6. HUMAN HEALTH RISK ASSESSMENT

Introduction

6.1 During the disinfection technology evaluation and selection exercise conducted under this Project, the Project Team need to answer "**Is chlorination an option for HATS at all**?" before shortlisting it for detailed evaluation in view of the concern on potential adverse environmental impacts due to discharge of chlorination by-products (CBPs) raised. A risk assessment has been conducted on the following types of risk to answer the above question on chlorination disinfection technology.

- Risk to human health
- Risk to aquatic ecological resources
- Acute toxicity to aquatic life
- Chronic toxicity to aquatic life

6.2 Apart from evaluating the environmental viability of chlorination for the disinfection technology selection, the risk assessment conducted also fulfils the EIA Study Brief requirement. With reference to Clause 3.4.3.6 (xi) of the EIA Study Brief, the EIA Study shall assess the adverse ecological effects that may result from exposure to toxic substances due to effluent discharges, and the potential human health risks associated with ingestion of and contact with contaminated seawater during swimming or engaging in other water related activities and with the consumption of potentially contaminated seafood.

6.3 The Human Health Risk Assessment (HHRA), which covers the assessment of risk to human health, is presented in this section of the EIA Report. Risk assessment for ecological resources is presented in **Section 7** of the EIA Report.

Objective, Scope and Focus of Assessment

6.4 The objective of the HHRA is described as follows:

- to assess the potential human health risks/impact associated with exposure to toxic substances from effluent discharges of the Project, due to ingestion of and contact with contaminated seawater during swimming or engaging in other water related activities and with the consumption of potentially contaminated seafood

6.5 The study area of this assessment was in line with the one for water quality assessment according to Clause 3.4.3.2 of the EIA Study Brief, which shall cover the following Water Control Zones as designated under the Water Pollution Control Ordinance: North Western, Western Buffer, Victoria Harbour, Eastern Buffer, Junk Bay and Southern.

6.6 Since this project is to provide disinfection facilities at SCISTW, the risk assessment focused on assessing the potential risks/impacts to human health due to chronic exposure to the contaminants produced in the chlorination process in the effluent discharge. Previous studies[1] for Harbour Area Treatment Scheme (HATS)/Strategic Sewage Disposal Scheme (SSDS) have assessed the impacts due to other toxic substances not related to the disinfection process (such as heavy metals and other organic pollutants). Risk assessments in previous studies showed that no unacceptable human health risk would be induced due to the SSDS/HATS effluent discharge.

Scenarios Considered in Assessments

6.7 Five project scenarios were considered in the assessments:

- Early commissioning of ADF (year 2009) – SCISTW discharges 1,576,300m^3 of chlorinated/dechlorinated (C/D) CEPT effluent per day (referred to as Project Scenario 1)
- Late ADF stage (year 2013) - SCISTW discharges 1,661,100m^3 of C/D CEPT effluent per day (referred to as Project Scenario 2)
- Late Stage 2A with disinfection (year 2020) - SCISTW discharges 2,341,600m^3 of C/D CEPT

[1] MW (1998). Detailed Risk Assessment (Final Version). Technical Note 4, prepared as part of the Strategic Sewage Disposal Scheme (SSDS) – Environmental Impact Assessment Study. Referred to as "SSDS/EIAS DRA (1998)".
CDM (2004). Environmental and Engineering Feasibility Assessment Studies in Relation to the Way Forward of the Harbour Area Treatment Scheme (HATS) – Final Study Report. Referred to as "HATS EEFS (2004)".

effluent per day (referred to as Project Scenario 3)

- Before commissioning of HATS Stage 2B – SCISTW discharges 2,800,000m^3 of C/D CEPT effluent per day (referred to as Project Scenario 4)
- HATS Stage 2B with disinfection (ultimate year) - SCISTW discharges 2,800,000m^3 of C/D secondary treated effluent per day (referred to as Project Scenario 5)

Assessment Methodology

6.8 The detailed risk assessment methodology for HHRA was presented in **Appendix 6-1**. The framework of the risk assessment is as follows:

- Problem Formulation
- Hazard Identification
  - Contaminant of Potential Concern (COPC) Identification and Contaminant of Concern (COC) Selection
  - Potential Human Receptors Identification
- Exposure Assessment
- Dose-response Assessment
- Risk/hazard Characterization

6.9 A brief overview of the risk assessment methodology is presented below:

Problem Formulation

This stage of the risk assessment establishes objective, scope and focus of the assessment, constructs the Site Conceptual Model (SCM) and defines assessment endpoint. SCM presents an overview of the chemical sources, exposure pathways and receptors of the risk assessment. SCM adopted in the HHRA was presented graphically in **Figure 6.1**. More detailed discussion was presented in **Appendix 6-1**.

COPC Identification

A total number of 35 chemicals were identified as COPCs in the risk assessments. The COPCs included 9 chlorination by-products (CBPs) regulated by USEPA National Primary Drinking Water Standards; 25 priority pollutants[2] (which may contain potential CBPs) regulated by the USA National Pollutant Discharge Elimination System (NPDES)[3]; and total residual chlorine (as disinfectant residue). Chemical analysis was conducted to determine the COPC concentrations in chlorinated/dechlorinated (C/D) CEPT effluent and ambient seawater for the subsequent tasks of the risk assessment.

