11 HAZARD TO LIFE

Introduction

Background

11.1 The Stonecutters Island Sewage Treatment Works (SCISTW), with a design capacity of 1.7 million cubic metres per day, is one of the key components of the Harbour Area Treatment Scheme (HATS). At present, sewage collected from the urban Kowloon, Kwai Tsing, Tseung Kwan O and north-eastern Hong Kong Island is treated at SCISTW by chemically enhanced primary treatment (CEPT) before discharge into the western harbour through a submarine outfall.

11.2 To further improve the water quality at Victoria Harbour, the Government announced in May 2005 the proposal to implement HATS Stage 2 in two phases, namely Stage 2A and Stage 2B based upon centralized treatment at Stonecutters Island.

11.3 Under Stage 2A, a deep sewage conveyance system will be constructed to convey the currently untreated sewage from the northern and western areas of Hong Kong Island to Stonecutters Island. The existing chemical treatment facilities at the SCISTW will be expanded to cope with the projected flow and load under the ultimate development scenario for the whole of HATS catchment and to provide disinfection facilities for the sewage collected. Under Stage 2B, a new biological treatment plant on a site adjacent to SCISTW is proposed.

11.4 Part of the Stage 2A disinfection facilities (i.e. the advance disinfection facilities (ADF)) will be expedited for completion by 2009 to bring early improvement to the harbour water quality and to facilitate re-opening of the Tsuen Wan beaches as soon as possible. The proposed Project is to construct and operate new disinfection facilities (i.e. ADF) within the existing Stonecutters Island Sewage Treatment Works (SCISTW) in order to reduce the E. coli level in the chemically enhanced primary treatment (CEPT) effluent at SCISTW before discharging.

11.5 Following a robust and comprehensive evaluation exercise on the disinfection technologies for wastewater treatment works conducted under this Study, disinfection using sodium hypochlorite followed by dechlorination with sodium bisulphite has been nominated as the preferred technology for the proposed disinfection facilities at SCISTW. Under the current proposal, sodium hypochlorite solution will be purchased directly from off-site manufacturers, who will then deliver the product to SCISTW. No on-site generation of sodium hypochlorite solution is proposed.

11.6 In accordance with Clause 3.4.7 of the EIA Study Brief, a hazard assessment of manufacture, storage, use and transport of dangerous goods shall be carried out following the criteria for evaluating hazard to life as stated in Annexes 4 and 22 of the EIAO Technical Memorandum. Under the scope of the Project, only two dangerous goods (DG) classified under the Dangerous Goods Ordinance in Hong Kong, namely sodium hypochlorite and sodium bisulphite, are identified. There will be no on-site generation of sodium hypochlorite and sodium bisulphite in the Project and hence the risk of the dangerous goods manufacturing does not exist.

11.7 In addition, sodium hypochlorite solution will be purchased from off-site manufacturers rather than produced on-site by electrochlorination process; therefore, hydrogen, which is a by-product of the electrochlorination process, will not be involved in the Project. Based on the above, the potential risk of storage, use and transport of these sodium hypochlorite and sodium bisulphite are assessed in the hazard assessment for the Project under this section. Ferric chloride, which is a chemical used in the existing sewage treatment process at SCISTW (not involved in the Project), is considered in the hazard assessment only because its hazardous interaction with sodium hypochlorite and sodium bisulphite.

Legislations, Policies, Plans, Standards, and Criteria

11.8 As set out in Annex 4 of the EIAO TM, the risk guidelines comprise two components:

- *Individual Risk Guideline*: the maximum level of off-site individual risk should not exceed 1 in 100,000 per year, i.e. 1 x 10^{-5} per year
- *Societal Risk Guidelines* is presented graphically in **Figure 11.1**, in terms of the "frequency" (F) of "number deaths in the population" (N) from accidents at the facility of concern. There are three areas:
  - Acceptable, where risks are so low that no action is necessary
  - Unacceptable, where risks are so high that they should usually be reduced regardless of the cost or else the hazardous activity should not proceed
  - ALARP (As Low As Reasonably Practicable), where the risks associated with the hazardous activity should be reduced to a level "as low as reasonably practicable", in which the priority of measures is established on the basis of practicability and cost to implement versus risk reduction achieved.

General Description

11.9 A general layout of the proposed chlorination/dechlorination facility is shown in **Figure 11.2** and an aerial view of SCISTW and surrounding area is shown in **Figure 11.3**. The preliminary layout of the proposed dechlorination and chlorination plants are shown in **Figures 11.4** and **11.5**, respectively. The key elements of the proposed disinfection facilities include:

- *Chlorination system* - provision of a sodium hypochlorite solution storage facility and associated dosing system, including:
  - Six sodium hypochlorite storage tanks (8m in diameter, 12.5m in height, with capacity of about 533m^3) within a steel shed
  - One day-tank for sodium hypochlorite storage (capacity of about 100m^3)
  - Pipes in pipe-trenches
  - Switch room
  - Bund wall (2m in height)
  - ISO tank unloading area
  - Sodium hypochlorite barge unloading facility
- *Dechlorination system* - provision of a sodium bisulphite solution storage facility and associated dosing system, including:
  - Two sodium bisulphite storage tanks (6m in diameter, 6.2m in height, with capacity of about 170m^3)
  - Chemical feeding and transfer system
  - Bund wall (1.5m in height)
  - ISO-tank unloading area
  - Security fence and gate

11.10 The chlorination system would serve for both ADF Stage and Stage 2A of HATS. The capacity of the sodium hypochlorite storage tanks is designed to cater for the Stage 2A operation. One of the storage tanks would serve as stand-by tank and be kept unfilled during operation. Under Stage 2A, five of the storage tanks would be used with a maximum sodium hypochlorite solution storage on-site of about 2,665,000L. During the ADF Stage, the maximum storage amount for sodium hypochlorite solution on-site for the ADF operation is estimated to be about 1,800,000L. Only four of the storage tanks would be utilized.

11.11 Sodium hypochlorite solution (v/v 10-12%) will be purchased and delivered to SCISTW by sea or by road. For sea transport, a specially designed barge will be designated for delivery of sodium hypochlorite solution and the sodium hypochlorite solution will be unloaded at the berthing facility at SCISTW at an interval of 2 to 3 times a week. When weather or other conditions do not allow chemicals delivery by sea, the sodium hypochlorite solution will be delivered by road tankers.

11.12 The dechlorination system to be constructed under the Project would serve for ADF Stage only. The dechlorination system under the Project would be replaced by another dechlorination system next to a future chlorine contact tank under Stage 2A. Hence, the capacity of the sodium bisulphite storage tanks is designed to cater for design capacity of the existing SCISTW (i.e. flow served during the ADF stage). One of the storage tanks would serve as stand-by tank and be kept unfilled during operation. The maximum storage amount for sodium bisulphite solution on-site for ADF operation will be about 150,000L.

11.13 Sodium bisulphite solution (v/v 38%) will be purchased and delivered to SCISTW at an interval of 1 to 2 time(s) a week by road tankers and then unloaded to the storage tanks.

11.14 As seen in **Figure 11.2**, road tankers delivering different chemicals will travel along different routes, as follows:

- Road tanker delivering sodium bisulphite will travel to the dechlorination plant direct via Ngong Shuen Road and will not enter the SCISTW main compound
- Road tankers delivering ferric chloride will enter the SCISTW main compound via the main entrance located at northeast corner of SCISTW main compound, then travel along the road separating the existing sedimentation tanks and the sludge treatment facilities and then to the ferric chloride tank farm
- Any road tankers delivering sodium hypochlorite will enter the SCISTW main compound via another entrance located at southern part of the SCISTW main compound, then travel along the road near the Northwest Kowloon Pumping Station and then to the sodium hypochlorite storage tank farm

11.15 Other chemicals used in the existing sewage treatment process and stored on site include ferric chloride (storage amount: 1,900,000L), sodium hydroxide (storage amount: 7,500L), anionic polymer (storage amount: 16 tonnes) and cationic polymer (storage amount: 60 tonnes). Since the ADF operation will not involve these chemicals; the operations associated with these chemicals are not within the scope of the Project. The potential hazards of manufacture, storage, use and transport of these chemicals, which are not within the scope of the Project, are not considered in the current hazard assessment.

11.16 Apart from ferric chloride that would interact with sodium hypochlorite or sodium bisulphite to produce toxic gas (the risk of such interaction was assessed in this hazard assessment and presented below), sodium hydroxide, anionic polymer and cationic polymer does not have hazardous interaction with sodium hypochlorite or sodium bisulphite.

11.17 It should be noted that the proposed dechlorination plant located near the Chamber No. 15 is of temporary nature. When HATS Stage 2A is commissioned, the dechlorination plant will be located at the site for chlorine contact tank (as indicated in **Figure 11.2**) permanently.

Assessment Approach

11.18 The hazard to life assessment consists of the following four tasks:

- *Data / Information Collection:* collects relevant data / information which is necessary for the hazard to life assessment
- *Hazard Identification*: identifies hazardous scenarios associated with the use of sodium hypochlorite and sodium bisulphite solutions for the HATS ADF.
- *Frequency Estimation and Consequence Analysis*: estimates the frequencies of the identified hazardous scenarios, with consideration of the HATS ADF specific conditions including the proposed precautionary / mitigation measures. Then, analyses the consequences of the identified hazardous scenarios
- *Risk Evaluation*: evaluates the risks associated with the identified hazardous scenarios. The evaluated risks will be compared with the Criteria for Evaluating Hazard to Life stipulated in Annex 4 of the TM to determine their acceptability. Risk

mitigation measures will be identified if they are needed for the compliance of the Criteria.

11.19 These are elaborated below.

Data Collection

Overview

11.20 The following relevant data / information were collected:

- Layout plans of the proposed chlorination and dechlorination systems
- Operations associated with the use of sodium hypochlorite and sodium bisulphite for disinfection at SCISTW
- Chemical properties of sodium hypochlorite and sodium bisulphite
- Population data around SCISTW
- Meteorological data (including atmospheric stability class, wind speed and wind direction)

11.21 The layout plans are shown in **Figures 11.2**, **11.4 and 11.5**. The other pieces of information are summarised below.

Activities involving Sodium Hypochlorite

11.22 Sodium hypochlorite solution (v/v 10-12%) will be used as the disinfection agent. It will be purchased and delivered to SCISTW by a specially designed delivery barge and unloaded at the berthing facility. It is estimated that there would be 115 barge deliveries per year; sodium hypochlorite solution will be delivered by vehicles when weather or other conditions do not allow chemicals delivery by sea. Sodium hypochlorite solution will be transferred to the storage tanks through a designated and isolated piping system laid within pipe trench. Then the chemical will be pumped from the storage tanks to a day tank next to the flow distribution chamber. The sodium hypochlorite solution from the day tank will then combine with carrier water (effluent) and dose to the flow distribution chamber through a diffuser installed below effluent surface. The maximum storage amount for sodium hypochlorite solution on-site for the ADF operation is estimated to be about 1,800,000L.

11.23 If all the sodium hypochlorite deliveries to SCISTW are made by barge, there will be 115 barge deliveries per year. The chemical will be delivered by road tankers when weather or other conditions do not allow delivery by barge. In the past 10 years, there were 146 days that typhoon signal (signal no. 1 of higher) was issued. This record indicates that poor sea conditions may occur at about 4% of time in a year. Also, regular maintenance and repair would be needed for the specially designed delivery barge. In order to maximize the use of barge for sodium hypochlorite delivery, such maintenance and repair will be scheduled at periods between two delivery operations. Therefore, it is assumed that the barge would be unavailable for delivery operation for only 1% of time in a year due to maintenance and repair.

11.24 Based on the above, it is expected that only about 5% of the sodium hypochlorite (equivalent to 6 barge deliveries) used in the disinfection operation would need to be delivered by road tanker. Nevertheless, a conservative assumption of 10% of the sodium hypochlorite (equivalent to 12 barge deliveries) being delivered by road tanker is adopted in this assessment to cover events of temporary suspension of barge services for reasons, such as large-scale emergency repair while a barge replacement is not readily available, even though such events are remote with proper barge maintenance. Each barge delivery would carry about 500m^3 of sodium hypochlorite and this is equivalent to the volume carried by about 30 road tankers. Therefore, the number of sodium hypochlorite deliveries by road tanker is estimated to be 30 x 12 = 360 per year.

Activities involving Sodium Bisulphite

11.25 Sodium bisulphite solution (v/v 38%) will be used as the dechlorination agent and dosed at the downstream end of the culvert (Chamber No. 15) before the effluent is discharged into the outfall system. It will be purchased and delivered to SCISTW at an interval of 1 to 2 time(s) a week only by road tankers (5 road tankers in total) and then unloaded to the storage tanks. Therefore, the number of sodium bisulphite deliveries by road tanker will be 5 x 52 = 260 per year. The maximum storage amount for sodium bisulphite solution on-site for ADF operation will be about 150,000L.

11.26 It should be noted that the above activities involving sodium hypochlorite and sodium bisulphite are commonly practiced in many sewage treatment works in other countries such as United States and Japan, including the Deer Island Sewage Treatment Plant located at Boston, US, which has a comparable capacity and scale to SCISTW.

Chemical Properties of Sodium Hypochlorite and Sodium Bisulphite

11.27 Both sodium hypochlorite and sodium bisulphite are corrosive substances; contact with either chemicals would cause the following effects for the following potential routes:

- Dermal: burning, blistering and tissue destruction for prolonged contact
- Eyes: corrosion, severe damage
- Ingestion: chemical burns to oesophagus and to stomach lining

11.28 Sodium hypochlorite and sodium bisulphite are not acutely toxic, flammable, or explosive substances. However, hazardous gas would be generated if sodium hypochlorite or sodium bisulphite accidentally mixes with incompatible chemicals. Ferric chloride is the only chemical stored in SCISTW that is incompatible with sodium hypochlorite or sodium bisulphite, due to the hydrochloric acid inside the ferric chloride solution.

11.29 The following scenarios may occur in the SCISTW disinfection operation if the incompatible chemicals are mixed together:

- Sodium hypochlorite mixes with ferric chloride: generate chlorine gas
- Sodium bisulphite mixes with ferric chloride: generate sulphur dioxide gas

11.30 If sodium hypochlorite mixes with sodium bisulphite, heat would be evolved, but no toxic gas would be generated.

11.31 The only identified hazardous scenario having potential to cause off-site fatality is mixing of incompatible chemicals. Under the circumstances of this Project, errors in chemical unloading, which will only be conducted during daytime, is the only possible cause for this hazardous scenario (detailed discussion on the hazardous scenario identification and assessment is presented in later sections). Since the hazardous scenario can only occur during daytime, daytime population and meteorological data was collected and presented below.

Population Data

11.32 The existing ferric chloride tank farm and the proposed sodium hypochlorite tank farm are located at the northeast and southeast parts of the SCISTW main compound respectively At northeast of the ferric chloride tank farm is the sea. The land use to the north of the SCISTW is industrial in nature and comprises the Container Terminal no. 8, the COSCO HIT Terminal Building, bus depot, shipyards and storage areas. Adjacent to the south-eastern boundary of the SCISTW main compound is the Government Dockyard at the seaside. The FSD Diving Training Centre, which is under construction, is located adjacent to the east boundary of the SCISTW main compound. The Ngong Shuen Chau Barracks are located at the south of Stonecutters Island.

11.33 For the proposed dechlorination plant accommodating sodium bisulphite storage tanks, it will be located near the Ngong Shuen Chau Barrack, Container Port Road South, Chi Ngong Road.

11.34 Residential Population was estimated based on Population Census data. Planning Department was contacted to obtain population data at locations accommodating non-residential uses surrounding SCISTW. However, Planning Department indicated that there was no detailed breakdown for the population figures. In order to obtain the best estimate of the population, data were collected from the following paths: (i) information obtained from government departments and private companies, (ii) references from previous EIAs or government reports, and (iii) on-site observation and communication with on-site personnel. Photo documentation of the site survey is presented in **Appendix 11.1**. Populations in vicinity of ADF are listed in **Table 11.1**, while the locations of the population are shown in **Figure 11.6**.

11.35 Population will not spend all time staying at the locations in vicinity of ADF. For example, workers will not stay in industrial building for all 12 hours of daytime in all 365 days of a year. The risk assessment will be over-conservative if it is assumed that the locations are occupied all the time. Therefore, occupancy factor for population is estimated to provide a more realistic population estimation for the risk assessment. The estimation of occupancy factor and outdoor population fraction of various locations are presented in **Appendix 11.2**.

11.36 The surveyed locations have covered all the locations could be impacted by the hazardous events occurred in ADF operations. Further details are given in later part of this section.

11.37 Traffic data of roads near SCISTW were obtained from the Annual Traffic Census 2005 of Transport Department to estimate the road population. For Lai Po Road, Ngong Shung Road, Mei Ching Road and Hing Wah Street West, traffic data was not available from the Traffic Census. Therefore, traffic population of these roads was estimated based on data obtained from site survey conducted by the Consultants during the peak hour (8am to 9am).

