APPENDIX 2A:

Review of Recent Studies and Trials on Chemicals for CEPT and Potential Disinfection Options

A 2. REVIEW OF RECENT STUDIES AND TRIALS ON CHEMICALS FOR CEPT AND POTENTIAL DISINFECTION OPTIONS

A 2.1 Introduction

A 2.1.1 *General*

A 2.1.1.1 This appendix examines the pros and cons of using various chemicals (e.g. $FeCl_3$, alum etc) for the Chemically Enhanced Primary Treatment (CEPT) process. Each chemical has implications on the efficiency of UV disinfection, and the quality and quantity of the sludge generated.

A 2.1.1.2 Besides, this appendix also reviewed the following disinfection options regarding their use for the proposed expanded San Wai STW:

- Chlorination;
- UV disinfection;
- Ozonation; and
- Microfiltration.

A 2.1.1.3 This review makes use of studies and trials carried out under several recent projects in Hong Kong. The scopes of these studies are briefly described below. The findings of the studies and trials are discussed under the relevant headings in **Sections A2.2 and A2.3**.

A 2.1.2 *SSDS Stage 1 Pilot Plant Study on Chemical Dosing and Disinfection*

A 2.1.2.1 This study, completed in 1996, was undertaken by Environmental Management Ltd. for EPD. It is referred to in later sections as "the SSDS Stage 1 Dosing and Disinfection Study".

A 2.1.2.2 The project comprised two main studies, one on chemical dosing and one on disinfection. The objectives of the Study on Chemical Dosing were:

i. To determine the sources of chemicals including the availability, reliability of supply, and budget costs for the future operation of the full-scale CEPT plant at Stonecutters Island Sewage Treatment Works (SCISTW).

ii. To determine the most suitable metal salt and its optimum dosing rate, through laboratory tests and pilot plant tests, for the coagulation of the local sewage in the CEPT process.

iii. To determine the need for polymers, and the most suitable polymer and its optimum dosing rate as coagulant aid, through laboratory tests and pilot plant tests, in order to achieve the above target removal efficiencies of SS and BOD_5 in the CEPT process.

iv. To determine the cost effectiveness of the chemicals in regard to the operation of the full-scale CEPT plant at SCISTW.

A 2.1.2.3 The objectives of the Study on Disinfection were:

i. To review the latest disinfection systems for sewage effluents to identify viable disinfection systems for different quality of effluent.

ii. To evaluate the viable disinfection systems taking into account technical, economical, safety, hazards and environmental aspects.

iii. To undertake pilot plant studies of viable disinfection system(s) using the effluent from the chemical dosing pilot plant.

iv. To recommend the most suitable disinfection system(s) for disinfecting the different quality of effluent with respect to different types of sites, including industrial area (similar to Stonecutters Island), residential area (similar to Green Island Reclamation) and remote area (on an island reclamation).

A 2.1.3 *Prototype Trials at Stonecutters Island STW*

A 2.1.3.1 From 10 February 1997 to 5 May 1997, four sequential prototype trials[1] were conducted in the built for purpose prototype treatment units at SCISTW. The trials were carried out for the DSD) Government of the Hong Kong, SAR. Montgomery Watson, as the Engineer, managed the trials, which were operated by Valu Add, a sub-contractor to the sedimentation E&M Contractor, ATAL Engineers, Ltd.

A 2.1.3.2 The first set of trials was designed to determine optimum rapid mixer speed, flocculation air agitation rates and polymer dosing locations. The rest of the trials were designed to determine optimum chemical dosing rates for ferric chloride and anionic polymer under different flow conditions.

A 2.1.4 *Ozone Disinfection Pilot Study for SSDS Stage 1*

A 2.1.4.1 This study was completed in 1999 by HKUST together with Trailigaz for DSD. It is referred to in later sections as “the SSDS Stage 1 Ozone Trials”. The main objectives were to generate data for the following purposes:

i. To ensure achievement of three different disinfection levels: 3-log reduction of *E.coli* on a 95-precentile basis; and *E.coli* count of 5,000/100 mL or less on a 95-precentile basis; and *E.coli* count of 1,000/100 mL or less on a 95-precentile basis.

ii. To enable preliminary design, land requirement, power consumption and whole life cost estimates for a full-scale ozone disinfection plant.

A 2.1.5 *SSDS Stage 2 Preliminary Project Feasibility Study*

A 2.1.5.1 The disinfection component of this PPFS study was completed in 2000 by Montgomery Watson for EPD. It is referred to in later sections as “the SSDS Stage 2 PPFS”. The main objectives were to:

i. Review all the existing information and findings of the previous studies and trials, including overseas experience, and assess the applicability of available disinfection technologies to the SSDS.

ii. Recommend and arrange any necessary prototype and pilot plant trials for the assessment of the applicability of the disinfection technologies;

iii. Compare and evaluate the disinfection methods, their layouts, the associated land and power requirements. Short-list at least two different preferred methods, with due consideration given to the environmental implications, the capital and recurrent costs, the operation and maintenance requirements, the impacts on the existing treatment facilities, and the associated risk.

iv. Recommend prototype trials (and pilot plant trials if necessary) which may be carried out during the subsequent project implementation stages for the short-listed disinfection options.