Unlike other conventional human health risk assessments for air pollution source (e.g. incinerator) and contaminated land/groundwater, a look-up table of contaminants/list of possible COPC for CBPs risk assessment in effluent was not identified from local and overseas authorities. Moreover, according to the review of local and overseas practice, list of “regulated CBPs in sewage effluent” was not identified.

Hence, a conservative approach was adopted in this Study to include all the regulated CBPs in drinking water plus the 25 priority pollutants (may contain potential CBPs) regulated by NPDES as COPCs, although these pollutants are not regulated due to the concern of generation during chlorination process.

[2] The 25 pollutants are regulated in NPDES due to their presence in industrial effluent but not their possible generation in chlorination process. However, a conservative approach is adopted to study all these regulated chlorinated organic substances, which are documented as potential CBPs, in US drinking water and wastewater discharge.

[3] The NPDES permit program controls water pollution by regulating point sources that discharge pollutants into water of the United States. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters.

The NPDES practice was adopted because it contains the most comprehensive list of regulated pollutants for effluent discharge, based on the review of practice in the USA, the United Kingdom, Australia, Canada, China and Hong Kong. Moreover, the purpose of NPDES is to ensure the US National Water Quality Criteria are complied by regulating pollutant concentrations in effluent discharge directly to surface water, in order to protect the human health and aquatic life.

Therefore, the 35 COPCs identified for the risk assessment include all documented potential CBPs/disinfectant residue which are regulated due to their potential to cause impact to human health and/or ecological resources. The list of identified COPCs (which the COCs for risk calculation were selected from the list) was considered sufficiently comprehensive to assess the potential risk to human health due to chronic exposure to the contaminants produced in the disinfection process in the effluent discharges.

<u>COC Selection</u>

The COCs were selected from the COPCs based on a number of selection rules and their risks were determined in the risk assessment.

<u>Potential Human Receptors Identification</u>

Based on the SCM for HHRA, the completed and significant COC exposure pathways are incidental ingestion and dermal contact of seawater, and ingestion of contaminated seafood. Therefore, the potential human receptors (children and adult) are:

- People who swim or engage in other water related activities in the sea area which is contaminated by the selected COCs discharged from the outfall of SCISTW
- People who consume seafood which is contaminated by the selected COCs discharged from the outfall of SCISTW

<u>Exposure Assessment</u>

This stage of the assessment involves water quality modelling, determination of exposure points, characterization of potential human receptors and calculation of COC exposure. COC bioconcentration and bioaccumulation along the food chain have been considered in the determination of COC concentration of seafood. As such, the risks associated with COC bioconcentration and bioaccumulation have been considered and evaluated in the HHRA.

<u>Dose-response Assessment</u>

This stage of HHRA involved determination of the relationship between the COC doses from exposure and corresponding response in humans (risk of cancer development, in terms of cancer slope factor and/or non-cancer health impact, in terms of reference dose).

<u>Risk/hazard Characterization</u>

This stage of the assessment characterizes the cancer risk (due to carcinogenic COCs) and health hazard (due to COCs inducing non-carcinogenic health impact) to the receptors associated with exposure of COCs.

Assessment Criteria

6.10 The assessment results needed to compare against the established assessment criteria to evaluate the environmental acceptability of the chlorination disinfection technology option, which are presented below.

Cancer Risk

6.11 At present USEPA has taken cancer risk in the range of 1 in 10,000 (0.0001) to 1 in 1,000,000 (0.000001) as being protective of human health for lifetime excess cancer risk. In light of the current criteria adopted by USEPA, the range of lifetime excess cancer risk of 1 in 10,000 to 1 in 1,000,000 was adopted as the cancer risk criteria in the HHRA.

Non-cancer Health Effect

6.12 Hazard Quotient (HQ) and Hazard Index (HI)[4] were used as the measure for the non-carcinogenic health hazards for both children and adult human receptor. At present USEPA has taken 1.0 as the screening value for HQ and HI. A HQ and/or HI below the screening value (i.e. 1) would indicate that the risk of the proposed action does not present an unacceptable risk and no further investigation would be required.

6.13 When the calculated HQ and HI are above the screening value, it does not immediately indicate that the proposed action would present an unacceptable risk. Rather, it triggers further investigation to examine whether the assumptions for the concerned chemicals are too conservative and whether the severities of the effect of the chemicals are of great concern.

6.14 The adoption of 1 as the screening value is consistent with the interpretation of HQ and HI in the approved "EIA for New Contaminated Mud Marine Disposal Facility at Airport East / East Sha Chau Area".

Data Collection

6.15 To obtain the data for the risk assessments, chemical analysis and whole effluent toxicity tests (WETT) were conducted for the chlorinated/dechlorinated (C/D) CEPT effluent from SCISTW and secondary treated effluent from Tai Po/Shatin Sewage Treatment Works. The chemical analysis aimed to determine the concentrations of identified 35 COPCs in the C/D effluents and ambient seawater for COC selection and calculation of human health and ecological risk; whereas the WETT aimed to determine the toxicity of C/D effluent in order to assess the compliance of acute and chronic toxicity criteria (which was detailed in **Section 7** of the EIA Report).