11.38 The estimated road and railway population is presented in **Table 11.2**.

Table 11.2 Road and Railway Population within the Assessment Area

Location	Road Population in vicinity of SCISTW during Daytime
Container Port Road South	73.0
Hing Wah Street West	9.9
Lai Po Road	37.5
Ngong Shung Road	3.3
Lin Cheung Road	32.4
West Kowloon Highway	198.1
Mei Ching Road	15.6
Sham Mong Road	10.1
KCRC West Rail	78.9

11.39 The raw data of the site survey and detailed calculations of the road population are presented in **Appendix 11.3**.

11.40 A site survey was conducted to gather data for the estimation of marine population in vicinity of SCISTW. The site survey data and observation, as well as the detailed estimation of marine population are presented in **Appendix 11.4**. Based on the site observation, most of the marine vessels were stationed in three clusters near SCISTW, and about 10% of marine vessels were mobile and travelling at the sea area near the SCISTW. The mobile marine population was assumed to be evenly distributed at the sea area near the SCISTW. The estimated population of the population clusters and mobile marine population are presented in **Table 11.3**. The locations of the marine population clusters are shown in **Figure 11.6**.

Table 11.3 Estimated Marine Population in vicinity of SCISTW

Marine Population	Estimated Population
Marine Population Cluster 1 - at the piers of Government Dockyard (location 1)	28
Marine Population Cluster 2 - at seawall near open storage area and New World First Ferry (locations 17 and 15)	53
Marine Population Cluster 3 - at pier of Wholesale Food Market Office (location 16)	29
Mobile marine population	28

Meteorological Data

11.41 Meteorological data are required for consequence modelling and risk calculation. Consequence modelling (dispersion modelling) requires wind speed and stability class to determine the degree of turbulent mixing potential whereas risk calculation requires wind-rose frequencies for each combination of wind speed and stability class.

11.42 Meteorological data at Ching Pak House (Tsing Yi) weather station, which is closest to SCISTW, of year 2005 was obtained from which wind speed, stability class, weather class and wind direction were available. This data represents the weather conditions for the whole year in 2005 and has already taken into account of seasonal variations, and is therefore considered applicable for the assessment.

11.43 **Table 11.4** shows the wind speed-stability frequencies.

Table 11.4 Stability Category-Wind Speed Frequencies at Ching Pak House Weather Station (day-time)

	Stability Class							
Wind Speed (m/s)	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**Total (%)**
0.0-1.7	0.71	5.68	0.02	3.33	0.02	4.41	0	14.18
1.8-3.2	0.32	8.26	5.46	5.73	3.36	1.99	0	25.11
3.3-5.2	0	5.71	15.57	14.06	2.21	0	0	37.56
5.3-8.2	0	0	3.56	16.92	0	0	0	20.48
Over 8.3	0	0	0.39	2.28	0	0	0	2.67
All (%)	**1.03**	**19.66**	**25**	**42.33**	**5.59**	**6.39**	**0**	**100**

11.44 From the data presented in **Table 11.4**, 6 combinations (2B, 1D, 4C, 7D, 1F and 3E) of wind speed and stability class were chosen as the representative daytime meteorological conditions. These combinations are considered adequate to reflect the full range of observed variations in these quantities. It is not necessary and efficient to consider every combination observed. The principle is to group these combinations into representative weather classes, which together cover all conditions observed.

11.45 Once the weather classes have been selected, frequencies for each wind direction for each weather class can then be determined. These frequency distributions are given in **Table 11.5** for the daytime meteorological conditions.

Table 11.1 Population in vicinity of ADF

Location	Distance to SCISTW[1] (m)	Type of Land Use	Land Use	Estimated Population during Daytime	Occupancy Factor during Daytime	Fraction of Outdoor Population	Remark
1	288	G/IC	Government Dockyard	1800[2]	0.57	0.1	• Population data provided by manager of the Government Dockyard
2	658	G/IC	Ngong Shuen Chau Barracks		1	0.5	• Population data provided by Security Bureau • It is assumed that population in barracks needs to stay on site all the time (i.e. occupancy factor = 1) • A factor of occupancy factor of 0.5 is assumed since the barracks personnel would be trained outdoor
3	247	Industrial	West Kowloon Refuse Transfer Station	104	0.57	0.1	• Population data provided in returned questionnaire
4	151	G/IC	FSD Diving Training Centre	50	1	0.5	• According to the layout plan of the FSD Diving centre, there will be totally 18 beds provided for trainees training at the training centre. Population of 50 people is therefore assumed during daytime taking into account the presence of other staff members such as trainers and other supporting staff • A factor of occupancy factor of 0.5 is assumed since the trainee would be trained outdoor • A conservative occupancy factor of 1 is assumed since trainee may need to stay on site all the time

5	370	Industrial	Wang Tak Building	150	0.57	0.1	• Population data provided in returned questionnaire • The estimated gross floor area (GFA) of the Wang Tak Building is $4032m^2$, and therefore the worker density is estimated to be $0.0372ppl/GFA\text{-}m^2$. This estimated worker density is used to estimate the population of other industrial buildings nearby, where questionnaire requesting population data was not returned
	260	Industrial	Ocean Ship Building Engineering	533	0.57	0.1	• Questionnaire to request population data was not returned • The estimated GFA of the building is $14,336m^2$, taking the worker density as $0.0372ppl/GFA\text{-}m^2$, the population is estimated to be 533 • The estimation population is considered conservative because the data obtained from communication with on-site personnel indicated a much lower population (90)
	315	Industrial	Choy Lee Shipyard Limited	50	0.57	0.1	• Questionnaire to request population data was not returned • The estimated GFA of the building is $1,344m^2$, taking the worker density as $0.0372ppl/GFA\text{-}m^2$, the population is estimated to be 50 • The estimation population is consistent with the data obtained (population = 40) from communication with on-site personnel indicated

5	288	Industrial	Yuet Hing Marine Supplies Company Limited	182	0.57	0.1	• Questionnaire to request population data was not returned. • The estimated GFA of the building is 4,896m^2, taking the worker density as 0.0372ppl/GFA-m2, the population is estimated to be 182 • The estimation population is considered conservative because the data obtained from communication with on-site personnel indicated a much lower population (60).
	425	Industrial	China Travel Service Parkview Shipyard Building	139	0.57	0.1	• Questionnaire to request population data was not returned. • The estimated GFA of the building is 3,744m^2, taking the worker density as 0.0372ppl/GFA-m^2, the population is estimated to be 139 • The estimation population is considered conservative because the data obtained from communication with on-site personnel indicated a lower population (100)
	452	Industrial	Hop Hing Marine Industrial (HK) Limited	243	0.57	0.1	• Questionnaire to request population data was not returned. • The estimated GFA of the building is 6,528m^2, taking the worker density as 0.0372ppl/GFA-m^2, the population is estimated to be 243 • The estimation population is considered conservative because the data obtained from communication with on-site personnel indicated a much lower population (100)

5	370	Industrial	Kowloon Motor Bus Depot	500	0.57	0.1	• With reference to the population estimation from previous EIAs; (i) Proposed Headquarters and Bus Maintenance Depot in Chai Wan (2001) - number of staff working was estimated to be 520 during daytime; (ii) New World First Bus Permanent Depot at Chai Wan (1999) - estimated (maximum) population was 500 persons • The population of the Kowloon Motor Bus Depot is estimated to be 500 since this Bus Depot is of similar scale with those in Chai Wan
6	616	-	Car Park (Open Storage)	30	1	1	• Based on observation during site survey, the number of people present on site was <10. As a conservative approach, a population of 30 was assumed • Since there is no indoor area at the site, the outdoor population portion is estimated to be 1
7	712	Industrial	Container Terminal 7 and 8	3000	0.57	0.5	• With reference to the population estimation from previous report South-East Tsing Yi Port Development Planning and Engineering Feasibility Study for Container Terminal No. 9 (1991), it was estimated that there were 1259 workers in Container Terminal 9 • Container Terminal 7 and 8 are of similar scale with Container Terminal 9, it is assumed that the population of each Container Terminal is 1500 • Based on the observation in site survey, it is estimated that there is 50% of population located outdoor.

8	959	-	Car Park (Open Storage)	30	1	1	• Based on observation during site survey, the number of people present on site was <10. As a conservative approach, a population of 30 was assumed • Since there is no indoor area at the site, the outdoor population portion is estimated to be 1
9	986	Recreational	Lai Chi Kok Park	50	1	1	• Based on observation during site survey, the number of people present on site was <20. As a conservative approach, a population of 50 was assumed • Since there is no indoor area at the site, the outdoor population portion is estimated to be 1
10	1014	Residential	Mei Foo Sun Chuen Phase 8	989	0.4	0.18	• Population data obtained from Population Census
11	959	-	Area accommodating Sand Depot and Car Park (Open storage)	30	1	1	• Based on observation during site survey, the number of people present on site was <10. As a conservative approach, a population of 30 was assumed • Since there is no indoor area at the site, the outdoor population portion is estimated to be 1
12	863	Residential	Hoi Lai Estate	4400	0.4	0.18	• Population data obtained from Population Census
13	918	Educational	Secondary School	1260	0.56	0.1	• For Secondary 1 to 5, assume there are 5 classes for each form and 40 students in each class. For Secondary 6 and 7, assume there are 2 classes for each form. Total number of students is (5 x 5 + 2 x 2) x 40 = 1160. Also, it is assumed that there is 100 staff. Total population is estimated to be 1260

14	836	Educational	Primary School	1060	0.56	0.1	• For Primary 1 to 6, assumed there is 4 classes for each form and 40 students in each class. Total number of students is 6 x 4 x 40 = 960. Also, it is assumed that there is 100 staff. Total population is estimated to be 1060
15	562	Industrial	New World First Ferry	100	0.57	0.1	• Population data provided in returned questionnaire
16	959	G/IC	Cheung Sha Wan Wholesale Food Market Office	50	0.57	0.1	• Population of the wholesale food market of 50 is based on on-site observation. The estimation is consistent with the estimation with reference to the previous EIA, Proposed Joint User Complex and Wholesale Fish Market at Area 44, Tuen Mun (2002) - population of 1/3 of the Joint User Complex and Wholesale Fish Market located within the assessment area during night-time and daytime was estimated to be 147 and 20 respectively. The total population of the Tuen Mun Wholesale Fish Market was about 60 during daytime
17	767	-	Open storage	30	1	1	• Based on observation during site survey, the number of people present on site was <10. As a conservative approach, a population of 30 was assumed • Since there is no indoor area at the site, the outdoor population portion is estimated to be 1

[1] Distance between the centre point of the location and the ferric chloride tank farm of SCISTW.
[2] Due to the confidentiality of population within barracks, the total population of the Government Dockyard and the Ngong Shuen Chau Barracks is shown.

Table 11.5 Weather Class-Wind Direction Frequencies at Ching Pak House Weather Station (day-time)

	Weather Class						
Direction	2B	1D	4C	7D	1F	3E	Total
0 – 30	5.18	0.55	7.56	3.65	0.46	0.84	18.24
30 – 60	0.66	0.39	0.16	0.02	0.27	0.14	1.64
60 – 90	1.35	0.14	1.14	0.39	0.34	0.09	3.45
90 – 120	1.32	0.34	1.62	0.48	0.16	0.25	4.18
120 – 150	1.71	0.30	3.11	0.34	0.68	1.05	7.19
150 – 180	1.62	0.34	1.53	0.73	0.78	0.59	5.59
180 – 210	0.71	0.21	1.23	0.21	0.18	0.30	2.83
210 – 240	1.12	0.14	4.43	1.76	0.30	1.21	8.95
240 – 270	0.84	0.16	3.93	2.47	0.37	0.91	8.68
270 – 300	0.96	0.21	4.45	4.59	0.09	0.68	10.98
300 – 330	2.72	0.34	8.68	6.78	0.50	1.16	20.18
330 – 360	2.49	0.25	2.99	1.74	0.30	0.32	8.08
All	**20.68**	**3.36**	**40.82**	**23.15**	**4.43**	**7.56**	**100.00**

Hazard Identification

Overview

11.46 The hazard identification stage consists of three tasks to identify hazardous scenarios associated with the sodium hypochlorite and sodium bisulphite related activities in HATS ADF operations, as follows:

- Incident Review
- Hazard and Operability (HAZOP) Study
- Review of Previous Relevant Studies

11.47 The risk of the identified hazardous scenarios was quantitatively assessed in the later stage of the hazard to life assessment.

Incident Review

<u>Scope of Incident Review</u>

11.48 In the incident review, a search of the recognized historical incident database, MHIDAS (Major Hazardous Incident Data Service), was conducted to identify incidents involving sodium hypochlorite and sodium bisulphite. Judgment was made to select the hazardous scenarios associated with the use of dangerous goods for the HATS ADF operations, which have been shown to occur in the history of projects of the same genus as the instant project. “Projects of the same genus as the HATS ADF” are projects having similar operations with chemicals of similar characteristics, i.e. projects that have at least one of those chemical-related activities listed below and involve chemicals with similar characteristics of sodium hypochlorite or sodium bisulphite.

11.49 The chemical-related activities of the HATS ADF include:

- Chemical transport by marine vessel (only for delivery of sodium hypochlorite)
- Chemical transport by road tanker (delivery of one chemical only for each road tanker)
- Chemical unloading to storage facility
- Chemical storage at aboveground storage tank
- Chemical transport via pipelines
- Chemical dosing

11.50 For the chemical characteristics, reference will be made to the International Maritime Dangerous Goods (IMDG) Code. In the IMDG Code, apart from assigning dangerous goods to one of the nine classes according to the hazard of the most predominant of the hazards they present, the Code also assigns dangerous goods to UN numbers. UN numbers are four-digit numbers that identify dangerous goods according to their characteristic - dangerous goods having similar characteristics share the same UN number, while a chemical in its solid state may receive a different UN number to the liquid phase if the hazardous properties differ significantly.

11.51 Therefore, chemicals share the same UN number with sodium hypochlorite (UN number: 1791) / sodium bisulphite (UN number: 2693) are considered as those having similar characteristics with sodium hypochlorite / sodium bisulphite. These chemicals include:

- UN number 1791: bleach liquor, hypochlorite solution, and potassium hypochlorite solution
- UN number 2693: ammonium bisulphite solution, bisulphite aqueous solution, magnesium bisulphite solution, potassium bisulphite solution, zinc bisulphite solution, and calcium bisulphite solution (calcium hydrogen sulphite solution)

11.52 In short, the projects of the same genus as the HATS ADF are those involving chemicals listed under UN1791 and 2693, and having at least one of the activities listed above.

<u>Approach to the Incident Review</u>

11.53 Having establishing the scope of the incident review, the approach of the incident review is developed and presented below:

- Step 1: Historical Incident Database Search and Review of Incidents
  - A search in the recognized historic incident database, MHIDAS, was conducted using the keywords “bleach”, “hypochlorite”, “bisulphite” and “hydrogen sulphite” to identify incidents involving chemicals with similar characteristics with sodium hypochlorite / sodium bisulphite solution, which will be used in the HATS ADF operation.
  - The incident review provided a list of incidents involving the chemicals with similar characteristics with sodium hypochlorite or sodium bisulphite solution. The following information items are usually available for each incident identified:
    - Date of incident
    - Location of incident
    - Facility / operation involved in the incident
    - Number of casualties (fatalities and injuries)
    - Material(s) involved
    - A brief description of the incident
  - The incidents identified by using the above keywords for MHIDAS database search are incidents involving chemicals with similar characteristics with sodium hypochlorite or sodium bisulphite solution only. As mentioned above, “Projects of the same genus as the HATS ADF” are projects having similar operations with chemicals of similar characteristics. Therefore, the incidents identified by the above MHIDAS database search needed to be reviewed and checked whether they involved one of the activities listed in **Section 11.48**, in order to confirm the incidents were involved in the “Projects of the same genus as the HATS ADF”. Only the incidents that involved one of the activities listed in **Section 11.48** were considered to be involved in the “Projects of the same genus as the HATS ADF”.
- Step 2: Scenario Development
  - The incidents involved in the “Projects of the same genus as the HATS ADF” identified by Step 1 were grouped into different incident scenarios (e.g. leakage from storage tank, spillage during transportation, accidental mixing with incompatible chemicals etc.).

Outcome of Incident Review

11.54 Using the above procedures, forty-six relevant incidents were identified in the incident review. A summary of these incidents was presented in **Annex D**. It should be noted that no fatality was reported in all identified incidents.

11.55 The following scenarios were identified from the incident review exercise:

- Mixing of incompatible chemicals
- Spillage of sodium hypochlorite from road tanker
- Spillage of sodium hypochlorite from delivery pipe
- Spillage of sodium bisulphite from delivery pipe
- Spillage of sodium hypochlorite from storage tank

11.56 With respect to mixing of incompatible chemicals, 21 incidents have been identified. The identified causes of such incidents of mixing of incompatible chemicals are as follows:

- Error in unloading operation
- Spillage of incompatible chemicals in different tanks
- Spillage of incompatible chemicals in two different pipelines
- Spillage of chemical from valve at soft drinks maker

11.57 In conclusion, the incidents identified can be grouped into two types, which will be further assessed in this hazard assessment.

