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Lessons Learnt from the Great Kaohsiung Gas Explosions and Disaster Management for Tsing Yi Island with Fuel Tanks

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1. Introduction

Multiple gas explosions occurred in Kaohsiung, Taiwan about midnight on 31 July 2014 and early on 1 August 2014 [1-10]. The flame height was observed to be over 15 storeys in height. Miles of roads surface was broken and adjacent buildings were seriously damaged [11] as shown in Fig. 1. More than 300 persons were killed, lost or injured.

On 2 August 2014, another explosion occurred in a factory for polishing car components in Kunshan, Jiangsu, China. The explosion was caused by the contamination and suspending of metal dust inside the factory as reported [12-20]. In that incident, 71 were killed and 186 were injured [21-23]. The official report of this explosion and related aspects was not yet released. The labours reported that the extraction rate of the metal powder generated during polishing might not be adequate. In fact, the factory had been warned by the local authority to watch occupational safety and health issues before the explosion [21,23]. Despite a fire 2 months ago, the fire safety management plan was not clearly illustrated to the parties concerned. The workers were not aware that metal dust could lead to explosions [21,23]. In recent years, several explosions were reported in flour, saw dust and other storage plants [15-17]. The general public should be warned on such incidents. More staff training should be provided to handle such risks in the Mainland.

The explosion risk is always there, particularly in areas storing large amounts of fuel such as the Tsing Yi Island (TYI) [24-26] in Hong Kong. If an accidental fire occurred, the fire could be big and difficult to suppress [27,28]. Negative consequences including environment pollution and disturbance to normal business might come with that. Therefore, an emergency plan should be worked out carefully by the oil company, the Fire Services Department and the TYI district.

2. Tsing Yi Island

As raised before [29-31], residents on TYI [24] are worrying about the potential fire hazards of storing large volumes of flammables in fuel tanks on the island. Two reports released to the public [25,26] claimed that storing those fuel tanks in the areas is safe. However, the grounds for drawing such conclusion were not clearly spelled out. Perhaps, housing two fire stations on TYI is the solution at the moment. The existing fire safety systems in Hong Kong were developed based on the systems used by the UK years ago [27]. However, the Buncefield Incident [28] revealed the inadequacy of the systems to stop the fire and mitigate the impact on the community.

The deadly explosions in Kaohsiung [1] are a big lesson to learn. Such large-scale fires with explosions must be avoided to happen on TYI. If a big fire breaks out in oil tanks, the consequences will be disastrous. The government should alert the public to the importance of working out a disaster management plan.

As reported before [29], based on the data from literature [32], it is estimated [30,31] that the possible fire in burning the fuels stored at TYI can reach 250000 MW! The possible heat flux at nearby highways, residential buildings and schools can be up to 60 kW/m^2. Wind action will definitely facilitate fire spread! On top of the thermal impact, the fire ball and smoke plume can affect the people, vehicles and even the planes flying above. Environmental pollution due to the fire products and suppressing agents discharged will be very serious. The estimated design data on fire safety deduced from theory must be justified by experimental evidence to ensure that it works in a big fire.

3. Explosions in Kaohsiung

The Kaohsiung explosions were suspected to be due to the spillage of 4,000 kg to 10,000 kg propene along the culvert. The leakage was caused by corrosion of the supply pipes without proper maintenance [1,3-6,9]. A time chart of the explosion incident compiled from information reported in the news [1-8] is shown in Fig. 2. The incident is still under investigation with variations in the time frames reported in different news [1,3-6,9]. Key elements were identified for such disaster was claimed to be due to the negligence of relevant parties for various aspects [1-6,9,10].

The citizens reported “gas leakage” about 3 hours before the first explosion but all the relevant parties concerned could not identify what the “suspicious gas” was and determine the sources of leakage promptly. Meanwhile, the fire bridge was implementing the “standard

precaution strategy" such as applying water spray at those manholes with "white smoke" coming out, but without stopping the operation of pipelines in the area [1-6,9,10].

As Kaohsiung is an industrial city, the effective operation of industrial supply pipelines incurs lots of social and economic impact. Shutting down the irrelevant pipelines may lead to lots of claims on the decision maker due to the loss in productivity and related issues. Also, there are different pipelines owned by various companies. The respondents from those companies and officers from different departments failed to pinpoint the source of leakage quickly and even denied their responsibility before and after the incident. Pipelines were shut down 15 minutes before the explosion. Officers could not properly react to the citizens' queries who called for help very late. The experts were at the site and confirmed the "suspicious gas" to be propene just about 30 minutes and 5 minutes before the explosion respectively [1-6,9,10]. That means the explosion could be avoided or at least the possible consequences minimized if the specialists were notified earlier.

A "pressure drop" from normal pressure 400 Pa to 130 Pa in a propene supply pipe for a petrochemical plant was known well before the people acknowledged the "gas leakage" but the plant operator did not terminate the operation for checking and resumed the supply of propene to the pipeline [10]. Other stakeholders would think such action is business-orientated.

It was claimed in the news [33] that the problem was there for over a decade, because the culvert should not enclose any pipelines during installation, which was known and maintenance fee charged for years. The pipeline might be corroded and so chemicals leaked out [33].

4. Disaster Management

The general public should ask about the following fire safety issues, at least:

- Rigorous and holistic engineering solutions in the storage plants.
- Evaluation of the fire protection system performance with reference to all possible scenarios.
- Effectiveness of water curtains [34,35] to cover the related fire area and lower the radiative heat imposed on other area.
- Storage of higher amount of foam to prepare for disasters.
- Fire robots to fight against any big fires instead of sending firemen to the fire site.

Learning from the Kaohsiung explosion disaster, a proper management plan for handling big fires on TYI must be worked out immediately. Additional fire safety equipment, which can limit the impacts imposed on the adjacent areas, should be provided. If a fire breaks out, the consequences can be disastrous.

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(a) Road surface collapsed

(b) Fire engine overturned

Fig. 1: Damages caused by the Kaohsiung gas explosions (Photos taken by Su 2014)

Date	Time	Events
31 July 2014	19:00	First report of gas leakage [4].
	20:30 to 20:46	Numerous reports of gas leakage and “white smoke” spillage from drainage manholes; fire brigade sprayed water to dilute [4].
	20:49	Abnormal delivery pressure noticed by propene supplier but supply still in operation at lower rate [1].
	21:00 to 21:20	Flame observed from under sewers [5].
	21:30	Environmental department called for help [6].
	21:40	Gas flow along underground drainage determined by police [4].
	21:50	Environmental department collected gas sample on site [4].
	22:00	Fire plumes popped up from drainage manhole [5].
	22:19	Rich enough gas sample collected by environmental department [6].
	22:20	Gas companies confirmed no leakage from their pipelines [4].
	22:22	Manhole cover blown up; and diluted suspected gas by water spray [7].
	22:30	Special task unit on site [6].
	23:00	Massive explosion caused collapse of road surface [4].
	23:35	Normal propene supply resumed [8].
	23:50	Another massive explosion caused collapse of road surface [4].
	23:55	Leakage of propene confirmed [6].
	23:57	Massive explosion and fire along the road [2].
1 August 2014	00:30	Another massive explosion occurred [4].
	01:10	All related supplies from associated suppliers shut down [1].
	01:24	Sought support from military [1].
	01:36	All natural gas supplies shut down [1].
	03:00	Army arrived at the site [3].
	06:00	Fire was put out [3].

All information compiled from news [1-8].

Fig. 2: Time chart of the Kaohsiung gas explosions