Chemical Analysis

6.16 Highest COPC concentrations determined among the replicates in the chemical analysis were adopted for COC selection and risk calculations. **Table 6.1** presented the summary of chemical analysis results.

[4] HQ is the measure of health hazard due to exposure of a COC whereas HI is the measure of health hazard due to exposure of all identified COCs, which is calculated by summing the HQs of all identified COCs.

Table 6.1 Summary of Chemical Analysis Results

COPC	Detection Limit (μg/L)	Max. Conc. in C/D CEPT Effluent (μg/L)	Max. Conc. in C/D Secondary Treated Effluent (μg/L)	Max. Conc. in Ambient Seawater (μg/L)[5]
Total residual chlorine	20	100	<20	<20
Bromoform	5	<5	49	<5
Bromodichloromethane	5	<5	<5	<5
Chloroform	5	7	<5	<5
Dibromochloromethane	5	<5	8	<5
Bromoacetic acid	2	<2	<2	<2
Chloroacetic acid	2	4	<2	<2
Dibromoacetic acid	2	4	10	<2
Dichloroacetic acid	2	45.9	3	<2
Trichloroacetic acid	2	22	7	<2
Methylene chloride	20	<20	<20	55
Carbon tetrachloride	0.5	<0.5	<0.5	<0.5
Chlorobenzene	0.5	<0.5	<0.5	<0.5
1,1-dichloroethane	0.5	<0.5	<0.5	<0.5
1,2-dichloroethane	0.5	<0.5	<0.5	<0.5
1,1-dichloroethylene	0.5	<0.5	<0.5	<0.5
1,2-dichloropropane	0.5	<0.5	<0.5	<0.5
Tetrachloroethylene	0.5	1.3	<0.5	<0.5
1,1,1-trichloroethane	0.5	<0.5	<0.5	<0.5
1,1,2-trichloroethane	0.5	<0.5	<0.5	<0.5
Trichloroethylene	0.5	2	<0.5	<0.5
2-chlorophenol	0.5	<0.5	<0.5	<0.5
2,4-dichlorophenol	0.5	<0.5	<0.5	<0.5
p-chloro-m-cresol	0.5	<0.5	<0.5	<0.5
Pentachlorophenol	2.5	<2.5	<2.5	<2.5
2,4,6-trichlorophenol	0.5	2	<0.5	<0.5
Bis(2-chloroethoxy)methane	0.5	<0.5	<0.5	<0.5
1,4-dichlorobenzene	0.5	<0.5	<0.5	<0.5
Hexachlorobenzene	0.5	<0.5	<0.5	<0.5
Hexachlorocyclopentadiene	2.5	<2.5	<2.5	<2.5
Hexachloroethane	0.5	<0.5	<0.5	<0.5
1,2,4-trichlorobenzene	0.5	<0.5	<0.5	<0.5
Alpha-BHC	0.5	<0.5	<0.5	<0.5
Beta-BHC	1	<1	<1	<1
Gamma-BHC	1	<1	<1	<1

Selected Contaminant of Concern and Effluent Concentration for Risk Assessment

6.17 From the 35 identified COPCs, COCs were selected and their effluent concentrations were determined for calculation of risks. The COC selection and effluent concentrations were based on the chemical analysis results and a number of established rules. The detailed COC selection and effluent concentration determination process were presented in **Appendix 6-1**; the selected COCs in HHRA and their determined effluent concentrations were summarized in **Tables 6.2a** (for Project Scenarios 1 to 4) and **6.2b** (for Project Scenario 5).

[5] For COPCs that were not detected in the ambient seawater samples, the background concentration was set as zero for risk calculation. Refer to Appendix 6I.1 for details.

Table 6.2a Selected COCs and Effluent Concentrations (Project Scenarios 1 to 4)

COC	Effluent Conc. (µg/L)
Total residual chloride	100
Chloroform	7
Bromodichloromethane	2.5[a]
Dibromochloromethane	2.5[a]
Chloroacetic acid	4
Dibromoacetic acid	4
Dichloroacetic acid	45.9
Trichloroacetic acid	22
Tetrachloroethylene	1.3
Trichloroethylene	2
Pentachlorophenol	1.25[a]
2,4,6-trichlorophenol	2
Alpha-benzene hexachloride	0.25[a]
Beta-benzene hexachloride	0.5[a]
Gamma-benzene hexachloride	0.5[a]

Note: [a]Selected COCs with concentration below detection limit in C/D effluent, their effluent concentrations were assumed to be one-half of the detection limit. This is a standard approach accepted by USEPA.

Table 6.2b Selected COCs and Effluent Concentrations (Project Scenario 5)

COC	Effluent Conc. (µg/L)
Bromoform	48.9
Chloroform	2.5[a]
Bromodichloromethane	2.5[a]
Dibromochloromethane	8
Dibromoacetic acid	10
Dichloroacetic acid	3
Trichloroacetic acid	7
Pentachlorophenol	1.25[a]
Hexachlorobenzene	0.25[a]
Alpha-benzene hexachloride	0.25[a]
Beta-benzene hexachloride	0.5[a]
Gamma-benzene hexachloride	0.5[a]

Note: [a]Selected COCs with concentration below detection limit in C/D effluent, their effluent concentrations were assumed to be one-half of the detection limit. This is a standard approach accepted by USEPA.