- spillage of chemicals
- accidental mixing between incompatible chemicals and release of toxic gas

HAZOP Study

Overview

11.58 A Hazard and Operability (HAZOP) Study has been conducted to systematically identify potential hazardous scenarios associated with sodium hypochlorite or sodium bisulphite related activities. This has also identified corresponding precautionary or mitigation measures to avoid the occurrence of the hazardous scenarios.

11.59 A HAZOP Study Meeting session participated by representatives from DSD and the Consultants has been carried out. The HAZOP study included several stages:

- Define the purpose of the Study
- Select the HAZOP Study Team
- Prepare for the HAZOP Study Meeting
- Execute HAZOP Study Meeting

Define the Scope of the Study

11.60 The scope of the Study was in line with the EIA Study Brief, which is:

- Identify hazards associated with on-site transport, storage, handling and use of sodium hypochlorite and sodium bisulphite
- Recommend risk mitigation measures for implementation

Select the HAZOP Study Team

11.61 The team members were selected in a manner that could ensure the Study Team has sufficient knowledge of the following items:

- Design of the existing SCISTW and future advanced disinfection facilities
- Daily operation of the existing SCISTW and future advanced disinfection facilities
- Chemical properties of sodium hypochlorite and sodium bisulphite

- Safety issues encountered at the existing SCISTW and future advanced disinfection facilities

Prepare for the HAZOP Study Meeting

11.62 The preparation work prior to the HAZOP Study Meeting involved:

- *Collect useful information* - Information collected prior to the Study Meeting included the followings:
  - Locations and design of the sodium hypochlorite and sodium bisulphite storage area, delivery pipeworks and dosing facilities
  - Sodium hypochlorite and sodium bisulphite delivery procedures
  - Dangerous goods handling and emergency procedures
  - Material Safety Data Sheet (MSDS) of chemicals and material encountered / to be encountered in SCISTW activities
- *Convert the collected information into a suitable form* - In order to provide concise and easy-understanding information to the Study Team members, the collected information was converted into layout plan and summary table.
- *Plan the Study Meeting sequence* - Prior to the Study Meeting, a Study Meeting sequence was prepared to ensure the Study Meeting could proceed smoothly and systematically. During the preparative work, the Study Meeting was conducted in an operation activity-based sequence. That is, all the possible sodium hypochlorite and sodium bisulphite activities involved were discussed in turn to identify possible hazards and mitigation measures.
- *Arrange Study Meeting* - After necessary information had been obtained and Study Meeting sequence had been planned, all the Study Team members were invited to attend the Study Meeting. In parallel, the obtained information (in form of layout plan and summary table) and Study Meeting sequence were sent to the Study Team members for their preparation before the meeting.

Execute HAZOP Study Meeting

11.63 In the Study Meeting, the items discussed were recorded during the Study Meeting.

Results

11.64 The identified scenarios by the HAZOP Study are as follows:

- Spillage of sodium hypochlorite from delivery barge
- Spillage of sodium hypochlorite from loading hose
- Spillage of sodium bisulphite from loading hose
- Spillage of sodium hypochlorite from road tanker
- Spillage of sodium bisulphite from road tanker
- Spillage of sodium hypochlorite from delivery pipelines
- Spillage of sodium bisulphite from delivery pipelines
- Spillage of sodium hypochlorite from storage tank
- Spillage of sodium bisulphite from storage tank
- Mixing of incompatible chemicals

11.65 Again, the incidents identified can be grouped into two types: (1) spillage of chemicals; and (2) accidental mixing of incompatible chemicals.

Review of Previous Relevant Studies

11.66 Previous relevant studies involving risk assessment for the operations associated with sodium hypochlorite or sodium bisulphite were reviewed to identify hazardous scenarios.

11.67 It was found that quantitative risk assessment for the operations associated with sodium hypochlorite or sodium bisulphite is sparse. It may be because these two chemicals are not particularly hazardous, which may be reflected by the observation that no fatality was noted in the incidents associated with these chemicals. The following previous studies involving evaluation of risk due to sodium hypochlorite / sodium bisulphite were identified and reviewed:

- Local Study
  - Construction of an International Theme Park in Penny's Bay of North Lantau together with its Essential Associated Infrastructures – Environmental Impact Assessment, completed in 2000 (Study A)
- Overseas Study
  - Croton Water Treatment Plant – Final Supplemental Environmental Impact Statement (Study B)[1], a study in the US completed in 2004
  - Yamba Sewerage Augmentation – Environmental Impact Statement[2] (Study C), a study in Australia completed in 2005

11.68 The hazard assessment methodology adopted and hazardous scenarios evaluated in the abovementioned studies are described below.

- *Study A* - Hazardous scenarios of sodium hypochlorite spillage as well as mixing of sodium hypochlorite with acids were identified in the study. Only the risk associated with the latter scenario was considered and assessed quantitatively.
- *Study B* - Sodium hypochlorite was proposed to be used as one of the chemicals in the water treatment process. No quantitative risk assessment for chemicals was conducted in the Study. The Study only mentioned mitigation measures, including installation of containment and storing incompatible chemicals in separate areas, would be implemented and concluded that no potentially significant adverse impacts are anticipated to occur from the transport, storage, or usage of the chemicals.
- *Study C* - Sodium hypochlorite was proposed to be used in the sewage treatment plant for recycled water reuse. The Study did not quantitatively assess the risk due to sodium hypochlorite. Rather, the Study proposed mitigation measures including installation of bunds and warning signs, worker training and use of personal protective equipment.

11.69 From the review of previous studies, two scenarios are noted:

- Spillage of chemicals
- Chemical to be used mixes with incompatible chemicals

Results of Hazard Identification

11.70 The identified hazardous scenarios from incident review, HAZOP Study, and review of previous relevant studies are listed as follows:

- **Spillage** of chemicals
  - Spillage of sodium hypochlorite from delivery barge (hazardous scenario 1)
  - Spillage of sodium hypochlorite from loading hose (hazardous scenario 2)
  - Spillage of sodium bisulphite from loading hose (hazardous scenario 3)
  - Spillage of sodium hypochlorite from road tanker (hazardous scenario 4)
  - Spillage of sodium bisulphite from road tanker (hazardous scenario 5)
  - Spillage of sodium hypochlorite from delivery pipelines (hazardous scenario 6)
  - Spillage of sodium bisulphite from delivery pipelines (hazardous scenario 7)
  - Spillage of sodium hypochlorite from storage tank (hazardous scenario 8)
  - Spillage of sodium bisulphite from storage tank (hazardous scenario 9)

[1] New York City Department of Environmental Protection (2004). Croton Water Treatment Plant – Final Supplemental Environmental Impact Statement.
[2] Clarence Valley Council (2005). Yamba Sewerage Augmentation – Environmental Impact Statement.

- **Mixing** of incompatible chemicals on-site (hazardous scenario 10), caused by:
  - Error in chemical unloading operations
  - Spillage of incompatible chemicals in different tanks
  - Spillage of incompatible chemicals in two different pipelines
  - Spillage of chemical from valve at soft drinks maker

11.71 In light of the identified hazards, a range of comprehensive chemical safety measures has been developed, as summarised in **Sections 11.71 to 11.96**. These hazardous scenarios are further assessed in **Sections 11.97** to **11.186**, with the application of the safety measures in mind.

Proposed Safety Measures for Chemicals-related Operations

11.72 A package of safety measures was identified for the Project to minimize the risk due to chemicals-related operation. The safety measures can be categorized into several groups: chemical supply contract arrangement, and design measures, procedures and safety measures.

Special Chemical Supply Contract Arrangement

11.73 A separate supply contract will be awarded for each of the three chemicals (sodium hypochlorite, sodium bisulphite and ferric chloride solutions). In each supply contract, the chemical supplier will be required to provide dedicated transport specifically used for delivering the chemical to be supplied, and the road tankers will need to be registered with SCISTW. In addition, the supply contract for sodium hypochlorite will specify that the delivery barge provided will be dedicated for delivering sodium hypochlorite directly and exclusively from the supplier's production plant to SCISTW during the contract period. The delivery barge will not be allowed to provide other services, such as carrying other chemical or carrying chemicals to other facilities other than SCISTW.

Design Measures

Separation of Chemical Storage Areas

11.74 Locate sodium hypochlorite and ferric chloride tank farms in separate areas of SCISTW, which is about 200 m apart, as shown in **Figure 11.1**. After the completion of Stage 2A construction works, the area separating the two tank farms will be occupied by existing Chemical Dosing Building and HATS 2A permanent structures such as pumping station and sedimentation tanks (**Figure 11.7** refers). Before the Stage 2A permanent structures are built, a temporary screening structure made of water-filled barriers will be erected between the two tank farms (**Figure 11.8** refers). The purpose of this design measure is to avoid the mixing of spilled sodium hypochlorite and ferric chloride in the situation of storage tanks failure. More details of this design measure are described in **Sections 11.131** to **11.137** below.

11.75 The sodium bisulphite tank farm will be located near the Chamber 15, which is outside the SCISTW main compound.

Protection and Separation of Chemical Delivery Pipelines

11.76 Each chemical delivery pipeline will be installed in designated and separate service duct or pipe trench to provide additional protection. The routes of the pipe trenches for sodium hypochlorite pipelines and the service duct that ferric chloride pipelines are laid are shown in **Figure 11.9**. Although it can be seen in **Figure 11.9** that there is an intersection between the routes of the service duct and the pipe trench, the two set of pipelines for ferric chloride and sodium hypochlorite are installed in separate service duct / pipe trench. **Figure 11.10a** shows the cross section of the service duct accommodating the ferric chloride delivery pipelines and the pipe trench where sodium hypochlorite delivery pipelines are installed. It can seen that the service duct and pipe trench are located at different level below ground.

11.77 Also, it is proposed to install a vibration sensing system at the ferric chloride and sodium hypochlorite tank farm to enable shut down of the chemical pumping system (at storage tank or sodium hypochlorite delivery barge) whenever excessive vibrations are detected, in order to minimize the amount of chemical that can escape in the event of pipeline failure due to excessive vibrations.

11.78 A section of the pipe trench accommodating sodium hypochlorite feeding pipelines is proposed to be wrapped by heavy-duty impervious membrane to provide an additional barrier to migration of the leaked sodium hypochlorite solution. Furthermore, a road kerb is proposed to be constructed near the section of hypochlorite pipeline near the barge unloading facility and a U-channel is proposed at the foot of the concrete barrier to facilitate surface drainage into the sea.

11.79 For the sodium bisulphite delivery pipelines, they will be installed in the dechlorination plant located more than 1km away from pipelines for sodium hypochlorite and ferric chloride. There is no intersection between the routes of the sodium bisulphite delivery pipelines and the pipeline of the other two chemicals.

Dedicated Chemical Delivery Route and Road Signs

11.80 Specific road tanker transport route will be assigned to each chemical. Such arrangement provides the most direct route for the road tanker travelling to the intended tank farm.

11.81 Provide road signs on service road indicating the route to specific chemical storage area.

Security of Chemical Loading Points

11.82 Chemical delivery staff will need to register with SCISTW staff upon entering the site. Loading points for ferric chloride, sodium hypochlorite and sodium bisulphite will be secured by locks and the keys will be kept by SCISTW staff. The chemical unloading operation cannot start without presence of SCISTW staff to open the locks.

Unique Colour and Size of Pipelines and Hose Coupling for Different Chemicals

11.83 Delivery pipelines for different chemicals will be in different colours and different sizes.

11.84 There will be specific hose connection design for each chemical, the type, size and colour of coupling will be specific for each chemical – for loading point at SCISTW, the coupling size, type and colour of the loading point of each tank farm will be unique (different from the other two tank farms). For the loading hose, the supplier will be required to carry the loading hose specifically used for the delivery to SCISTW in each chemical delivery. The loading hose should be clearly coloured and labelled with the name of chemical to be delivered, with its coupling matches the size, type and colour of the one at the tank farm loading point. This measure will be included in the chemical supply contract.

11.85 There are many specialty couplings available by different manufacturers, not only those couplings are available in a large range of sizes, but they also offer different fittings which would make coupling not of the same type could not be fitted or would render inoperable when forced together. Examples of different types of hose coupling are presented in **Figure 11.11**. The locking arms or the switch of the coupling can only be fastened or turned when two pieces of matched (i.e. same type and same size) hose coupling are put together, in order to open the seal of both pieces of coupling. By adopting this mechanism, chemical unloading can only proceed when two pieces of matched hose coupling are put together.

Operation Procedures and Safety Measures

11.86 Clear Labelling of Chemicals-related Equipment:

- Provide clear and sufficient signage / labels to indicate the identity (i.e. for which chemical) of each tank farm and associated equipment including pipelines, loading points and loading hoses

11.87 Ensuring Quality of Chemical Supplier:

- Only appoint chemical suppliers with satisfactory quality system. Suppliers equipped with good quality system are less prone to errors in chemical delivery operations
- Request the chemical supplier to employ an independent checker to audit the quality and safety management system of the supplier, in order to ensure the standard of the quality and safety management system. This measure will be included in the chemical supply contract
- The chemical supplied to SCISTW can only be produced in designated chemical production plants and delivered directly from designated locations. This requirement will help ensure the quality of the chemical supplied and reduce the likelihood of errors in chemical delivery operation. This measure will be included in the chemical supply contract

<u>Procedural Control of Chemical Unloading Operation</u>

11.88 Develop clear procedural controls for barge / road tanker filling and unloading operation. Procedural controls should include: chemical supplier staff cannot start chemical unloading without authorization and presence of SCISTW staff, checking of the delivery documentation prior to unloading process etc.

11.89 SCISTW staff will be present at the tank area to receive the barge / road tanker, check barge / road tanker labels, check the transport documents carried by the barge crew / road tanker driver, check type, size and colour of coupling and hose coupler, conduct chemical analysis to check the identity of delivered chemical and only then authorize the driver to unload the content.

11.90 Chemical supplier needs to fax or electronically transmit copies of delivery bills-of-lading information and barge crew / road tanker driver identification to SCISTW prior to delivery barge / road tanker arriving on-site. Such information will be in compliance with the supplier's independently accredited quality assurance system (to ISO:9000 or equivalent), to ensure that the right person driving the right tanker / barge to the right tank farm and further avoid occurrence of delivery operation error. This measure will be included in the chemical supply contract.

11.91 Conduct chemical analysis to confirm the right chemical is delivered. The analysis needs to be conducted by SCISTW staff or independent checker before the chemical is authorized to be unloaded to the tank farm. HKOLAS accredited analysis methods are currently used in the laboratory in SCISTW to analyze the identity and concentration of ferric chloride (GB4482-93 Section 5.1) and sodium hypochlorite (ASTM D2022-89 cl. 6 to 9). Accredited analysis method for sodium bisulphite will be adopted in SCISTW for testing of delivered chemical in the future.

11.92 If the coupling of hose connected to the barge / road tanker is found to be unmatched with the coupling of loading point of tank farm, chemical unloading operation must not proceed and the situation must be reported to the SCISTW management for follow-up actions.

11.93 Chain-of-custody documentation system will be used to ensure both the supplier (factory) and SCISTW staffs have checked the chemical identity and the consistency of the chemical analysis result. Such measure will ensure that the identity of the delivered chemical has been checked twice by two different parties before it is unloaded to the storage tank. This measure will be included in the chemical supply contract.

Measures to Identify and Stop the Chemical Unloading in Error Events

11.94 Error in chemical unloading operation could lead to mixing of incompatible chemicals and toxic gas could be produced in such event. The abovementioned safety measures were identified to avoid the occurrence of such event. Further, in order to identify and stop such unlikely event, chlorine gas detectors will be installed near the tank vent for each ferric chloride and sodium hypochlorite storage tank, whereas sulphur dioxide gas detectors will be installed near the tank vent for each ferric chloride and sodium bisulphite storage tank. When chlorine gas detectors detect a chlorine gas concentration of 3ppm or higher, or sulphur dioxide gas detectors detect a sulphur dioxide gas concentration of 15ppm or higher, alarm will annunciated at the tank farm area and in the central control centre.

11.95 Emergency shutdown valve will be installed on the inlet of the tank farms, to stop chemical unloading to the storage tank when the valve is closed. Closure of the emergency shutdown valve can be automatically initiated by the activation of the alarm in the tank farm area or central control centre. Also, as chemical supplier staff and SCISTW operator will be present throughout the chemical unloading operation, they can stop the chemical unloading operation by turning off the pump for pumping the chemical to the storage tank when they notice the activation of the alarm or other abnormal conditions (e.g. emission of gas from the tank vent). In such case, it is expected that the wrong chemical unloading operation can be stopped within 3 minute in most cases.

