlessly. One of the aims is to allow the public experience virtual environment that are capable of communicating with assessment models, augmented reality, 360 degree virtual reality and movies through motion sensing system. Hazard to life aspect will be incorporated into the system as well, for instances, hazard effect distances, failure probabilities and selection of mitigation measures. The user will be able to interact with the scenes, features and elements projected in the virtual space.

By experiencing the environmental issues virtually such as conceivable future scenarios, it would be easier for the public to understand projects and issues, and to offer suggestions, solutions, alternatives or even innovative measures. This interactive platform not only increases the transparency of impact evaluation process, but also facilitates efficient communication. This new system also aims to promote continuous public involvement and stakeholder engagement. The application is being developed and would be completed in early 2020s.

Conclusions

The development and application of Hong Kong risk management on hazardous installations in recent 30+ years were shared in this paper. Principally, the Government aims to control and reduce the potential risks to acceptable levels and to avoid major disasters under both administrative and statutory regimes, the details of these frameworks are elaborated. As Hong Kong is a highly populated city, various difficulties are encountered in balancing the interest of the public at large and the risk concerns. Having said that, it is confirmed that all PHIs have been in compliance with the Hong Kong Government Risk Guidelines since 2000 through the continuous efforts of the Government, facilities owners and project proponents.

In order to further reduce potential hazards to the public, strategic examples such as replacement of risky operations using liquid chlorine in public facilities by onsite chlorine generation and relocation of PHI were illustrated. There were judicial review applications relating to a non-PHI facility project, the court cases and implications to current hazard assessment practice were summarised. The implementation of information technology in public engagement was also discussed, benefited from new technologies such as 5G, hazard assessment scenarios can be better illustrated. All in all, amid plaguing land shortages, the Government is committed to create a sustainable development environment and to assure compatible and safe land uses.

We look forward to Hong Kong's risk management experience and lessons learnt dovetailing with the 30th Hazards conference be shared among risk practitioners, regulatory authorities and relevant stakeholders.

References

[1] Census and Statistics Department (C&SD), Hong Kong SAR, Hong Kong in Figures, 2019 Edition.

[2] Task Force on Land Supply (TFLS), How to tackle land shortage?, April 2018.

[3] Environmental Protection Department (EPD), Hong Kong SAR, Risk Management of Potentially Hazardous Installations, March 2019.

[4] The Court of First Instance in The High Court for Judicial Review (CFI), Judgment for "Permanent Aviation Fuel Facility", 30 Sep 2003.

[5] The Court of Appeal in The High Court (CA), Judgment for "Permanent Aviation Fuel Facility", 18 Mar 2005.

[6] The Court of Final Appeal (CFA), Judgment for "Permanent Aviation Fuel Facility", Jul 2006.

[7] Reed, Tromp and Lam, "Major Hazards – Thinking the Unthinkable" Environmental Management, Vol. 16, No. 6, pp 715-722, 1992.

[8] Planning Department (PlanD), Hong Kong SAR, Hong Kong Planning Standards and Guidelines, November 2019.

[9] Reed, Stuart; Tromp, Fred; Lam, Alain, Environmental Protection Department (EPD), Hong Kong SAR, Environmental Management, Volume 16, Issue 6, November 1992.

[10] Water Supplies Department (WSD), Hong Kong SAR, Special Features: On-site Generation of Ozone Gas and Chlorine Gas, April 2019.

[11] Water Supplies Department (WSD), Hong Kong SAR, Tseung Kwan O Desalination Plant, April 2019.

[12] Water Supplies Department (WSD), Hong Kong SAR, Supplementary Project Information and Questions, August 2016.

[13] Environmental Protection Department (EPD), Hong Kong SAR, Link to 3D-EIA, https://www.epd.gov.hk/eia/english/3deia/index.html, Apr 2011.

[14] Information Services Department (ISD), Hong Kong SAR, Mining and Quarrying, Hong Kong Yearbook, 1998.

[15] Water Supplies Department (WSD), Hong Kong SAR, Drinking Water Quality Management System of Water Supplies Department, February 2018.

[16] Water Supplies Department (WSD), Hong Kong SAR, EIA report for In-situ Reprovisioning of Sha Tin Water Treatment Works - South Works, AEIAR-187/2015, 2015.

Short outline: This paper reviews the risk management policy in Hong Kong, problems, challenges, measures and achievements were discussed in detail. It aims to give readers a better understanding on the statutory and administrative (i.e., non-statutory) frameworks on hazard assessment requirements, covering the past, present and future risk management missions in the recent three decades.