Risk Assessment Results

Dilution Factors for ZID and Far-field COC Concentration

6.18 As discussed in Section 5 and shown in Figure 5.20 and Figure 5.21, the effluent plume from SCISTW, Tai Po/Shatin STW and Pillar Point STW would not overlap each other. This means the CBPs potentially discharged from Tai Po/Shatin STW and Pillar Point STW (if chlorination is adopted as the disinfection technology under the assumed worst-case scenario) would not significantly contribute to the CBP concentrations at the edge of ZID, edge of mixing zone (of the effluent plume from SCISTW) and the Tsuen Wan beaches, which would be due to the C/D CEPT effluent from SCISTW.

6.19 Therefore, it is appropriate to apply the dilution factors calculated by water quality modelling at different exposure points (i.e. edge of ZID, edge of mixing zone and the nearest beach from SCISTW outfall) to calculate the contamination concentration. **Tables 6.3a** to **6.3d** presented the estimated dilution factors at various exposure points for Project Scenarios 1 to 5. As shown in **Tables 6.3a** to **6.3d**, 10 %tile dilution factors (dry and wet season combined) achieved at the exposure points were adopted for risk calculations. This approach has been adopted in previous relevant studies HATS

EEFS (2004) and SSDS/EISA DRA (1998). Since activities leading to COC exposure (swimming and seafood consumption) are assumed to be conducted in both wet and dry season, dry and wet season combined dilution factors were adopted. Adopting 10 %tile dilution factor for risk calculation is an approach consistent with previous studies, which results in a more realistic yet conservative range of risk calculations.

Table 6.3a Estimated Dilution Factors (Project Scenario 1)

Exposure Point	Season	Min. Dilution Factor	10 %tile Dilution Factor[a]	Average Dilution Factor	Min. 4-day Average Dilution Factor
Edge of ZID	Dry and Wet Season Combined	47	53[b]	74	Cannot be determined by near field model
	Dry Season	Not calculated – not used for risk assessments		83	
	Wet Season			62	
Edge of Mixing Zone*	Dry and Wet Season Combined	62	115[c]	182	197
	Dry Season	83	109	170	197
	Wet Season	62	125	193	234
Nearest Beach from SCISTW Outfall	Dry and Wet Season Combined	189	217[d]	Not calculated – not used for risk assessments	
	Dry Season	189	213		
	Wet Season	295	316		

Note: * The edge of mixing zone of dichloroacetic acid (the COC with the largest mixing zone)
[a] Dilution factor exceeded 90% of the time (i.e. 10% of values are below this value)
[b] Applied to determine COC conc. at edge of ZID
[c] Applied to COC conc. at edge of mixing zone
[d] Applied to determine COC conc. at the nearest beach

Table 6.3b Estimated Dilution Factors (Project Scenario 2)

Exposure Point	Season	Min. Dilution Factor	10 %tile Dilution Factor[a]	Average Dilution Factor	Min. 4-day Average Dilution Factor
Edge of ZID	Dry and Wet Season Combined	48	53[b]	79	Cannot be determined by near field model
	Dry Season	Not calculated – not used for risk assessments		92	
	Wet Season			62	
Edge of Mixing Zone*	Dry and Wet Season Combined	60	110[c]	173	188
	Dry Season	79	103	162	188
	Wet Season	60	118	184	222
Nearest Beach from SCISTW Outfall	Dry and Wet Season Combined	179	206[d]	Not calculated – not used for risk assessments	
	Dry Season	179	203		
	Wet Season	280	301		

Note: * The edge of mixing zone of dichloroacetic acid (the COC with the largest mixing zone)
[a] Dilution factor exceeded 90% of the time (i.e. 10% of values are below this value)
[b] Applied to determine COC conc. at edge of ZID
[c] Applied to determine COC conc. at edge of mixing zone
[d] Applied to determine COC conc. at the nearest beach

Table 6.3c Estimated Dilution Factors (Project Scenario 3)

Exposure Point	Season	Min. Dilution Factor	10 %tile Dilution Factor[a]	Average Dilution Factor	Min. 4-day Average Dilution Factor
Edge of ZID	Dry and Wet Season Combined	36	49[b]	61	Cannot be determined by near field model
	Dry Season	Not calculated – not used for risk assessments		65	
	Wet Season			57	
Edge of Mixing Zone*	Dry and Wet Season Combined	50	74[c]	118	130
	Dry Season	53	69	111	130
	Wet Season	50	81	124	152
Nearest Beach from SCISTW Outfall	Dry and Wet Season Combined	124	148[d]	Not calculated – not used for risk assessments	
	Dry Season	124	145		
	Wet Season	200	214		