11.96 In addition, CCTV system will be installed to monitor the situation at the chemical tank farm. In case the rapid stoppage (within 3 minute) of wrong chemical unloading operation fails, SCISTW operator at the central control centre will be notified of the incident by the CCTV image, and apply appropriate action (e.g. close the emergency shutdown valve) within a short period time, probably 10 minutes.

Special Arrangement of SCISTW Public Event

11.97 Public evens might sometimes be held in SCISTW which allow access of public to the plant facilities. As a precautionary measure, chemical delivery operation will be suspended on days of SCISTW public event. Also, public members visiting the SCISTW will be guided by DSD staff and will not be allowed to visit the area near the chemical storage locations in SCISTW.

Assessment of Chemical Spillage Hazards (Scenarios 1 to 9)

Introduction

11.98 As mentioned above, sodium hypochlorite and sodium bisulphite are not acutely toxic, flammable, or explosive substances. It is acknowledged that there is the potential for off-site population to contact and/or ingest the spilled chemicals in these chemical spillage scenarios. However, there will be no lethal effects on off-site population due to contact with and ingestion of these chemicals. Further elaboration is given below.

Dermal Contact

11.99 Under the IMDG Code, both sodium hypochlorite (12%) and sodium bisulphite are assigned to be Class 8 dangerous goods (corrosive substances) with packing group III. Packing group III is assigned to substances that cause skin tissue damage within an observation period of up to 14 days starting after an exposure time of more than 60 minutes but not more than 4 hours. As indicated in the assigned packing group, sodium hypochlorite (12%) and sodium bisulphite will not cause chemical burn to skin unless there is a prolonged exposure (i.e. more than 1 hour) to the chemical.

11.100 Individuals will not be exposed to chemicals for a prolonged period unless they are unable to escape from an area holding considerable depth of chemicals (e.g. chemical storage tank or bund area filled with spilled chemicals). Such structures that are able to contain chemicals are present within the site boundary but not identified outside the site boundary.

11.101 For Scenarios 2 (hose connecting delivery pipe and road tanker) to 9, the spilled chemical might spread on land and form a liquid pool, which might extend out of the site boundary. However, the depth of the liquid pool extended out of the site boundary will not be considerable because no structure, which could contain the spilled liquid, is identified outside the site boundary. Since the spilled chemical pool will not have considerable depth, off-site population will not have large area of skin exposed to the spilled chemical for a prolonged period. Therefore, there will be no off-site fatality in these scenarios due to dermal contact of the spilled chemicals.

11.102 For Scenarios 1 and 2 (hose connecting the delivery barge and delivery pipe), the spilled sodium hypochlorite will be largely diluted by seawater immediately and the corrosivity of the spilled chemical will be greatly reduced due to the dilution. Therefore, these chemical spillage scenarios will not cause off-site fatality. Note that the sea area near the delivery barge berthing location is not an area for swimming activities or other water-based recreational activities.

Ingestion

<u>Sodium Hypochlorite</u>

11.103 Literatures have been reviewed to understand the clinical effects of acute exposure of sodium hypochlorite via ingestion. It is revealed that the vast majority of patients ingesting sodium hypochlorite developed no symptoms or only minor gastrointestinal irritation. Corrosive damage to the gastrointestinal tract is unusual following ingestion of the chemical unless a large quantity of the chemical is ingested. It should be noted that no description of "lethal impact due to ingestion" was stated in literatures reviewed.

11.104 The above findings are consistent with the hazardous properties described in the IMDG Code, a widely used document and the "risk phrases" for dangerous substances defined in the EU Commission Directive (2001/59/EC). In the IMDG Code, sodium hypochlorite is only classified as a corrosive substance (packing group III, indicating slight corrosivity) but not considered as a toxic substance. The risk phrase "R22 – harmful if swallowed" (rather than R25 – toxic if swallowed or R28 – very toxic if swallowed) is assigned to sodium hypochlorite. Such descriptions do not indicate lethal effect due to ingestion of the chemical concerned.

<u>Sodium Bisulphite</u>

11.105 In addition, literatures were reviewed to understand the clinical effects of acute exposure of sodium bisulphite via ingestion. It is revealed that ingestion of sodium bisulphite will cause swelling of the tongue, angioedema, difficulty in swallowing. Ocular injury may occur from exposure to high concentrations. Acute ingestions of 3.5mg/kg produce vomiting in most individuals. Larger doses may result in gastric irritation, abdominal pain, and gastric haemorrhage. Again, it should be noted that no description of "lethal impact due to ingestion" was stated in literature reviewed.

11.106 The above findings are consistent with the hazardous properties described in the IMDG Code, a widely used document and the "risk phrases" for dangerous substances defined in the EU Commission Directive. In the IMDG Code, sodium bisulphite is only classified as a corrosive substance (packing group III, indicating slight corrosivity) but not considered as a toxic substance. The risk phrase "R22 – harmful if swallowed" (rather than R25 – toxic if swallowed or R28 – very toxic if swallowed) is assigned to sodium bisulphite. Such descriptions do not indicate lethal effect due to ingestion of the chemical concerned.

Conclusion

11.107 In conclusion, an assessment of the consequence of the chemical spillage scenarios (hazardous scenarios 1 to 9) has found that while there is the potential for off-site population to expose to the spilled chemical, there will be no lethal effects on off-site population due to contact with or ingestion of these chemicals. Hence, the chemical spillage scenarios will not cause off-site fatality under the circumstances of the current Project.

Assessment of Incompatible Chemical Mixing Hazards (Scenario 10)

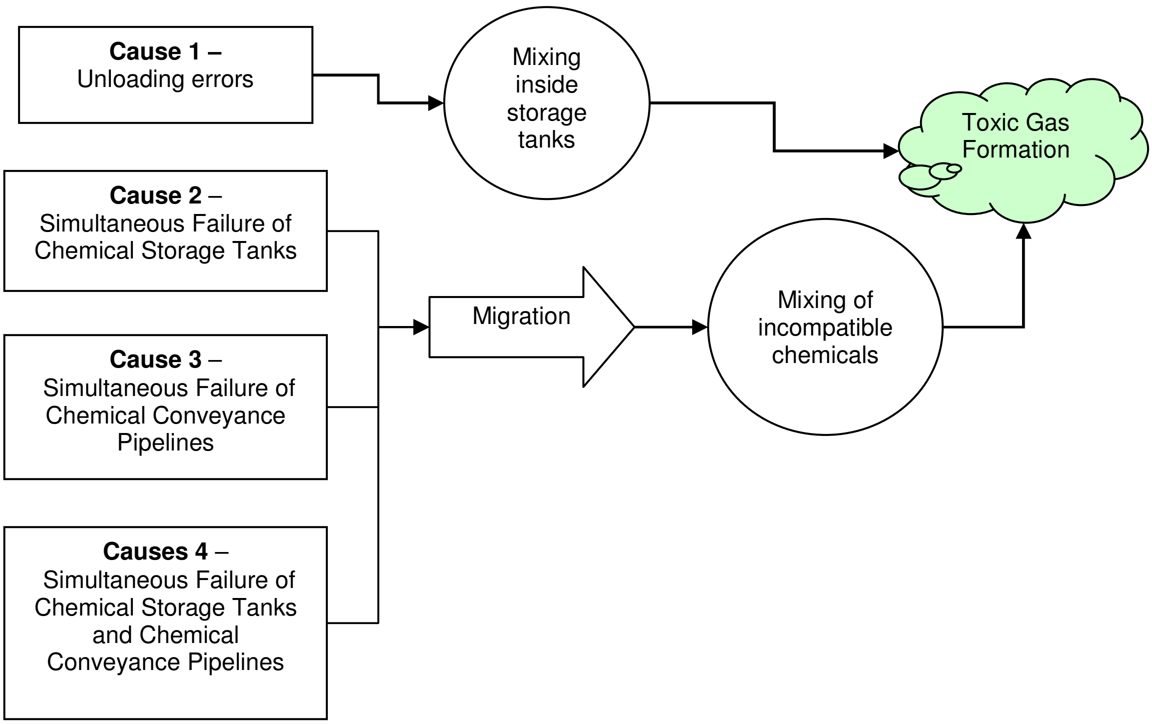
Overview

11.108 There would be the potential for off-site fatality when mixing of incompatible chemicals occur on-site leading to generation of toxic gas that eventually migrates off-site. There are four identified causes for the scenario of mixing of incompatible chemicals:

- Cause 1 - Error in chemical unloading operations
- Cause 2 – Simultaneous release of incompatible chemicals from their respective storage tanks
- Cause 3 – Simultaneous release of incompatible chemicals from their respective conveyance pipelines
- Cause 4 – Simultaneous release of incompatible chemicals from their storage tanks and pipelines

11.109 These three causes are illustrated in **Exhibit 11.1**.

Exhibit 11.1 Diagrammatic Illustration of Pathways for Toxic Gas Formation due to Mixing of Incompatible Chemicals



Cause 1 - Error in Unloading Operations

11.110 There will be separate supply contracts each for ferric chloride, sodium hypochlorite, and sodium bisulphite. For ferric chloride and sodium bisulphite, these two chemicals will only be delivered by road tanker, as there is no barge-unloading facility for the ferric chloride or sodium bisulphite tank farm.

11.111 For sodium hypochlorite, barge-unloading facilities will be provided so that the chemical can be delivered by a specially designed delivery barge, unloaded to the sodium hypochlorite storage tank via separate dedicated pipelines. Road tanker unloading facilities will also be provided at the sodium hypochlorite tank farm, so that the chemical can be delivered by road tanker in the event that conditions do not allow barge delivery.

11.112 As sodium hypochlorite will be mainly delivered by barge, special conditions will be included in the supply contract for sodium hypochlorite. In the contract, the use of the delivery barge provided will be restricted for delivering sodium hypochlorite directly and exclusively from the supplier's production plant to SCISTW during the contract period. The delivery barge will not be allowed to provide other services, such as carrying other chemical or carrying chemicals to other facilities other than SCISTW. In addition, SCISTW staff will only accept the chemical delivered by the specially designed delivery barge from the chemical supplier. Under such circumstances, the delivery barge provided by the sodium hypochlorite supplier will only carry sodium hypochlorite to SCISTW.

11.113 As mentioned above, no barge-unloading facility will be provided for ferric chloride and sodium bisulphite tank farm. Therefore, there is no physical pipe connection from the barge unloading facilities to ferric chloride and sodium bisulphite tank farm so it is impossible to unload sodium hypochlorite from delivery barge to ferric chloride or sodium bisulphite tank. As a result, sodium hypochlorite carried by the specially designed delivery barge will only be unloaded to the sodium hypochlorite tank farm via the dedicated pipeline but not ferric chloride and sodium bisulphite tank farms. Hence, sodium hypochlorite will not mix with ferric chloride or sodium bisulphite in the unloading operation by delivery barge. Therefore, the cause "error in unloading operation" is not applicable to barge delivery operation.

11.114 Nevertheless, error in unloading operations via *road tanker delivery* of chemicals could be possible in the current Project. The frequency of occurrence of this event is further assessed in **Sections 11.187** to **11.215**.

Cause 2 - Simultaneous Release Incompatible Chemicals from Storage Tanks

<u>Release Mode</u>

11.115 The incompatible chemical mixing scenario under the cause "release of incompatible chemicals from their respective storage tanks" can only occur if:

- Both the ferric chloride and sodium hypochlorite solutions are somehow released, at the same period of time, into unintended areas of SCISTW from their respective storage; and
- Then, the two substances are allowed to migrate to a location(s) where they come into contact with each other

11.116 Unintended release of either chemical from their respective storage tanks could be caused by failure of the storage tank because of cracks, punctures, rupture, etc. These in turn could be caused by intrinsic factors (e.g., weathering of tank material) or external impacts (e.g., a crashing airplane, earthquakes, malicious attacks, etc).

11.117 The following paragraphs outline the existing/proposed engineering control measures in place/to be implemented to prevent the ferric chloride and sodium hypochlorite solutions from coming into contact with each other, in the event of simultaneous failure of the storage tanks leading to unplanned release of the chemicals.

11.118 Firstly, it should be noted that ferric chloride and sodium hypochlorite are stored under ambient atmospheric pressure conditions, which are not pressurised. Therefore, in the event of leakage of chemical from the storage tank, the content will be released from a hole in the tank discharged as a liquid stream under the force of gravity.

11.119 In the event of storage tank rupture, the stored chemical will be released in a manner similar to a cylindrical column of liquid free to collapse under gravity (i.e. released liquid would fall vertically into the bund). Owing to the vertical momentum of the released liquid, some liquid may splash over the bund wall and spread to other areas of SCISTW.

Existing Ferric Chloride Storage Facility

11.120 There are six existing ferric chloride solution storage tanks (each about 8m diameter, 13m tall). These are located in a tank farm on the northeastern corner of the SCISTW, as shown in **Figure 11.7**. The figure presents a proposed layout plan of SCISTW after HATS Stage 2A construction works are completed, which shows the layout of the existing facilities, the proposed sodium hypochlorite storage tanks (located at the southern side of the site) and other structures for HATS Stage 2A.

11.121 To the north of the ferric chloride tank farm is the sea. At its farthest point, the tank farm is approximately 30m from the seawall cope line. The waterfront pavement is graded towards the sea to facilitate surface drainage. Stormwater drains are also present to intercept surface runoff.

11.122 Immediately behind the tank farm on the south (landward) side is the Chemical Dosing Building, which is approximately 64m long by 9m wide, with a height greater than the ferric chloride tanks and the filled ferric chloride level by 1 to 7m and 2.5 to 8.5m respectively. Photos showing such feature are presented in **Figure 11.12**. A bund wall of more than 1m above adjacent ground level surrounds the ferric chloride tank farm; this is to contain any chemicals spilled or leaked from tanks in the event of failure of the tanks. Per design requirements overseen by Fire Services Department, the volume of the containment is 110% of the capacity of a single tank, acknowledging that it is unlikely that all tanks will fail at the same time.

11.123 Any leaked or spilled ferric chloride solution will be caught initially inside the bund wall. Depending on the rate of release, two scenarios may arise:

- Scenario 1 - If the rate of the unintended release is low, the ferric chloride solution can be pumped out before it overtops the containment. The pumped-out liquid can then be disposed of as chemical waste safely and transported out of the SCISTW. This way, the released ferric chloride will not enter into the vicinity of the chlorination plant located on the other (southern) side of the site.
- Scenario 2 - If the rate of release is high or violent (e.g., due to rupture of several or all storage tanks at the same time), the ferric chloride solution could overtop the bunded containment before it can be pumped away or it somehow could escape the confines of the bunded containment. In this case, there is a potential for the escaped solution to migrate farther than the immediate vicinity of the tank farm.

11.124 However, even under Scenario 2, given the substantial size and form of the Chemical Dosing Building relative to the storage tanks, it is providing a solid, effective barrier to prevent any spilled or leaked chemical from flowing towards the south side of the SCISTW site (where the chlorination plant is located). Moreover, the new pumping station and associated works will serve as additional barrier to stop spilled ferric chloride flowing towards southward.

11.125 Further, the site surface gradient will direct the spilled ferric chloride solution towards the sea before it can reach the road separating the sedimentation tank and the sludge treatment facilities. In addition, the surface drains located southwest of the ferric chloride tank farm will intercept any spilled ferric chloride that find its way in the uphill direction and will discharge the ferric chloride solution into the sea through the stormwater outfall.

11.126 In view of the above mitigating factors or engineering controls, it is concluded that any ferric chloride solution released unintentionally from the tank farm would not flow to the southeastern part of SCISTW, where the sodium hypochlorite tank farm will be located.

11.127 The above HATS Stage 2A structures will not be in place when ADF is commissioned. Nevertheless, the construction stage of HATS Stage 2A will have been commenced. As shown in **Figure 11.8**, during the construction of HATS Stage 2A, the site for the new pumping station will be an excavated area. Rather than a screening structure, this excavated area will be a large area to contain the spilled ferric chloride and prevent it from flowing to the southeastern part of SCISTW.

11.128 **Figure 11.8** also shows that location of a screening structure made of water-filled barriers, which will be constructed southwest of excavated area. The purpose of the screening structure will be explained below.

Proposed Sodium Hypochlorite Tanks

11.129 The proposed sodium hypochlorite tank farm will be located at the southeastern part of SCISTW, as shown in **Figure 11.7**. In the tank farm, there will be six sodium hypochlorite storage tanks (each about 8m in diameter, 12.5m tall) and these tanks are surrounded by bund walls with 2m high.

11.130 As mentioned previously, located between the two tank farms will be the existing Chemical Dosing Building, a new pumping station, rapid mixing tanks as well as flocculation tanks to be constructed under HATS Stage 2A. These permanent structures would serve as obstacles to prevent the pools of the two spilled chemicals from coming into contact with each other.

11.131 Before the completion of Stage 2A works, mitigation measures will be provided to contain, intercept, and direct any spillages to flow in opposite directions to avoid the mixing of the spilled chemicals, as elaborated in the following paragraphs.