Note: * The edge of mixing zone of dichloroacetic acid (the COC with the largest mixing zone)
[a] Dilution factor exceeded 90% of the time (i.e. 10% of values are below this value)
[b] Applied to determine COC conc. at edge of ZID
[c] Applied to determine COC conc. at edge of mixing zone
[d] Applied to determine COC conc. at the nearest beach

Table 6.3d Estimated Dilution Factors (Project Scenarios 4 and 5)

Exposure Point	Season	Min. Dilution Factor	10 %tile Dilution Factor[a]	Average Dilution Factor	Min. 4-day Average Dilution Factor
Edge of ZID	Dry and Wet Season Combined	34	46[b]	61	Cannot be determined by near field model
	Dry Season	Not calculated – not used for risk assessments		66	
	Wet Season			53	
Edge of Mixing Zone*	Dry and Wet Season Combined	Cannot be determined as no mixing zone determined for dry season			
	Dry Season	No mixing zone determined			
	Wet Season	43	64[c]	104	127
Nearest Beach from SCISTW Outfall	Dry and Wet Season Combined	104	126[d]	Not calculated – not used for risk assessments	
	Dry Season	104	121		
	Wet Season	132	144		

Note: *The edge of mixing zone of bromoform (the COC with the largest mixing zone)
[a] Dilution factor exceeded 90% of the time (i.e. 10% of values are below this value)
[b] Applied to determine COC conc. at edge of ZID
[c] Applied to determine COC conc. at edge of mixing zone
[d] Applied to determine COC conc. at the nearest beach

6.20 The edge of ZID is defined as the point when the plume reached the water surface or reached the maximum rise height. It can be observed from **Tables 6.3a** to **6.3d** that estimated highest initial dilution factors would not occur at the scenario with the lowest effluent flow. It is because the jet velocity would be smaller under the lowest effluent flow condition and there was not enough momentum for the effluent plume to reach the upper water layer. Under a higher effluent flow condition, the effluent plume may have larger momentum to induce more mixing and better dilution. This is an important factor influencing the initial dilution rate particularly in dry season where the effluent plume would have weaker buoyancy and would easily trap in the lower water layer if there is not enough jet velocity.

Human Health Risk Assessment

6.21 In the HHRA, there are two main categories of human receptors, namely general public and fisherman (the more sensitive receptor since they consume more seafood in their diet). The following COC exposure scenarios were considered and evaluated:

- Accidentally drop into the harbour (at edge of ZID) and consumption of contaminated seafood
- Frequent swimming at the edge of mixing zone[6] and consumption of contaminated seafood
- Frequent swimming at Tsuen Wan beaches and consumption of contaminated seafood

6.22 Lifetime incremental cancer risk and non-cancer health hazard quotient/hazard index were calculated to determine the health impact due to exposure of carcinogenic COCs and COCs would pose non-carcinogenic health effect respectively. For non-cancer health hazard, the effect on adult and child of the 2 categories of human receptors were determined. The detailed assessment results were presented in **Appendix 6-2**. **Tables 6.4a**, **6.4b** and **6.4c** present the estimated cancer risk and non-cancer health hazard to the receptors in the 5 Project Scenarios described in Section 6.7.

Table 6.4a Estimated Lifetime Incremental Cancer Risk due to Potential CBPs

	Incremental Lifetime Cancer Risk					
	General Public			Fishermen		
Project Scenario	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption
Scenario 1	0.00000006	0.00000234	0.00000124	0.00000006	0.00000234	0.00000124
Scenario 2	0.00000006	0.00000245	0.00000131	0.00000006	0.00000245	0.00000131
Scenario 3	0.00000006	0.00000363	0.00000182	0.00000006	0.00000364	0.00000182
Scenario 4	0.00000006	0.00000420	0.00000214	0.00000007	0.00000420	0.00000214
Scenario 5	0.00000007	0.00000420	0.00000213	0.00000007	0.00000420	0.00000214

Table 6.4b Estimated Non-cancer Health Hazard Index (Adult Receptor) due to Potential CBPs

	Hazard Index					
	General Public (Adult)			Fishermen (Adult)		
Project Scenario	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption
Scenario 1	0.0000359	0.00151	0.000803	0.0000363	0.00152	0.000803
Scenario 2	0.0000362	0.00158	0.000846	0.0000368	0.00158	0.000847
Scenario 3	0.0000388	0.00235	0.00113	0.0000392	0.00235	0.00113
Scenario 4	0.0000402	0.00272	0.00138	0.0000410	0.00272	0.00138
Scenario 5	0.0000302	0.00185	0.000942	0.0000310	0.00186	0.000943

[6] The edge of mixing zone would be located well offshore and would be difficult by swimmers. This exposure scenario was included as a worst case scenario. The mixing zone of dichloroacetic acid (the largest one among those of other COCs) was adopted for risk calculations for Scenarios 1 to 3; whereas the mixing of bromoform (the largest one among those of other COCs) was adopted for risk calculations for Scenario 4. The same mixing zones were adopted for cumulative risk impact assessment.

Table 6.4c Estimated Non-cancer Health Hazard Index (Child Receptor) due to Potential CBPs

	Hazard Index					
	General Public (Child)			Fishermen (Child)		
Project Scenario	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption
Scenario 1	0.0000421	0.00174	0.000922	0.0000425	0.00174	0.000922
Scenario 2	0.0000424	0.00182	0.000934	0.0000430	0.00182	0.000934
Scenario 3	0.0000455	0.00270	0.00135	0.0000459	0.00270	0.00135
Scenario 4	0.0000472	0.00312	0.00159	0.0000480	0.00312	0.00159
Scenario 5	0.0000340	0.00207	0.00105	0.0000348	0.00207	0.00105

6.23 As seen in **Tables 6.4a** to **6.4c**, in all project scenarios, the incremental lifetime cancer risk and non-cancer health hazard index imposed to all human receptors in all exposure scenarios were found to be acceptable under the established assessment criteria. According to the HHRA results, the human health risk due to the Project would be acceptable.

6.24 The health risk due to the extremely conservative (and not realistic) exposure scenario "Accidentally drop into the harbour at edge of ZID + Frequent swimming at the edge of mixing zone + Consumption of contaminated seafood (fishermen diet)" was calculated and the results were presented in **Table 6.5**.

Table 6.5 Estimated Lifetime Incremental Cancer Risk for Extremely Conservative Exposure Scenario

	Exposure Scenario :Drop at edge of ZID + Freq. swim at edge of mixing zone + seafood consumption		
Project Scenario	Incremental Lifetime Cancer Risk – Fishermen Lifetime	Hazard Quotient - Fishermen adult	Hazard Quotient – Fishermen child
Scenario 1	0.00000240	0.00155	0.00178
Scenario 2	0.00000250	0.00162	0.00186
Scenario 3	0.00000370	0.00239	0.00257
Scenario 4	0.00000427	0.00276	0.00317
Scenario 5	0.00000427	0.00188	0.00211

6.25 As seen in **Table 6.5**, the health risk due to the extremely conservative exposure scenario was also found to be acceptable under the established assessment criteria.

Cumulative Impacts

6.26 While the assessment focused on assessing the potential risks/impacts to human health due to chronic exposure to the contaminants produced in the disinfection process in the HATS effluent discharge, cumulative impact of the possible C/D effluent discharge from Tai Po/Shatin Sewage Treatment Works (TP/ST STW), Pillar Point Sewage Treatment Works (PPSTW) and other pollutants (not related to the disinfection process) in the effluent discharge from SCISTW was considered and evaluated.

<u>Cumulative Impact of the Possible C/D Effluent Discharge from TP/STSTW and PPSTW</u>

6.27 Results of water quality modelling showed that the effluent plume from SCISTW, TP/ST STW and PPSTW would not overlap each other. The results indicated that CBPs potentially discharged from TP/ST STW and PPSTW (if chlorination is adopted as the disinfection technology under the assumed worst-case scenario) would not significantly contribute to the concentration of CBPs at the edge of ZID, edge of mixing zone (of the effluent plume from SCISTW) and the Tsuen Wan beaches. Therefore, possible C/D effluent from the TP/ST STW and PPSTW would not induce cumulative impact with the C/D effluent from SCISTW.

6.28 The evaluation above is further supported by the findings of approved EIA Study for Tai Po Sewage Treatment Works - Stage V. The EIA Study for TPSTW Stage V indicated that the impact from the TPSTW and STSTW effluent would be very localized and confined within the Kai Tak Approach Channel and the existing Kwun Tong Typhoon Shelter. The effluent plume from SCISTW and TPSTW/STSTW would not overlap with each other.

Cumulative Impact of Other Pollutants in SCISTW Effluent

6.29 Apart from potential CBPs generated in the C/D process, other pollutants (not related to C/D process) in the HATS effluent would also impose risks to human health. The cumulative impact due to the risks from CBPs and other pollutants (e.g. heavy metals) present in the HATS effluent was considered and evaluated.

6.30 A comprehensive chemical analysis was conducted under the HATS EEFS (2004) to determine the pollutant concentrations in HATS CEPT effluent (Stage 1 and Stage 2A) and CEPT plus Biological Aerated Filters (BAF) effluent (Stage 2B). The chemical analysis data from the previous study was used to evaluate the cumulative impact.

6.31 The methodology for cumulative risk impact assessment was similar to the one presented in **Appendix 6-1**. Additional information for the cumulative risk impact assessment was presented **Appendix 6-3**.

6.32 The detailed assessment results were presented in **Appendix 6-4**. **Tables 6.6a, 6.6b** and **6.6c** present the estimated cancer risk and non-cancer health hazard due to CBPs and other pollutants in HATS effluent to the receptors in the 5 Project Scenarios

Table 6.6a Estimated Lifetime Incremental Cancer Risk (due to CBPs and Other Pollutants)

	Incremental Lifetime Cancer Risk					
	General Public			Fishermen		
Project Scenario	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption
Scenario 1	0.0000006	0.0000276	0.0000263	0.0000009	0.0000278	0.0000266
Scenario 2	0.0000008	0.0000279	0.0000266	0.0000013	0.0000283	0.0000271
Scenario 3	0.0000006	0.0000290	0.0000270	0.0000009	0.0000292	0.0000272
Scenario 4	0.0000009	0.0000299	0.0000276	0.0000014	0.0000304	0.0000281
Scenario 5	0.0000008	0.0000262	0.0000240	0.0000011	0.0000266	0.0000244