Multi-barrier Approach to Avoid Mixing of Ferric Chloride and Sodium Hypochlorite Solutions

11.132 Since the spilled chemicals will spread by flowing along the ground surface, the scenario of ferric chloride mixes with sodium hypochlorite (in the event of simultaneous tank failure in both tank farms) can be avoided by the following design features, which serve as a "multi-barrier system", along the separation area between the tank farms:

- Surface gradient to direct the spilled chemicals to flow in opposite direction
- Screening structures as shown in **Figure 11.8** to block the spilled sodium hypochlorite from flowing towards the ferric chloride tank

11.133 The objective of the above mitigation measures is to prevent the spilled sodium hypochlorite from flowing to the northeastern corner of SCISTW, to avoid the pools of the two spilled chemicals from contacting with each other.

11.134 At the same time, the areas where the two pools of spilled chemicals will be contained would be served by separate drainage systems with different discharge points to prevent mixing of spilled chemicals in the drainage system.

11.135 Specific design measures will include:

- Proposed Design Feature – Containment Structure
  - A bund wall of 2m tall will be built around the sodium hypochlorite tank farm to contain spillage of the chemical (up to 110% of the capacity of a single tank), which will retain the spilled sodium hypochlorite within the bund wall in the event of storage tank leakage.
- Proposed Design Feature – Screening Structure
  - An impermeable screening structure made of water-filled barriers with about 1m high, covered with impermeable plastic sheetings, will be erected at about 70m

northeast of the sodium hypochlorite tank farm, before the future flocculation and rapid mixing tanks are constructed directly adjacent to the sodium hypochlorite tank farm. The screening structure, together with the existing Stage 1 sedimentation tanks, will form an additional containment structure that can contain a volume of more than [3]4,200m^3,which is greater than the maximum storage amount of sodium hypochlorite of ADF operation. Moreover, the drains serving the southeast region of the SCISTW will have intercepted some of the spilled sodium hypochlorite and discharge into the sea via storm outfall.

- It is expected that the screening structure would effectively contain the spilled sodium hypochlorite and avoid the spilled chemicals from flowing seaward across the road separating the sedimentation tank and the sludge treatment facilities.

- Proposed Design Feature – Surface Gradient
  - To enhance further the effectiveness of the screening structure, the surface for the land reserved for the future flocculation tanks and rapid mixing tanks will be designed to grade towards the sodium hypochlorite tank farm. This arrangement could reduce some momentum of the spilled chemical flowing northeast when it travels uphill along the 70m long surface.
- Proposed Design Feature – Separate Drainage System
  - To avoid mixing of spilled chemicals within the drainage systems, the drainage channels within the containment made of screening structure will be connected to drainage system different from those serving the area around the ferric chloride tank farm. The two drainage systems will discharge via different outfall to different sea area.

11.136 **Figures 11.13** and **11.14** presents the cross section from the ferric chloride tank to the sodium hypochlorite tank farm in 2009 (commissioning of ADF) and 2013/14 (completion of HATS Stage 2A works) respectively. The cross sections show a series of structures and engineering measures that avoid mixing of spilled sodium hypochlorite and ferric chloride.

11.137 In view of the above mitigating factors or engineering controls, it is concluded that any sodium hypochlorite solution released unintentionally from the tank farm will not flow to the northern part of SCISTW, where the ferric chloride tank farm is located.

11.138 A sodium hypochlorite day tank with capacity of about 100m^3 will be installed at the southwestern corner of SCISTW, at about 320m from the ferric chloride tank farm. Due to the small capacity of the sodium hypochlorite day tank, even assuming the spilled liquid pool is allowed to spread freely in an undiked area, the largest possible size of the liquid pool will be limited, with a radius of [4]56m. In reality, spillage from the day tank flowing in the direction towards the ferric chloride tank farm will be blocked by the surrounding structures (the existing main pumping station, switchgear building, and sedimentation tanks). Therefore, spilled sodium hypochlorite from the day tank would not be in contact with the spilled ferric chloride.

<u>Conclusion</u>

11.139 The above discussion has demonstrated that in the events of low chemical release, such as tank leakages and single-tank rupture, the provision of the bund wall, the large separation distance and also the physical barriers between the two chemical farms will be more than adequate to prevent the spilled incompatible chemicals from mixing.

11.140 Even in the extreme scenario when all storage tanks in the two tank farms collapse simultaneously (which by the way is considered an extremely remote scenario), the

[3] 4200m^3 = 70m (length of the area surrounded by water-filled barriers) x 60m (width of the area surrounded by water-filled barriers) x 1m (height of water-filled barriers).
[4] According to USEPA (1999) "Risk Management Program Guidance for Offsite Consequence Analysis", the spilled chemical can be assumed to spread instantaneously to a depth of 10mm in an undiked area. Therefore, the 100m^3 of sodium hypochlorite in the day tank, if spilled and allowed to spread freely in undiked area, the radius of the spilled pool $=\sqrt{(100m^3/\pi\ 0.01m)} = 56m$.

proposed design features can prevent the spilled ferric chloride solution from flowing to the south-eastern part of SCISTW and prevent the spilled sodium hypochlorite from flowing to the north-eastern corner of SCISTW.

11.141 Therefore, ferric chloride and sodium hypochlorite will not mix with each other, under any situations at SCISTW involving unintended release of the two chemicals from their storage tanks. Therefore, the occurrence frequency of incompatible chemicals mixing due to the cause “simultaneous release incompatible chemicals from storage tanks” is zero.

Cause 3 - Simultaneous Release Incompatible Chemicals from Conveyance Pipelines

Release Mode

11.142 The incompatible chemical mixing scenario under the cause “simultaneous release of incompatible chemicals from conveyance pipelines” can only occur if:

- Both the ferric chloride and sodium hypochlorite solutions are somehow released, at the same period of time, into unintended areas of SCISTW from their respective conveyance pipelines; and

- Then, the two substances are allowed to migrate to a location(s) where they come into contact with each other

11.143 Unintended release of either chemical from their respective pipelines could be caused by failure of the pipeline because of cracks, punctures, rupture, etc. These in turn could be caused by intrinsic factors (e.g., weathering or degradation of pipe material) or external impacts (e.g., earthquakes, malicious attacks, etc).

11.144 The following paragraphs outline the existing/proposed engineering control measures in place/to be implemented to prevent the ferric chloride and sodium hypochlorite solutions from coming into contact with each other, in the event of simultaneous failure of the pipelines leading to unplanned release of the chemicals.

Existing Ferric Chloride Pipeline

11.145 As shown in **Figure 11.9**, the alignment of the existing ferric chloride delivery pipeline runs from the ferric chloride tank farm to a reception point at the upstream end of the CEPT plant. As shown in **Figure 11.10a**, the ferric chloride pipeline is protected by an external sleeve pipeline in a pipe-in-pipe configuration, inside a buried watertight reinforced-concrete service-duct. Alongside the duty pipeline is a duplicate (standby) pipeline that is kept empty.

11.146 The service-duct cross-section has internal height and width of 2.2m and 3.0m, respectively, and provides for easy access by personnel for regular maintenance and inspections. The service-duct is buried with a minimum cover of 0.55m below ground surface. The thickness of both the wall and the roof slab is 0.3m, and the ground slab is 0.6m thick. The service-duct structure is supported on piles.

Release Mitigation Measures

11.147 The ferric chloride solution is pumped from the tank farm to the CEPT plant. Two measures are in place to minimise the amount of chemical release from the pipeline in case of pipe leaks or bursts. These are:

- While there are six storage tanks (five-duty and one-standby) in the tank farm, only one tank will be connected to the delivery pipeline at any one time. This is achieved by controlling the valves at the bottom of each storage tank.

- In addition, pump pressure is continuously monitored by plant operators, who will shut down the pumps immediately if irregular pressure drops occur (indicating faults such as pipe leaks or bursts).

11.148 In addition, it is proposed to install a vibration sensing system[5] at the ferric chloride tank farm to enable shut down of the chemical pumping system whenever excessive vibrations are detected. The objective of the vibration sensing system is to isolate the ferric chloride delivery pipeline from the upstream storage tanks in case of excessive vibrations, so that the amount of chemical that can escape in the event of failure of the pipeline due to excessive vibrations is minimised.

Release during Normal Operations

11.149 Owing to the above multi-barrier arrangement, release of ferric chloride solution into the environment is impossible under *normal operating* conditions. In this scenario, the concern is on intrinsic factors such as weakening or failure of pipe material due to aging, leading to leakage. Alternatively, pipe bursting could occur at undetected weak points of the pressurised pipeline. For this to happen, however, the condition of the pipeline will have to deteriorate significantly without being noticed, which is unlikely given regular inspection and maintenance. In any case, there are two further barriers that will prevent release of the chemical into the environment:

- Firstly, any ferric chloride solution released from the duty pipeline due to leakage or a pipe burst will be contained by the sleeve pipeline.

- Secondly, even if the sleeve pipe fails, the pressure monitoring procedure would have worked to isolate the pipeline from the upstream storage tank. If the isolation could be effected immediately, then the amount of chemical release would be limited to the volume of the pipeline (i.e., about 7.8m^3). In practice, a short period would have elapsed before all the concerned pumps and valves can be completely closed. Therefore, it is possible that more than one pipe volume of chemical would be released. Given that the pumping rate for ferric chloride is 0.4L/s and assuming that it would take 10 minutes to completely isolate the pipeline, then up to 1.03 (1 pipe-volume of chemical originally filled in the pipeline plus the additional 0.03 pipe-volume leak before the pipeline isolation) (i.e. 8.03m^3) could be released into the service-duct. However, the void space available in the service-duct[6] is about 2,464m^3, which is more than adequate to contain the released chemical. This also means that, even in the unlikely scenario of failure of the pressure monitoring procedure, and a whole tank of ferric chloride solution (about 400m^3) is released, the entire tank load will still be able to be contained in the service-duct. No release into the environment is possible.

Release during Extreme Scenario

11.150 In the *extreme scenario*, a catastrophic external impact on the chemical pipeline is assumed to occur at SCISTW. In this context, as the pipeline is buried underground, the external impact may be represented by large vibrations caused by an earthquake affecting Hong Kong.

11.151 In this case, the duty pipeline could burst and sleeve pipeline could crack simultaneously, but the pressure and vibration monitoring procedures would have worked to contain the chemical release to 8.03m^3. Even if the both the pressure and vibration monitoring procedures were to fail, the reinforced-concrete service duct would still act as a barrier to release of chemical into the environment, as elaborated below.

11.152 The reinforced concrete service-duct is a strong piled-structure. Therefore, it could only fail in the sense that its watertightness might be compromised due to cracks induced by excessive vibrations, and that it may suffer some minor structural damages, but the service-duct should physically remain intact. This means that the service-duct would still act a barrier to the immediate release of the chemical solution to the environment.

[5] The vibration sensing system will raise an alarm signal to the plant operators when excessive vibrations (exceeding 25mm/s peak particle velocity and 0.2mm amplitude) are detected. Upon receiving the alarm signal, the operators will stop pumping immediately.
[6] As seen in **Figure 11.10**, the cross section area of the service duct is = 3m x 2.2m = 6.6m^2. Assume 15% of the area (i.e. 1m^2) is occupied by the ferric chloride pipeline and other cables installed in the service duct. As the length of the service duct is about 440m, the volume of the service duct is about 5.6 x 440 = 2,464m^3.

11.153 While the cracks so opened up in the reinforced concrete slab by the vibrations would allow liquid to seep through under the force of gravity, several mitigating factors would stop the spread of the chemical beyond the immediate vicinity:

- Firstly, the liquid chemical in the large confines of the service-duct would be spread along the length (several hundred metres) of the service-duct. This means that the liquid chemical will not create a sizable hydraulic head that can rapidly drive the liquid through the cracks under the force of gravity only.
- Secondly, the concrete slabs are extremely thick (0.3m sidewalls and 0.6m bottom slab), presenting significant resistance to the flow of liquid even through the cracks.
- Thirdly, unsaturated concrete could absorb some of the liquid into its own material matrix, thereby reducing the amount of ferric chloride that could pass through.
- Fourthly, any liquid chemical that eventually migrates through the reinforced-concrete box duct, which will be relatively small in quantity, will be quickly soaked up by the vast underlying soil matrix.

11.154 Overall, it is concluded that no ferric chloride solution can migrate beyond the immediate alignment of the box duct even in the extreme scenario.

Proposed Sodium Hypochlorite Pipelines

11.155 The alignments of the proposed sodium hypochlorite pipelines are shown in **Figure 11.9**. The first section (or feed section) starts at the barge unloading point and travels in a buried reinforced-concrete pipe trench to the sodium hypochlorite tank farm. This section of pipeline (0.25m diameter) is pressurised in that the liquid has to be pumped to the top of the tanks for discharge into storage tanks. As barge deliveries will only be made twice a week, the feed section will not be in constant use, but only once every three days and for four hours on each occasion to convey the sodium hypochlorite solution to the storage tanks. After each use, the sodium hypochlorite feed pipeline will be completely drained to avoid accumulation of any residual chemical solution in the pipeline.

11.156 From the tank farm, the second section (or dosing section) of the pipeline (0.1m diameter) starts at the bottom of the tanks and convey the hypochlorite solution by pumping to the day tank adjacent to the flow distribution chamber. The dosing section will convey hypochlorite solution to the day tank on a daily or bi-daily basis for about three hours each time.

11.157 The hypochlorite pipe trench is of watertight reinforced-concrete construction. Alongside the duty pipeline in the same trench will be a standby pipeline. **Figures 11.10a** and **11.10b** show the typical cross-sections of the feed and dosing sections, respectively.

11.158 Similarly, a multi-barrier approach to containment of any leaks or pipe bursts is proposed:

- The duty pipeline (for both feed and dosing sections) will be protected by a sleeve pipeline, and both will be contained in a covered concrete trench
- The pipeline sections will be regularly inspected and maintained, such that any deterioration in pipe material condition will be repaired or rectified before it becomes critical
- A leak (pressure) monitoring procedure will be implemented during unloading of the hypochlorite solution from the barge
- A vibration sensing system will be installed at the hypochlorite tank farm to raise alarm for shut down of the pumping system in the event of excessive vibrations
- Further, a section of the hypochlorite *feed* pipe-trench will be wrapped by heavy-duty impervious membrane[7] to provide an added barrier to migration of hypochlorite solution in the unlikely event of failure of all the other barriers. As shown in **Figure 11.9**, this section has a length of about 170m and runs alongside the existing ferric

[7] The membrane would be made of high-density polyethylene (HDPE), which is a high-tensile strength, impermeable, and corrosion-resistant material that is typically used in landfill liners.

chloride service duct. As shown in **Figure 11.10a,** the impervious membrane will be applied to the three external surfaces (two sidewalls and the bottom slab) of the hypochlorite pipe trench to prevent passage of liquid from inside to the outside. To isolate the impervious membrane from the concrete surface, such that the impervious membrane will not be stressed by any movement of the concrete, a geo-textile[8] sheet (i.e., a de-bonding layer) will be installed between the impervious membrane and the concrete surface.

- Also shown in **Figure 11.9**, the hypochlorite pipe trench will cross over the ferric chloride service-duct at a point near the middle of the southern site boundary. At this cross over location, the impervious membrane will be protected by a geo-textile sheet (de-bonding layer) on both sides to isolate it from the concrete surface. Details of the arrangement are shown in **Figure 11.10c**.

Feed Section (from Barge Unloading Point to Storage Tank Farm)

11.159 With respect to the sodium hypochlorite feeding pipe trench (section between the barge unloading facility and hypochlorite storage tank), its average cross-section area is 1.0m x 1.7m = 1.7m^2. With a pipe trench length of about 357m, the effective void space available in the pipe trench to contain leaked sodium hypochlorite[9] would be about 548m^3.

11.160 The crossover section is the point where the hypochlorite pipeline will be closest to the ferric chloride pipeline. Therefore, in addition to the multi-barriers (i.e., sleeve pipe, watertight reinforced-concrete pipe trench, impervious membrane, feed pressure monitoring, vibration monitoring, etc), it is proposed to grade (drain) the pipe trench to prevent accumulation of any spilled or leaked hypochlorite solution inside the feed pipe trench. The intention is to eliminate the possibility of hypochlorite migrating to the ferric chloride pipeline located below under any circumstances. The proposed cross-over arrangement is illustrated in **Figure 11.10c**, and described below:

- The hypochlorite pipe trench normally runs flush with ground surface except at where it crosses over the ferric chloride pipeline service-duct. At this point, the former will rise above the ground surface to cross over the latter. Thereafter, the hypochlorite pipe trench will sink back to below ground surface and runs towards the hypochlorite tank farm
- To prevent accumulation of any spilled or leaked hypochlorite solution at this point (which is the highest point of the feed pipe trench), the feed pipe trench will be drained in two directions from this point:
    - Moving upstream from this point, the pipe trench will be graded to fall towards the north and northeast so that any liquid inside this section of the pipe trench will be discharged into the sea via an opening at the upstream end of the pipe trench through the existing seawall near the Barge Unloading Facility.
    - Moving downstream from this high point, the pipe trench will be graded to fall towards the southwest so that any liquid inside this section of the pipe trench will be collected in a sump inside the hypochlorite tank farm bunded enclosure.

11.161 Under *normal chemical unloading conditions*, any leakage or pipe burst (due to undetected weak points in the pipe material) causing a pressure drop will be identified by the operators, who will quickly shut down the pumps to isolate the pipeline from the delivery barge. Assuming that the pump rate is 0.035m^3/s, and it would take 10 minutes to completely isolate the pipeline, up to about 2.2 (1 pipe-volume of chemical originally filled in the pipeline plus the additional 1.2 pipe-volume leak before the pipeline isolation) pipe-volumes (38.5m^3) may be released. In such case, the pipe trench will be able to

[8] A geotextile fabric, similar to felt in appearance, has high puncture resistance, large elongation before break, and drainage characteristics will be used to separate the impervious membrane from the concrete surface.

[9] With consideration of the space taken by the two sodium hypochlorite feed pipes (with outer diameter of 370mm for sleeve pipeline), the void space of pipe trench would be about = (1.7m^2 x 357m) – 2 x (π x 0.185^2 x 357) = 530m^3. Since the feed pipelines will not be filled except during the barge unloading process, the cavity of the duty feed pipeline will provide space to contain the sodium hypochlorite being unloaded. With diameter of 250mm for the delivery pipe, the cavity of the delivery pipe is about (π x 0.125^2 x 357)m^3 = 17.5m^3. Therefore, the available void space for containment of the unloading sodium hypochlorite would be about 530m^3 + 17.5m^3 = 547.5m^3.

contain totally the released sodium hypochlorite solution. It will be impossible for any chemical to escape into the environment.

11.162 It should be noted that as the chemical is fed from the top into the storage tanks, no hypochlorite solution could escape back into the feed pipe under any circumstances.

11.163 Again, for the purposes of this assessment, the *extreme scenario* would be for excessive vibrations from an earthquake affecting Hong Kong to damage the feed pipeline and sleeve pipeline simultaneously, and to jeopardise the watertightness of the reinforced-concrete pipe trench. For this to happen, the catastrophic impact must occur at the same time as chemical unloading is conducted (which only occurs once every three days for about four hours each time). The likelihood of this is extremely remote.

11.164 However, in any case, the unloading operation will cease within a short period after the catastrophic impact strikes, as the vibration detection system will raise an alarm to cause the operators to stop the pump at the barge. Allowing for 10 minutes for reaction time, the maximum quantity of chemical release into the pipe trench would be equivalent to perhaps no more than 2.2 pipe-volumes of chemical ($38.5m^3$), which would be comfortably contained by the pipe trench (capacity $548m^3$). Even if the alarm system was to fail or the operators were unable to shut down the system for whatever reasons, and the whole barge load ($500m^3$) of hypochlorite is drained, the hypochlorite solution would still be contained by the feed pipe trench (capacity $548m^3$). Then, the collected liquid will be drained to the sea or a sump inside the hypochlorite tank farm.

11.165 As mentioned previously, while the cracks so opened up in the reinforced concrete slab by the vibrations would allow liquid to seep through under the force of gravity, several mitigating factors would stop the spread of the chemical beyond the immediate vicinity:

- Firstly, as mentioned above, the gradient in the pipe trench will quickly drain the liquid rather than allowing it to accumulate at any point in the pipe trench. This means that the condition for formation of a sizable hydraulic head that can rapidly drive the liquid through the cracks will not occur.
- Secondly, the reinforced concrete slab of 0.15m thick, would present much resistance to the flow of liquid even through the cracks. As the liquid will flow through the path of least resistance, it will drain preferentially to the sea or the sump inside the hypochlorite tank farm, rather than vertically through the cracks.
- Thirdly, unsaturated concrete could absorb some of the liquid into its own material matrix, thereby reducing the amount of ferric chloride that could pass through.
- Fourthly, any liquid chemical that eventually migrates through the reinforced-concrete pipe trench, which will be relatively small in quantity, will be stopped by the heavy-duty impervious HDPE membrane. The membrane will probably deform under stress, but owing to its high tensile strength, it will not tear, break, or puncture in the circumstance.

11.166 Overall, it is concluded that no sodium hypochlorite solution can migrate beyond the immediate alignment of the concrete pipe trench even in the extreme scenario. An assessment of the potential for the sodium hypochlorite solution released from the feed pipeline to mix with the ferric chloride solution simultaneously released from the ferric chloride is summarised in **Section 11.170**.

Dosing Section (from Hypochlorite Tank Farm to Day Tank)

11.167 The cross sectional area of the sodium hypochlorite dosing pipe trench (from storage tank to day tank) is about 0.5m x 1.3m = $0.65m^2$. The cross-section area taken up by the duty and stand-by dosing pipes[10] would be = $2 \times \pi \times 0.135^2 = 0.115m^2$. With a length of about 332m, the void space available in the dosing pipe trench would be about $177.6m^3$.

11.168 Under normal conditions, any leakage or pipe burst (due to undetected weak points in the pipe material) can be quickly identified by the pressure monitoring procedure and rectified by shut down of the upstream valve connecting it to the storage tank. As mentioned

[10] The diameter of the dosing pipeline and sleeve pipeline is 150mm and 270mm respectively.

previously, if instantaneous isolation is achieved, the volume of chemical that can be released cannot be more than the capacity of the duty dosing pipeline, which is about $\pi \times 0.075^2 \times 332 = 5.9m^3$. Assuming that the pump rate is $0.01m^3/s$, and it would take 10 minutes to completely isolate the pipeline, up to about two (1 pipe-volume of chemical originally filled in the pipeline plus the additional 1 pipe-volume leak before the pipeline isolation) pipe-volumes ($12m^3$) may be released. Therefore, the pipe trench (capacity of $177.6m^3$) will be able to contain totally the released sodium hypochlorite solution.

11.169 In case the alarm system was to fail or the operators were unable to shut down the system for whatever reasons, a whole tank load of sodium hypochlorite could be drained. However, even in this case, mixing of the two chemicals will not be possible, as there is significant separation (160m) with a substantial barrier (e.g. the existing sedimentation tanks) located in between the service duct accommodating the ferric chloride dosing pipelines and the sodium hypochlorite dosing pipe trench.

11.170 In conclusion, in the extreme scenario of an earthquake affecting Hong Kong, the vibration sensing system, the reinforced concrete pipe trench, and the underlying soil matrix will work together to stop chemical migration beyond the immediate vicinity of the pipe trench alignment. In any case, as mentioned earlier, the presence of a massive barrier (in the form of the existing sedimentation tanks) will prevent any released hypochlorite solution from reaching the ferric chloride pipeline located some 160m away.

Assessment of Possibility of Mixing of Incompatible Chemicals

11.171 For mixing of sodium hypochlorite and ferric chlorides solutions to occur, they must be released from their respective pipelines at the same time due to a rare catastrophic impact (e.g., a significant earthquake), and then be allowed to migrate to a point(s) where they meet.

11.172 The above assessments have demonstrated that any chemical releases from the pipelines in the event of either normal or extreme conditions will not be able to migrate beyond the immediate vicinity of the service-duct/ pipe trench alignments:

- For the feed section of the hypochlorite pipeline, the most critical section for mixing is where the two pipelines run parallel to each other (as shown in **Figure 11.9**). Here, the extreme case will be an earthquake (occurring at the same time as unloading of the hypochlorite solution) leading to excessive vibrations that simultaneously damage the two pipelines and associated ducting/trenches. However, as discussed above, mixing of the two chemicals will still not be possible due to the multi-barriers, in particular the functioning of the heavy-duty impervious membrane (which might deform but will not tear or fail) which will totally contain the hypochlorite solution in this extreme circumstance.
- For the dosing section of the hypochlorite pipeline, it is both remote and separated from the ferric chloride pipeline. As shown in **Figure 11.9**, the two pipelines are located on opposite sides of the existing sedimentation tanks (which may be regarded as a massive physical barrier) with a separation of about 160m. It is therefore impossible for any released chemicals from the dosing section of the hypochlorite pipeline and the ferric chloride pipeline to reach each other, even without any leakage containment or mitigation measures for the dosing section of hypochlorite pipeline.
- Therefore, mixing of the two chemicals is not possible in any circumstances.

11.173 In conclusion, ferric chloride and sodium hypochlorite will not mix with each other, under any situations at SCISTW involving unintended release of the two chemicals from their respective pipelines. A range of mitigation measures has been proposed, including measures to drain the released hypochlorite solution rapidly to the sea or an underground sump pit even under the extreme scenario. Therefore, the occurrence frequency of incompatible chemicals mixing due to the cause “simultaneous release incompatible chemicals from conveyance pipelines” is zero.

Cause 4 - Simultaneous Failure of Storage Tanks and Pipelines

11.174 This scenario is a combination of Causes 2 and 3, and refers to mixing due to the simultaneous failure of pipeline and storage tank. It can only occur if:

- Both the ferric chloride and sodium hypochlorite solutions are somehow released, at the same period of time, into unintended areas of SCISTW from their respective conveyance pipeline and storage tank; and
- Then, the two substances are allowed to migrate to a location(s) where they come into contact with each other

11.175 For this scenario, two cases are considered:

- Case 1 – Simultaneous Failure of a Ferric Chloride Tank and a section of the Sodium Hypochlorite Pipeline
- Case 2 – Simultaneous Failure of a Hypochlorite Tank and a section of the Ferric Chloride Pipeline

Case 1

11.176 The Ferric Chloride Tank Farm is located on the eastern edge of the SCISTW site adjacent to the sea, as shown in **Figure 11.9**. As mentioned earlier, failure of any ferric chloride storage tank will lead to a release of the chemical. As the tank farm is surrounded by a 1.2m high bund wall all round, any leaks from the storage tanks will be contained within the bunded enclosure.

11.177 In the event of tank rupture, however, some of the released chemical solution could overtop the bund wall. As the tank farm is shielded on the western side by the massive Chemical Building, the ferric chloride solution that manages to overtop the bund wall would spread to the other three directions, where the spilled ferric chloride spreading to the eastern direction will flow into the sea. This means that, if not controlled, some ferric chloride solution could reach the sodium hypochlorite pipeline near the Barge Unloading Facility, which is located about 35 metres away to the north of the Ferric Chloride Tank Farm.

11.178 Therefore, in the extreme scenario of a seismic event occurring during unloading of sodium hypochlorite solution and simultaneous failure of the feed hypochlorite pipeline/pipe-trench and one or more ferric chloride storage tanks, there is a potential for the two chemicals to mix with each other.

11.179 To prevent the mixing of incompatible chemicals from occurring in the extreme scenario, the following precautionary or mitigation measures are proposed (**Figure 11.9** and **11.10d** refers):

- Increase the height to 2.3m of a (12m + 10m =) 22m long section of the bund wall around the northernmost storage tank (which is the tank closest to the hypochlorite pipeline to the west). This tank is hereinafter referred to as Tank A.
- Construct a raised road kerb with height of 0.1m near the barge unloading facility, which is located about 22m from the nearest ferric chloride tank farm bund wall. The kerb is to run perpendicular to the seawall, and has a length of about 20m.
- Construct a drain at the foot of the kerb to collect and drain any spilled ferric chloride solution to the sea.
- Restrict storage of ferric chloride storage solution in Tank A to no more than 350m^3, which means that the height of the liquid in the tank will be no higher than about 6.96m[11].

11.180 The following calculations explain how the abovementioned precautionary mitigation measures could avoid released ferric chloride solution from storage tank spreading to the barge unloading facility.

[11] The maximum required ferric chloride solution capacity at SCISTW during HATS Stage 2A is 1,900m^3 and each storage tank has a capacity of 433m^3. By limiting the volume of stored liquid to 350m^3 at Tank A, each of the other 4 duty storage tanks will need to share a storage volume of 387.5m^3, which is lower than the tank capacity. Therefore, such precautionary measure is feasible in terms of SCISTW operation.

11.181 Thyer *et al*. (2002) give the following correlation for the bund overtopping fraction Q over vertical bund walls:

- Q = 0.044 – 0.229 ln(h/H) – 0.116 ln(r/H)
- Where Q = bund overtopping fraction; h = bund wall height (which is 2.3m in this case); H = tank liquid height (which is 6.96m), and r = distance from the centre of the Tank A to the bund wall (which is 5m)

11.182 This gives Q = 0.044 – 0.229 ln(2.3/6.96) – 0.116 ln(5/6.96), that is Q = 0.336. In other words, 33.6% of the liquid in the tank could overtop the bund wall. Therefore, the volume of ferric chloride solution that could overtop the bund wall is = 350m^3 x 0.336 = 117.6m^3.

11.183 Considering a circular liquid pool is formed by the 117.6m^3 of ferric chloride solution with radius of 22m (the distance between the road kerb and the bund wall), the depth of the circular liquid pool would be 0.077m. This calculation shows that the proposed 0.1m high kerb can prevent the spilled ferric chloride solution from reaching the hypochlorite pipeline at the barge unloading facility. The proposed drain at the foot of the road kerb will intercept and drain the some of spilled ferric chloride to the sea before it reaches the road kerb.

11.184 In conclusion, with the above proposed precautionary mitigation measure, it will be impossible for the two chemicals to mix in any circumstances at this location.

Case 2

11.185 As shown in **Figure 11.9**, the Hypochlorite Tank farm is located on the western side of the SCISTW site. The nearest section of the ferric chloride pipeline is located about 80m away to the east. The ferric chloride pipeline is located in a reinforced-concrete service duct buried below ground. Also, additional primary sedimentation tanks will be built in the intervening space under HATS Stage 2A. These two features (pipeline in buried underground service-duct and presence of a massive barrier in the form of sedimentation tanks) will serve as effective barriers to prevent mixing of the two chemicals in the extreme scenario of a seismic event.

11.186 Before HATS 2A is commissioned in 2014, a temporary but solid screening structure made of water-filled barriers (covered by impervious membrane or plastic sheeting) will be provided between the hypochlorite tank farm and the ferric chloride pipeline, as shown in **Figure 11.9**. This will function to prevent the two chemicals from mixing with each other even in the extreme scenario of a seismic event causing simultaneous failure of the ferric chloride pipeline and hypochlorite tank(s).

Conclusion

11.187 In conclusion, with the proposed precautionary design features (i.e., For Case 1, measures listed in paragraph 11.178 and, for Case 2, temporary water-filled barriers between the hypochlorite tank farm and the ferric chloride pipeline as discussed in paragraph 11.185), mixing of the two chemicals is not possible under any circumstances. Therefore, the occurrence frequency of incompatible chemicals mixing due to simultaneous release incompatible chemicals from pipeline and storage tank is zero.

Frequency Estimation

Frequency Estimation based on Incident Review Data

11.188 As mentioned above, the chemical spillage scenarios will not cause off-site fatality under the circumstances of the current Project. Therefore, the frequency of such scenarios to cause off-site fatality is zero.

11.189 The occurrence frequency of “mixing of incompatible chemicals on-site” may be determined based on an incident review. By using the incident review results, the occurrence frequency of the scenario of ‘mixing of incompatible chemicals on-site” for the Project can be determined by the following equation:

Occurrence frequency = A / B Equation 1

Where,
A = No. of incompatible chemicals mixing incidents in wastewater disinfection facilities (or similar facilities, e.g. wastewater recycling plant) identified in incident review
B = The population of wastewater disinfection facilities (in terms of facility-year) located in the region during the period that the incident review has covered

11.190 A comprehensive review of recorded international incidents involving mixing of either sodium hypochlorite or sodium bisulphite with an incompatible chemical has been conducted, as summarized in Annex D. In summary,

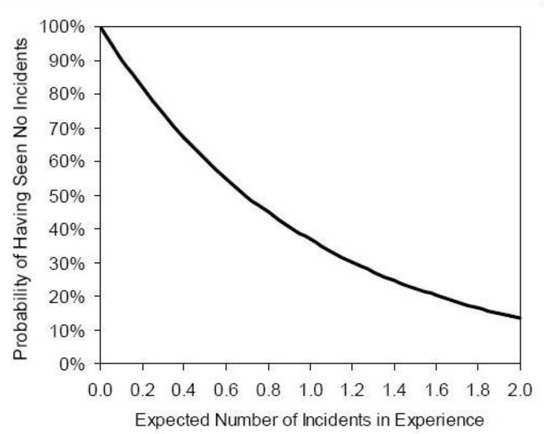
- This showed that mixing did occur at leisure centres (swimming pools) and some industrial facilities, because of unloading errors or spillage/leakage from storage tanks, but none of these incidents caused fatality.
- Further, the review did not find any incompatible chemicals mixing incidents in wastewater disinfection facilities (i.e. A = 0). This may be explained by the generally stringent safety measures (particularly in handling chemicals) adopted in wastewater disinfection facilities.