Table 6.6b Estimated Non-cancer Health Hazard Index (Adult Receptor, due to CBPs and other pollutants)

	Hazard Index					
	General Public (Adult)			Fishermen (Adult)		
Project Scenario	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption
Scenario 1	0.005	0.186	0.184	0.007	0.188	0.186
Scenario 2	0.006	0.188	0.186	0.011	0.192	0.190
Scenario 3	0.005	0.188	0.184	0.007	0.190	0.187
Scenario 4	0.007	0.191	0.187	0.015	0.196	0.192
Scenario 5	0.007	0.181	0.179	0.011	0.186	0.183

Table 6.6c Estimated Non-cancer Health Hazard Index (Child Receptor, due to CBPs and other pollutants)

	Hazard Index					
	General Public (Child)			Fishermen (Child)		
Project Scenario	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption	Drop at edge of ZID + seafood consumption	Freq. swim at edge of mixing zone + seafood consumption	Freq. swim at Tusen Wan beaches + seafood consumption
Scenario 1	0.005	0.220	0.217	0.008	0.222	0.220
Scenario 2	0.007	0.222	0.219	0.011	0.226	0.223
Scenario 3	0.005	0.222	0.218	0.007	0.225	0.221
Scenario 4	0.007	0.226	0.221	0.012	0.230	0.226
Scenario 5	0.007	0.212	0.209	0.012	0.216	0.214

6.33 As seen in **Tables 6.6a** to **6.6c**, in all project scenarios, the incremental lifetime cancer risk and non-cancer health hazard index imposed to all human receptors in all exposure scenarios were found to be acceptable under the established assessment criteria. According to the cumulative risk impact assessment results, the human health risk due to CBPs and other pollutants in HATS effluent would be acceptable.

6.34 The cumulative health risk due to CBPs and other pollutants in the extremely conservative (and not realistic) exposure scenario "Accidentally drop into the harbour at edge of ZID + Frequent swimming at the edge of mixing zone + Consumption of contaminated seafood (fishermen diet)" was calculated and the results were presented in **Table 6.7**.

Table 6.7 Estimated Lifetime Incremental Cancer Risk for Extremely Conservative Exposure Scenario (due to CBPs and other Pollutants)

	Exposure Scenario :Drop at edge of ZID + Freq. swim at edge of mixing zone + seafood consumption		
Project Scenario	Incremental Lifetime Cancer Risk – Fishermen Lifetime	Hazard Quotient - Fishermen adult	Hazard Quotient – Fishermen child
Scenario 1	0.0000282	0.191	0.225
Scenario 2	0.0000287	0.194	0.229
Scenario 3	0.0000296	0.192	0.227
Scenario 4	0.0000308	0.198	0.233
Scenario 5	0.0000269	0.188	0.219

6.35 As seen in **Table 6.7**, the cumulative health risk due to the extremely conservative exposure scenario was also found to be acceptable under the established assessment criteria.

6.36 Moreover, by comparing the results in **Tables 6.4a-c** and **6.6a-c**, it can be observed that in Scenarios 1 to 4, cancer risk and hazard index due to CBPs is at least 6 and 70 times lower than that due to pollutants present in CEPT effluent. The results showed that the chlorination/dechlorination process for CEPT effluent would only induce a very low level of incremental human health risk, which is very small when compared to the health risk due to the pollutants existed in CEPT effluent. Noted that the cumulative health risk (i.e. risk due to CBPs and other pollutants in CEPT effluent) was found to be acceptable.

Assumptions in Risk Assessment

6.37 A description of the assumptions associated with the HHRA is presented below.

- For each COC, the maximum effluent concentration and the maximum background concentration were used to calculate the COC concentration at exposure point. This conservative approach yielded higher estimated risk than using mean concentrations.
- It was assumed that after the effluent is discharged, COCs in the effluent would only have their concentrations decrease as a result of dilution and dispersion. It was a conservative approach because COCs concentrations in the water column would also decrease because of different mechanisms such as degradation and / or volatilization.

- The assumption made for the incidental water ingestion rate – 50 ml/hour with an exposure duration 2.6 hours/day appeared to be fairly conservative, especially for seawater which is less palatable to ingest than fresh water. While the seafood consumption rate of 0.3kg/day assumed for fishermen was considered to be an upper bound value and is not expected to occur in reality, in turn provide a conservative risk estimate.

- The inclusion of exposure scenarios involving dropping into the harbour and frequent swimming at the edge of mixing zone was to provide a worst case scenario in the risk assessment. The unrealistic assumption of dropping into the harbour once every year was made for the purpose of assessment. While the edge of mixing zone would be located well offshore and would be very difficult for swimmers to reach there frequently.