11.191 For the estimation of parameter “B”, since the incident review has covered the incidents occurring in Europe and the USA for the period from 1970 to 2005, the population of wastewater disinfection facilities (that use hypochlorite) located in Europe and the USA for the above period was determined. Based on the results of survey on disinfection practice in coastal cities conducted under this Study, 57 wastewater treatment works (that use sodium hypochlorite for disinfection) were identified in 10 cities with a total population of 37,355,000. That is, a wastewater disinfection facility using sodium hypochlorite would serve a population of about 655,351 people.

11.192 The human population at 1990 was taken to represent the population for the period from 1970 to 2005. The population of Europe and the USA at 1990 was 721,390,000 and 248,000,000 respectively; giving a total population of 969,390,000.

11.193 From the above data, the population (in terms of facility-year) of the wastewater disinfection facility in Europe and the USA for the period from 1970 to 2005 can be estimated by the equation: [(969,390,000 / 655,351)] x 35 = 1,479 facilities x 35 operation-year = 51,765 facility-year. Since no identified incompatible chemicals mixing incident occurred in wastewater disinfection facilities, the number of such incident occurring in wastewater disinfection facilities is <1, hence the incompatible chemicals mixing scenario occurrence frequency at wastewater disinfection facilities is estimated to be less than 1.9×10^{-5} (i.e. < 1 / 51,765) per year.

11.194 None of the identified incompatible chemicals mixing incidents occurred in wastewater disinfection facilities. This shows that such mixing incident has not occurred in the experience history of wastewater disinfection facilities. Where an incident that could occur (but has not occurred) it is normal to base the expected number of incidents on a 50% chance of it having (or not having) occurred, leading to an estimate of 0.7 incidents based on a Poisson distribution. The probability of not having seen an incident as a function of the expected number of incidents based on a Poisson distribution is shown below.



11.195 Generally, wastewater disinfection facilities are operated by experienced and trained personnel in an organized and careful manner. Design and operational measures for wastewater disinfection facilities are mature and well developed. Therefore, assuming a 50% chance of occurrence of mixing of incompatible chemicals, per the general Poisson model, leading to an estimate of 0.7 incidents, may be overly pessimistic for wastewater disinfection facilities. For a less pessimistic but yet cautious estimate, we propose to apply a factor of "2" to the expected number of incidents (making it 0.35 instead of 0.7), which is equivalent to a 30% chance that an incompatible chemicals mixing incident should have occurred in the experience history of wastewater disinfection facilities.

11.196 Therefore, the generic occurrence frequency of incompatible chemicals mixing incident in wastewater disinfection facilities is estimated to be = 0.35 / 51,765 = 6.76×10^{-6} per year.

Adjustment of Generic Occurrence Frequency based on Project-specific Circumstances

11.197 Next, the generic occurrence frequency of 6.76×10^{-6} per year for incompatible chemicals mixing incident in wastewater disinfection facilities needs to be adjusted to take into account the specific circumstances of the ADF in SCISTW.

11.198 In considering what might be a reasonable adjustment factor, the following aspects may be relevant:

- Precautionary measures to avoid incompatible chemicals mixing in ADF
- Number of transportation modes for chemical delivery to ADF
- Number of incompatible chemicals to be handled at ADF
- Number of chemicals delivery to be made to ADF

<u>Precautionary Measures to Avoid Incompatible Chemicals Mixing</u>

11.199 As mentioned above, a comprehensive package of precautionary measures, including special chemical supply contract arrangement, design measures as well as operation procedures and safety measures, has been developed for HATS ADF to avoid the occurrence of incompatible chemical mixing incidents. These measures represent latest generation of state-of-the-art hazard/risk control measures for chemical management at wastewater disinfection plants.

11.200 Referring to the surveyed wastewater disinfection plants, these included facilities that have been operating for a long period. For example, some of the wastewater disinfection facilities using sodium hypochlorite were commissioned in the 1970s or earlier years.

11.201 Therefore, while chemical hazard control measures are routinely adopted in wastewater disinfection facilities, it is likely that the level and sophistication of the precautionary measures adopted in the proposed ADF would be somewhat higher (better) than the "average" conditions of wastewater disinfection plants in general. This is because the latter group would include modern as well as older disinfection plants, where the hazard control measures could be less stringent than the ADF.

11.202 This suggests that, with respect to precautionary measures for avoiding unloading error, the proposed ADF would have a lower frequency of unloading error incidents when compared to wastewater disinfection facilities in general.

<u>Number of Transportation Mode for Chemical Delivery</u>

11.203 In HATS ADF, there will be technically two chemical transportation modes because sodium hypochlorite can be delivered either by barge or road tankers. However, sodium bisulphite and ferric chloride will only be delivered by road tankers. As mentioned above, barge-unloading facility would be provided only for sodium hypochlorite tank farm via a dedicated pipeline in a separate pipe trench. It is therefore impossible for sodium hypochlorite delivered by barge to be unloaded into sodium bisulphite or ferric chloride tanks. Therefore, it may be argued that, for the purposes of the present discussion on frequency of incompatible chemical mixing, the proposed ADF will involve a single mode of delivery.

11.204 For wastewater disinfection plants in general, they could involve one or more modes of chemical delivery. Obviously, the minimum would be “one”, either by land or by sea. On this basis, and considering the unique chemical delivery arrangement for the ADF, it is considered that the number of delivery mode for wastewater disinfection plants in general and the ADF are the same (i.e., one). No adjustment to the frequency of occurrence of incompatible mixing due to number of delivery mode is therefore proposed for the ADF.

<u>Number of Incompatible Chemicals to be Handled</u>

11.205 Three incompatible chemicals (sodium hypochlorite, sodium bisulphite, and ferric chloride) will be handled in SCISTW after the commencement of in the ADF project. There are two key concerns, i.e., mixing of sodium hypochlorite with ferric chloride solutions, and mixing of sodium bisulphite with ferric chloride solutions. However, as discussed earlier, the sodium bisulphide tank farm is located remote from the ferric chloride tank farm at a different area of SCI. Tanker delivery of sodium bisulphide solution to the sodium bisulphite tank farm will be made following a dedicated route that via an entrance/exit gate that is isolated from the ferric chloride tankers. In essence, the sodium bisulphite tank farm is isolated from the other incompatible chemical. Therefore, it may be argued that, for the purposes of the present discussion on frequency of incompatible chemical mixing, the proposed ADF will involve only two incompatible chemicals.

11.206 It is not clear from the incident review or survey the average number of incompatible chemicals that are handled in wastewater disinfection plants in general. Obviously, the minimum would be “two”, but for those chlorination plants employing dechlorination, the number could be “three”, as in the case of the ADF.

11.207 On this basis, and considering the unique chemical delivery arrangement for the ADF, it is considered that the number of incompatible chemicals handled at the ADF would not be dissimilar to the *average* number of incompatible chemicals handled at wastewater disinfection in general. Therefore, no adjustment to the frequency of occurrence of incompatible mixing due to number incompatible chemicals is therefore proposed for the ADF.

<u>Number of Chemical Delivery to be Made</u>

11.208 The ADF in SCISTW is a facility of large scale (serving a population of about 3,900,000) when compared to wastewater disinfection facilities in general (each facility serves on average 655,351 people). On a population basis, the ADF is about six times larger than an average wastewater disinfection plant.

11.209 Owing to the larger scale of the ADF operation, the amount of chemicals used in the ADF and in turn, the number of chemical delivery operations would be larger than other wastewater disinfection facilities in general. Therefore, in principle, an adjustment to the generic frequency of occurrence of incompatible mixing would be warranted.

11.210 However, for the ADF, owing to the large amount of chemical to be used, bulk transport (i.e. barge) has been chosen to be the main transportation mode for sodium hypochlorite. As mentioned above, it is impossible for sodium hypochlorite delivered by barge to be unloaded to the sodium bisulphite or ferric chloride tanks (i.e. unloading error).

11.211 In view of this barge delivery arrangement, the number of land delivery of sodium hypochlorite solution to the ADF is greatly reduced (as this is restricted to situations when sea delivery is not possible due to adverse weather or other unforeseen conditions). This means that while the number of chemical delivery to ADF could be higher than a wastewater disinfection plant of average capacity or size, the magnitude of adjustment to the generic frequency should be moderate.

Conclusion

11.212 The above assessment suggests that:

- The ADF would employ better than average chemical hazard/risk control measures, which would serve to lower the generic frequency of incompatible chemical mixing.
- On the number of transportation mode and number of incompatible chemicals, no adjustment to the generic frequency is proposed.
- The larger scale/capacity of the ADF compared to wastewater disinfection plants in general would suggest that an upward adjustment to the generic frequency of incompatible mixing would be warranted.

The first and last point would act to counter-balance the adjustment factor to be applied to the ADF. In our opinion, for the case of the ADF, the enhanced control measures would greatly reduce the frequency of occurrence of incompatible mixing, while the larger than average scale of the ADF would only have limited impact on the generic frequency.

11.213 Nevertheless, as a conservative approach, we propose to apply an upward adjustment factor of 6 to the generic frequency. This means that the occurrence frequency of incompatible chemicals mixing incident of ADF operations should be:

= 6.76×10^{-6} per year x 6
= 4.056×10^{-5} per year.

Reference to Estimated Frequency in other Relevant Project

11.214 Reference is drawn to the approved EIA Study Report for the Hong Kong International Theme Park (HKITP), which provides relevant information on the occurrence frequency of incompatible chemical mixing in its on-site attractions water disinfection facility (also using sodium hypochlorite solution). In this case, the frequency of occurrence of mixing sodium hypochlorite with an incompatible chemical has been estimated at 3×10^{-6} per year. .

11.215 In the HKITP operation, it was estimated that the operation of the attractions water disinfection facility would involve about 312 chemical deliveries per year. For the ADF operation, there will be a total of less than 1,140 road tanker deliveries of sodium hypochlorite (360), sodium bisulphite (260) and ferric chloride (520) per year to the SCISTW after the commencement of the ADF Project, which is about 4 times of the deliveries made for the HKITP attractions water disinfection facility.

11.216 In comparing the occurrence frequency and conditions of both HATS ADF and the HKITP project, it can be seen that the adopted occurrence frequency of 4.056×10^{-5} per year for incompatible chemicals mixing scenario at HATS ADF, which is over 10 times higher than the HKITP disinfection plant, would likely be a very conservative estimate.

Consequence Analysis and Risk Summation

Determination of Toxic Gas Generation Rate

11.217 In HATS ADF operation, the scenario "mixing of incompatible chemicals on-site" (due to error in chemicals unloading operation) could lead to one of the following events:

- Sodium hypochlorite is unloaded into ferric chloride tank, generates chlorine gas – event 1
- Ferric chloride is unloaded into sodium hypochlorite tank, generates chlorine gas – event 2
- Sodium bisulphite is unloaded into ferric chloride tank, generates sulphur dioxide gas – event 3
- Ferric chloride is unloaded into sodium bisulphite tank, generates sulphur dioxide gas – event 4
- Sodium hypochlorite is unloaded into sodium bisulphite tank, generates heat (but no toxic gas would be generated) – event 5
- Sodium bisulphite is unloaded into sodium hypochlorite tank, generates heat (but no toxic gas would be generated) – event 6

11.218 The rate of toxic gas generation in events 1 to 4 is estimated by the following steps:

<u>Determination of Toxic Gas Generation Reaction</u>

11.219 When ferric chloride solution is accidentally mixed with sodium hypochlorite / sodium bisulphite, the hydrochloric acid in the ferric chloride solution will react with sodium hypochlorite / sodium bisulphite to form chlorine / sulphur dioxide gas. The chemical reactions and the molecular weight of the reactants are written as follows:

- Sodium hypochlorite reacts with hydrochloric acid to give chlorine gas

$$\underset{74.45}{NaOCl} + \underset{36.45}{HCl} \rightarrow \underset{40.00}{NaOH} + \underset{70.91}{Cl_2}$$

- Sodium bisulphite reacts with hydrochloric acid to give sulphur dioxide gas

$$\underset{104.06}{NaHSO_3} + \underset{36.45}{HCl} \rightarrow \underset{18.02}{H_2O} + \underset{35.00}{NaCl} + \underset{64.1}{SO_2}$$

<u>Determination of Density and Concentration of Involved Chemicals</u>

11.220 According to the Material Safety Data Sheet, the density and concentration of the involved chemicals are as follows:

- Sodium hypochlorite – density: 1.2kg/L, concentration: 12% w/w
- Sodium bisulphite – density: 1.33kg/L, concentration: 38% w/w
- Ferric chloride – density: 1.3kg/L, concentration of HCl: 1% w/w

11.221 Combining the unloading rate of the chemical with the abovementioned data, the toxic gas generation rate of the incompatible chemicals mixing events can be calculated. The toxic gas generation rate is estimated based on the conservative assumption that there would be perfect mixing and reaction between the incompatible chemicals. In the real situation, chemical is loaded from high level of storage tank (i.e. above the liquid level of chemical present in the tank) and therefore the loaded chemical and the chemical present in the tank will not perfectly mix with each other. Hence, the toxic gas generation rates estimated below are at the conservative side.

11.222 The calculation of toxic gas generation rate for events 1 to 4 is shown below:

Event 1

11.223 The sodium hypochlorite unloading rate by the road tanker is assumed to be 10L/s. Therefore, there will be 10L x 1.2kg/L x 0.12 = 1.44kg of NaOCl unloaded to the ferric chloride tank per second. Assuming there is sufficient HCl in the ferric chloride tank for the reaction, 1.44kg of NaOCl reacts with 0.71kg of HCl to give 1.37kg of Cl_2. Therefore, the Cl_2 generation rate of 1.37kg/s is estimated for the event "sodium hypochlorite unloaded to ferric chloride tank".

Event 2

11.224 The ferric chloride unloading rate by the road tanker is assumed to be 10L/s. Therefore, there will be 10L x 1.3kg/L x 0.01 = 0.13kg of HCl unloaded to the sodium hypochlorite tank per second. Assuming there is sufficient sodium hypochlorite in the sodium hypochlorite tank for the reaction, 0.27kg of NaOCl reacts with 0.13kg of HCl to give 0.25kg of Cl_2. Therefore, the Cl_2 generation rate of 0.25kg/s is estimated for the event "ferric chloride unloaded to sodium hypochlorite tank".

Event 3

11.225 The sodium bisulphite unloading rate by the road tanker is assumed to be 10L/s. Therefore, there will be 10L x 1.33kg/L x 0.38 = 5.05kg of $NaHSO_3$ unloaded to the ferric chloride tank per second. Assuming there is sufficient HCl in the ferric chloride tank for the reaction, 5.05kg of $NaHSO_3$ reacts with 1.77kg of HCl to give 3.11kg of SO_2. Therefore, the SO_2 generation rate of 3.11kg/s is estimated for the event "sodium bisulphite unloaded to ferric chloride tank".

Event 4

11.226 The ferric chloride unloading rate by the road tanker is assumed to be 10L/s. Therefore, there will be 10L x 1.3kg/L x 0.01 = 0.13kg of HCl unloaded to the sodium bisulphite tank per second. Assuming there is sufficient sodium bisulphite in the sodium bisulphite tank for the reaction, 0.37kg of $NaHSO_3$ reacts with 0.13kg of HCl to give 0.23kg of SO_2. Therefore, the SO_2 generation rate of 0.23kg/s is estimated for the event "ferric chloride unloaded to sodium bisulphite tank".

11.227 The sodium hypochlorite, sodium bisulphite and ferric chloride storage tanks are atmospheric tanks equipped with vent pipe for venting of built up air / gas inside the tanks. When the air / gas pressure inside the tanks is higher than the atmospheric pressure outside, the built up air / gas will be released to the outside atmosphere through the vent pipe. Since the toxic gas will be continuously generated during the wrong chemical unloading operation, it is reasonable to assume that the toxic gas release rate (from storage tank to the atmosphere) is equal to the estimated toxic gas generation rate.

11.228 The toxic gas generated will be released through the vent pipe at the top of the storage tank. Therefore, the toxic gas will be released at an elevation level similar to the top of the storage tank.

Events 5 and 6

11.229 No toxic gas will be generated in Events 5 and 6.

11.230 **Table 11.6** presents the summary of the estimated toxic gas generation rates in various incompatible chemicals mixing events.

Table 11.6 Estimated Toxic Gas Generation Rates in Various Incompatible Chemicals Mixing Events

Event No.	Incompatible Chemicals Mixing Event	Toxic Gas Generation Rate	Toxic Gas Release Location	Toxic Gas Release Height
1	Sodium hypochlorite unloaded into ferric chloride tank	Chlorine, 1.37kg/s	Ferric chloride tank farm	13m above ground
2	Ferric chloride unloaded into sodium hypochlorite tank	Chlorine, 0.25kg/s	Sodium hypochlorite tank farm	12.5m above ground
3	Sodium bisulphite unloaded into ferric chloride tank	Sulphur dioxide, 3.11kg/s	Ferric chloride tank farm	13m above ground
4	Ferric chloride unloaded into sodium bisulphite tank	Sulphur dioxide, 0.23kg/s	Sodium bisulphite tank farm	6m above ground
5	Sodium hypochlorite unloaded into sodium bisulphite tank	No toxic gas generated		
6	Sodium bisulphite unloaded into sodium hypochlorite tank	No toxic gas generated		

Consequence and Risk Summation Modelling

11.231 Risk Software SAFETI *micro* was used as the tool to execute the consequence analysis and risk summation. SAFETI *micro* is a consequence and risk summation model, which can handle heavy gas (such as chlorine) dispersion and has been used in previous risk assessment studies in Hong Kong. Description of the modelling works is presented below.

<u>Frequency of the Incompatible Chemicals Mixing Events</u>

11.232 As presented above, the occurrence frequency of incompatible chemicals mixing incident of ADF operations is estimated to be 4.056 x 10^{-5} per year and there are 6 possible incompatible chemicals mixing events in the ADF operation. The estimation of the distribution of the occurrence frequency of the mixing events is presented in the paragraphs below.

11.233 The occurrence frequency of incompatible chemicals mixing incident, which is due to the chemical unloading error, is estimated to be 4.056 x 10^{-5} per year. There would be 1,140 chemical unloading operations made per year and therefore each unloading operation would contribute to an occurrence frequency of 3.56 x 10^{-8} per year (= 4.056 x 10^{-5} / 1140).

11.234 As an example, if chemical unloading operation error occurs in a sodium hypochlorite delivery operation, the delivered chemical is not unloaded into the sodium hypochlorite tank (the intended storage tank) and would be unloaded into either sodium bisulphite or ferric chloride storage tank. Since dedicated road tanker transport route will be assigned to each chemical, the probable cause of the unloading operation error would be the road tanker driver enters the SCISTW site at the wrong entrance. It is considered that the probability of the road tanker driver enters the wrong entrance for ferric chloride tank farm would be the same to that for entering the wrong entrance for sodium bisulphite tank farm. Hence, in case of chemical unloading operation error, the probability of delivered sodium hypochlorite being mistakenly unloaded into the ferric chloride tank would be equal to that being mistakenly unloaded into the sodium bisulphite tank, which is equal to 0.5.

11.235 The situation is similar to chemical unloading error in sodium bisulphite and ferric chloride delivery operation. Based on the above, the occurrence frequency of each incompatible chemicals mixing event can be estimated as shown in **Table 11.7**:

Table 11.7 Estimated Frequency of Various Incompatible Chemicals Mixing Events

Event No.	Event Description	Estimated Frequency
1	Sodium hypochlorite unloaded into ferric chloride tank	= 3.56 x 10^{-8} per year (freq. of error of an unloading operation) x 360 (no. of NaOCl unloading operation) x 0.5 (prob. of NaOCl being unloaded into ferric chloride tank, given error occurs) = 6.41 x 10^{-6} per year
2	Ferric chloride unloaded into sodium hypochlorite tank	= 3.56 x 10^{-8} per year x 520 (no. of $FeCl_3$ unloading operation) x 0.5 (prob. of $FeCl_3$ being unloaded into sodium hypochlorite tank, given error occurs) = 9.26 x 10^{-6} per year
3	Sodium bisulphite unloaded into ferric chloride tank	= 3.56 x 10^{-8} per year x 260 (no. of $NaHSO_3$ unloading operation) x 0.5 (prob. of $NaHSO_3$ being unloaded into ferric chloride tank, given error occurs) = 4.63 x 10^{-6} per year
4	Ferric chloride unloaded into sodium bisulphite tank	= 3.56 x 10^{-8} per year x 520 (no. of $FeCl_3$ unloading operation) x 0.5 (prob. of $FeCl_3$ being unloaded into sodium bisulphite tank, given error occurs) = 9.26 x 10^{-6} per year
5	Sodium hypochlorite unloaded into sodium bisulphite tank	= 3.56 x 10^{-8} per year x 360 (no. of NaOCl unloading operation) x 0.5 (prob. of NaOCl being unloaded into sodium bisulphite tank, given error occurs) = 6.41 x 10^{-6} per year
6	Sodium bisulphite unloaded into sodium hypochlorite tank	= 3.56 x 10^{-8} per year x 260 (no. of $NaHSO_3$ unloading operation) x 0.5 (prob. of $NaHSO_3$ being unloaded into sodium hypochlorite tank, given error occurs) = 4.63 x 10^{-6} per year
	Total	4.056 x 10^{-5} per year

11.236 Wrong chemical unloading operation would be detected by the installed toxic gas detectors (and alarm will be annunciated) and stopped rapidly by automatic closure of emergency shutdown valve upon alarm activation. Also, as chemical supplier staff and SCISTW operator will be present throughout the chemical unloading operation, they can stop the chemical unloading operation by turning off the pump for pumping the chemical to the storage tank when they notice the activation of the alarm or other abnormal conditions. With the gas detector activated automatic stoppage system, toxic gas emission could be stopped almost immediately and the staff on-site provides a backup mechanism to stop the wrong chemical unloading operation. The time needed for the rapid stoppage of wrong chemical unloading operation is assumed to be 3 minutes. This assumption of the time needed for isolation by such stoppage system (gas detector automatic stoppage system, with manual stoppage as backup) is consistent with previous risk assessment study (Meinhardt Infrastructure and Environment Limited, 2007) considering similar emergency shutdown systems. Events 1b, 2b, 3b and 4b are developed to represent the above scenario.

11.237 It is specified that the gas detector activated automatic stoppage system shall meet the Safety Integrity Level (SIL) 2. According to International Electrotechnical Commission (1997), a system meeting SIL 2 shall have a failure probability (on demand) of 0.001 to 0.01. Taking into account the extreme case of the automatic stoppage system failure, a failure probability of 0.01 (higher bound failure probability for SIL 2) is taken for the rapid stoppage of unloading operation.

11.238 In the case of automatic unloading operation rapid stoppage failure, the chemical unloading operation can be stopped by the SCISTW operator by turning off the pump for pumping the chemical to the storage tank. Nevertheless, it is conservatively assumed that the wrong chemical unloading operation does not stop until all chemical in the road tanker is unloaded. Such scenario is represented by Events 1a, 2a, 3a and 4a. **Table 11.8** presents the properties for each incompatible chemicals mixing event.

Table 11.8 Properties of Various Incompatible Chemicals Mixing Events

Event No.	Release Material	Release Rate	Occurrence Frequency	Release Location	Toxic gas Release Duration	Rapid Stoppage of Wrong Unloading Operation?
1a	Cl_2	1.37kg/s	6.41×10^{-8} per year	$FeCl_3$ tank farm	1700s[a]	No
1b	Cl_2	1.37kg/s	6.35×10^{-6} per year	$FeCl_3$ tank farm	180s[b]	Yes
2a	Cl_2	0.25kg/s	9.26×10^{-8} per year	NaOCl tank farm	1700s[a]	No
2b	Cl_2	0.25kg/s	9.17×10^{-6} per year	NaOCl tank farm	180s[b]	Yes
3a	SO_2	3.31kg/s	4.63×10^{-8} per year	$FeCl_3$ tank farm	1700s[a]	No
3b	SO_2	3.31kg/s	4.58×10^{-6} per year	$FeCl_3$ tank farm	180s[b]	Yes
4a	SO_2	0.23kg/s	9.26×10^{-8} per year	$NaHSO_3$ tank farm	1700s[a]	No
4b	SO_2	0.23kg/s	9.17×10^{-6} per year	$NaHSO_3$ tank farm	180s[b]	Yes
5	Event not modelled as no toxic gas is generated					
6						

Note: [a] The release duration is the time for the chemical delivery road tanker to unload all the chemical delivered, where the duration is = capacity of road tanker / chemical unloading rate = 17000L / 10L/s = 1700s
[b] The wrong unloading operation is rapidly stopped within 3 minutes (180s)

Evaluation of Toxic Impact

11.239 In SAFETI *micro*, the probability of death due to toxic gas impact at a point is calculated by the "probit equation", Pr = a + ln L, where "Pr" is the probit value, "a" is probit equation constant and "L" is the toxic load. The Probit value can be transformed to probability of fatality. For example, probit value of 6.28, 5.00, 3.12 and 2.67 corresponds to fatality probability of 90%, 50%, 3% and 1% respectively.

11.240 Toxic load "L" is calculated by the following equation, where the toxic load at a particular point is dependent to the toxic gas concentration-time history over the point:

$$L = \int_0^T C^n \, dt,$$

where "T" = duration of toxic gas exposure
"C" = concentration of toxic gas
"n" = probit equation constant

11.241 The probit equation constants applied for chlorine and sulphur dioxide gas are listed as follows, which are consistent with the probit constants recommended by the Dutch Government (TNO, 1992):

	a	n
Chlorine	-14.3	2.3
Sulphur dioxide	-19.2	2.4

11.242 The maximum duration of toxic gas exposure by population for each event is taken as 10 minutes. Even in the cases of failure to stop the wrong chemical unloading operation rapidly (toxic release duration = 1700s), the population exposed to the released toxic gas shall be able to take action to escape from the toxic gas cloud rather than remains at the original location and exposes to the toxic gas for the whole toxic gas release period. Therefore, the maximum duration of toxic gas exposure in these cases is limited to 10 minutes. This assumption is consistent with the previous risk assessment studies for local water treatment works (ERM, 2001).

11.243 According to the User Manual of SAFETI *micro*, in the case of toxic gas continuous release, the duration of the toxic cloud's passage at various locations is equal to the duration of the toxic gas release. Therefore, for Events 1b, 2b, 3b and 4b that rapid stoppage of wrong chemical unloading operation is successful, the toxic gas exposure duration is same as the toxic gas release duration (3 minutes).

Model Parameters

11.244 The relevant SAFETI parameters are presented in **Appendix 11.5**. By adopting the parameters, probability of fatality for a person indoor is 10% of that for a person remains at outdoor environment.

11.245 By extracting the modelling results from SAFETI *micro*, the estimated fatality probability at various distances (at 25m interval) from the toxic gas release location for various events is presented in **Figures 11.15**. **Table 11.9** summarizes the distance from the toxic gas release location that receives a fatality probability of 3% and 1% under the weather class 1F (the weather class with worst dilution).

Table 11.9 Distance from Toxic Gas Release Location Receiving Fatality Probability of 3% and 1% under Weather Class 1F

Hazardous Event	Distance to Receive 3% Fatality Probability	Distance to Receive 1% Fatality Probability
Event 1a	700m, from ferric chloride tank farm	825m, from ferric chloride tank farm
Event 1b	425m, from ferric chloride tank farm	500m, from ferric chloride tank farm
Event 2a	175m, from sodium hypochlorite tank farm	225m, from sodium hypochlorite tank farm
Event 2b	80m, from sodium hypochlorite tank farm	100m, from sodium hypochlorite tank farm
Event 3a	110m, from ferric chloride tank farm	150m, from ferric chloride tank farm
Event 3b	70m, from ferric chloride tank farm	75m, from ferric chloride tank farm
Event 4a	45m, from sodium bisulphite tank farm	50m, from sodium bisulphite tank farm
Event 4b	Fatality probability at 25m from sodium bisulphite tank farm is estimated to be lower than 1%	

Population Input

11.246 Since the outdoor population / indoor fraction of the population at locations listed in **Table 11.1** varies, adjustments were made for population input in SAFETI *micro* from locations to locations. For the population at the primary school (location 14), a vulnerability factor of 3.3 is applied because the primary school population is considered as sensitive population, which is more susceptible to the toxic effect than average population. Road population and marine population are considered as outdoor population, adjustments were also made for population input in SAFETI *micro*.

11.247 After the population data, meteorological data and failure case was input, SAFETI *micro* combined these input data and characterized the risk levels in terms of individual risk (presented by individual risk contours) and societal risk (presented by FN curves and Potential of Loss of Life).

Evaluation of Hazard to Life Impact

Introduction

11.248 Individual risk is a measure of the risk to a chosen individual at a particular location. As such, this is evaluated by summing the contributions to that risk across a spectrum of incidents that could occur at a particular location.

11.249 Societal risk is a measure of the overall impact of an activity upon the surrounding community. As such, the likelihoods and consequences of the range of incidents postulated for that particular activity are combined to create a cumulative picture of the spectrum of the possible consequences and their frequencies. This is usually presented as an FN curve and the acceptability of the results can be judged against the societal risk criterion under the risk guidelines.

11.250 The hazard distance calculated by SAFETI *micro* was compared with the assessment results in previous hazard assessment study for local water treatment works. It was found that modelling results by SAFETI *micro* are comparable to the previous assessment under weather class with neutral stability. For weather class with stable condition, the modelling results of SAFETI *micro* were found to be more conservative than that of the previous hazard assessment study. Details of the comparison of estimated hazard distance are presented in **Appendix 11.6**.

Assessment Results – Individual Risk

11.251 The associated individual risk levels are shown in **Figure 11.16**. The risk levels are based on a 100%-occupancy, which can be referred from the user manual of SAFETI *micro*. Two risk contours of individual risk level of $1x10^{-7}$, and $1x10^{-8}$ per year are shown. As no off-site location would experience an individual risk level of greater than $1x10^{-5}$ per year, it can be concluded that the level of individual risk associated with the Project should be acceptable when compared to the individual risk guideline stipulated in Annex 4 of the EIAO TM.

Assessment Results – Societal Risk

11.252 **Table 11.10** presents the FN results of each incompatible chemicals mixing event. Fraction fatalities are conservatively rounded up to a fatality for presentation of the calculated societal risk in form of FN curve.

Table 11.10 FN Results of Various Incompatible Chemicals Mixing Events

	Cumulative Frequency (per year)	
Event No.	Fatality of 1 or more	Fatality of 10 or more
1a	3.91E-8	3.64E-10
1b	1.76E-6	0
2a	6.85E-9	0
2b	2.90E-7	0
3a	1.14E-8	0
3b	1.41E-7	0
4a	0	0
4b	0	0

Note: Cumulative frequency for fatality of 1 or more of all events = 2.25×10^{-6} per year

11.253 The FN curves showing the societal risk level with fractional fatalities rounded up to 1 are shown in **Figure 11.17**. As shown in the figure, the societal risk associated with the Project was estimated to be in the "acceptable" region. Therefore, it can be concluded that the level of societal risk associated with the Project should be acceptable when compared to the societal risk guideline stipulated in Annex 4 of the EIAO TM.

Conclusion

11.254 Hazard to life impact associated with the proposed disinfection facilities at SCISTW was quantitatively assessed. The risk of identified hazardous scenarios involving sodium hypochlorite and sodium bisulphite was quantitatively assessed, with consideration of identified precautionary measures / operation procedures that minimize the risks associated with the chemicals related operations.

11.255 The individual risk and societal risk associated with the chemicals related operations were found to be acceptable in accordance with the risk guidelines stipulated in the Annex 4 of the EIAO TM.

References

1. Chlorine Institute (2003). Sodium Hypochlorite Manual.
2. Clarence Valley Council (2005). Yamba Sewerage Augmentation – Environmental Impact Statement.
3. ERM (2000). Construction of an International Theme Park in Penny's Bay of North Lantau together with its Essential Associated Infrastructures – Environmental Impact Assessment.
4. ERM (2001). Reassessment of Chlorine Hazard for Eight Existing Water Treatment Works: Hazard Assessment for Au Tau Water Treatment Works.
6. Health Council of the Netherlands (2005). Sodium hydrogen sulphite; Health-based Reassessment of Administrative Occupational Exposure Limits.
7. International Electrotechnical Commission (1997). IEC 61508, "Functional Safety of Electrical / Electronic / Programmable Electronic Safety Related Systems".
8. International Maritime Organization. The International Maritime Dangerous Goods Code.
9. International Programme on Chemical Safety. Poisons Information Monographs 495 – Sodium Hypochlorite.
10. Major Hazard Incident Data Service (MHIDAS)
11. Meinhardt Infrastructure and Environmental Limited (2007).I Environmental Assessment Services for Permanent Aviation Fuel Facility – Final EIA Report.
12. New York City Department of Environmental Protection (2004). Croton Water Treatment Plant – Final Supplemental Environmental Impact Statement.
13. Ove Arup (2001). EIA Study for Comprehensive Feasibility Study for the Revised Scheme of South East Kowloon Development
14. TNO (1992). Methods for the Determination of Possible Damage to People and Objects Resulting from Release of Hazardous Materials. CPR 16E "The Green Book".

15. Thyer *et al*. (2002). Bund Overtopping – The Consequence of Catastrophic Tank Failure. Journal of Loss Prevention in the Process Industries *15* 357-363.
16. United Nations Population Division (2005). 2004 Revision World Population Prospects : The 2004 Revision Population Database.
17. United States National Library of Medicine. Hazardous Substances Data Bank.
18. US Census Bureau. Population Profile of the United States: 2000