- Since a list of "regulated CBPs in sewage effluent" is not available locally or overseas, the COPC identification was based on literature search of documented potential CBPs[7] and regulatory practice of chlorinated organic substances in drinking water/sewage effluent[8]. This approach was conservative, as it may include chemicals that actually are not produced as COPC by chlorination of HATS effluent, as reflected by the fact that most of the identified COPC were not detected in C/D effluent. Nevertheless, for the purposes of the risk assessment, a concentration equivalent to half of the analytical detection limit of each undetected COC was adopted in the risk calculation. This conservative approach served to counter the possibility that some chemicals from chlorination of HATS effluent may be present but were not included as a COPC in the risk calculation. Overall, in line with common practice, this approach to COPC identification is considered sufficiently comprehensive to assess the potential risk to human health.

- The COC concentrations of chlorinated/dechlorinated effluent were obtained from a number of bench scale process simulating the C/D treatment using a higher hypochlorite dosage (higher than the dosage in actual full-scale process implementation) to provide conservatism.

- Dilution factor estimated by water quality modelling was used to predict the COC dispersion in water and the COC concentrations at exposure points. Computer models are sophisticated tools used to simulate mother-nature, and uncertainties inherent in these models have been minimized by vigorous model calibration and verification. The conservative 10% dilution factor was used to estimate COC concentrations exposure points, in turn provided a more conservative risk estimate.

- The characteristic parameter values for human receptors were point estimates adopted from literatures, which may not precisely reflect the conditions of a range of potential human receptors. However, inclusion of fishermen receptors in the HHRA could provide risk estimate for more sensitive population.

- The health benchmarks[9] adopted from agencies would introduce uncertainty to the HHRA. These health benchmarks are used as single-point estimates throughout the analysis with uncertainty and variability associated with them. However, it should be noted that much of the uncertainty and variability associated with the health benchmarks shall be accounted for in the process that the agencies setting verified benchmarks, especially the more stringent values from agencies were adopted.

[7] Some of the documented potential CBPs were generated by applying very high chlorine dose (in the order of hundreds or thousands mg/L) to sewage effluent, which would not occur in the HATS scenario.
[8] Regulation of chlorinated organic substances was due to their presence in industrial effluent but not their possible generation in chlorination process.
[9] Cancer slope factor and reference dose of COCs.

- Health hazard index was calculated by summation of all hazard quotients due to various COCs. This approach assumed that the health effects of the various COCs are additive, which did not consider the possible synergistic or antagonistic interaction of various COCs. However, several studies have demonstrated that the additive approach often predicts reasonably well the toxicities of mixtures composed of a substantial variety of both similar and dissimilar compounds (USEPA 1986).

6.38 In summary the health risk assessment by design is very protective of human health by overstating potential exposures and risks. Conservative assumptions made in the risk assessment include (i) adopting maximum effluent concentration and background seawater concentration for risk calculation; (ii) assuming COCs in effluent would only have their concentrations decrease as a result of dilution and dispersion; (iii) applying conservative exposure parameters; (iv) inclusion of exposure scenarios involving dropping into the harbour and frequent swimming at the edge of mixing zone to provide a worst case scenario in the risk assessment. Despite uncertainties involved in some aspects of the risk assessment, conservative treatments (e.g. adopted the more stringent health benchmark values from agencies) were applied where appropriate. The health risk assessment represents the most useful tool that can be used to determine and protectively manage the risk to human health. It is considered that the human health risk assessment overall provided a conservative estimate of risk level and would not underestimate the risk.

Evaluation of Residual Impacts

6.39 The above health risk assessment indicated that calculated risks of all scenarios were found to be acceptable under the established assessment criteria. In view that the inherent conservative health risk assessment indicated acceptable health risk levels, no residual impact from the Project on human health is anticipated.

Mitigation of Environmental Impact

6.40 Dechlorination process was incorporated into the effluent disinfection process to remove TRC and reduce formation of CBPs. As discussed above there would be no unacceptable human health risk induced by the Project and therefore no mitigation measures would be required.

Environmental Monitoring and Auditing

6.41 It is recommended to establish a monitoring programme to determine whether the Project would induce increase of TRC and CBP concentrations in seawater and to verify the predictions of the risk assessment. Details of the programme are provided in a stand-alone EM&A Manual.

Conclusions

6.42 A detailed Human Health Risk Assessment was conducted to assess the potential adverse human health effects that may result from exposure of toxic substances due to HATS effluent discharge. The findings were summarized below:

6.43 Results of Human Health Risk Assessment revealed that potential risk/hazard impact due to chlorination by-products present in the chlorinated/dechlorinated HATS effluent would be acceptable under established assessment criteria in all the 5 Project Scenarios. Cumulative risk assessment indicated that the potential risk/hazard impact due to CBPs and other pollutants present in the C/D HATS effluent would also be acceptable under established assessment criteria in all the 5 Project Scenarios.

6.44 According to the risk assessment results, the Project would not cause unacceptable risk to human health. Therefore, the Project was considered to be environmentally acceptable in terms of risks/impacts to human health.

Reference

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4. ERM (2005). Detailed Site Selection Study for a Proposed Contaminated Mud Disposal Facility within the Airport East/East of Sha Chau Area. Environmental Impact Assessment (EIA) and Final Site Selection Report.
5. MCAL (2004). Tai Po Sewage Treatment Works – Stage V. Environmental Impact Assessment Study.
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