[1] GK Kukreja, WW Chui, DD McLearie, SF Baker: Prototype Trials at Stonecutters Island Sewage Treatment Works, Hong Kong

A 2.1.6 *Outlying Islands Sewerage Stage 1 Phase 1: Siu Ho Wan STW Upgrading Disinfection Pilot Plant Study*

A 2.1.6.1 The initial disinfection trials component of this project study was completed in March 2000 by Maunsell Consultants Asia for DSD under Agreement CE49/95. The main objectives were to:

i. assess the feasibility to disinfect chemically enhanced primary effluent to meet discharge standards;

ii. obtain site specific data as the basis to select the most suitable disinfection option for Siu Ho Wan STW.

A 2.1.6.2 Under the same study further trials were carried out culminating in another report entitled *"Upgrading of Siu Ho Wan STW: UV Disinfection Pilot Test on Low Pressure High Intensity System"*. The draft report was issued in December 2001. The primary objective was to assess the feasibility of low-pressure high intensity UV disinfection for Siu Ho Wan STW and to establish the appropriate design parameters for a full-scale UV disinfection facility to achieve the required *E.coli* standards. The specific objectives of the pilot test included:

i. To assess the influent characteristics that pertains to UV disinfection

ii. To develop dose-response relationship for UV disinfection under various influent conditions.

iii. To assess the UV lamp fouling rates and required frequency of cleaning

iv. To assess the hydraulic head loss through the UV system under different flow conditions.

v. To conduct assessment on the possible formation of disinfection by-products and photoreactivation under the expected UV dose levels.

A 2.1.6.3 Both of these reports are referred to in later sections as "the Siu Ho Wan STW Disinfection Study".

A 2.2 Review of Chemicals for CEPT

A 2.2.1 *Introduction*

A 2.2.1.1 This section examines the advantages and disadvantages of using various chemicals for the CEPT process at San Wai. Implications for removal of SS and BOD, the efficiency of UV disinfection, and sludge treatment are described, based on the results of previous studies and trials.

A 2.2.2 *Range of Chemicals Considered*

A 2.2.2.1 In the SSDS Stage 1 Dosing and Disinfection Study, the following chemicals for use in CEPT were considered:

- Ferric Chloride
- Ferric Sulphate
- Ferrous Chloride
- Ferrous Sulphate
- Aluminium Sulphate
- Poly Aluminium Chloride
- Polymers

A 2.2.2.2 Detailed surveys[2] of existing treatment works and suppliers in the mid-1990s revealed the following:

- widespread use of ferric chloride for CEPT, and adequate production capacity for the SSDS;
- less information on the use of other iron salts (ferric sulphate, ferrous chloride and ferrous sulphate) in full-scale CEPT plants, and indications that the available production capacity is lower than for ferric chloride;
- a range of potential sources for alum.

A 2.2.2.3 Given the quantities required for the SSDS, the guarantee of product delivery was one of the most critical criteria in chemical selection. Concern was expressed about the sourcing of chemicals such as ferrous chloride and alum for Stonecutters Island STW. For San Wai STW the required quantities are much lower. It should also be noted that many of the potential suppliers chose not to reveal their production capacity in the survey, classifying this as commercially sensitive information. It is therefore likely that the information obtained on production capacity in the SSDS Stage 1 Dosing and Disinfection Study underestimated the actual availability.

A 2.2.3 *Effectiveness and Likely Dosage Rates*

Laboratory and Pilot Trials in HK

A 2.2.3.1 In the SSDS Stage 1 Dosing and Disinfection Study, ferric chloride, ferric sulphate, ferrous sulphate, aluminium sulphate (alum), poly-aluminium chloride (PAC) and two cationic polymers were selected for evaluation in laboratory-scale jar tests and column tests. Anionic polymers were used as flocculation aids (Magnafloc 1011 and SNF DQ926) to enhance the effectiveness of the metal salts, and cationic polymeric coagulants (Zetag 92 and SNF C9012) were evaluated as replacements for the metal salts.

A 2.2.3.2 In the jar tests, different doses of chemicals were added to the jars to simulate the CEPT process. Clarity of supernatant collected after settling for 5 minutes was taken as representative of the predicted effluent quality. Based on jar test results (conducted under ideal laboratory conditions), the optimum doses to achieve 85% removal of Suspended Solids (SS) are reported in **Table A2.1**.

[2] "SSDS Stage 1 Pilot Plant Study on Chemical Dosing and Disinfection", EML, Dec 1996

Table A2.1 Jar Test Optimum Dose to Achieve 85% Removal of SS (SSDS Stage 1 Dosing and Disinfection Study)

Coagulant	Dose	Flocculant	Dose
Ferric Chloride	10-11 mg/L $FeCl_3$	No flocculant	-
	7 mg/L $FeCl_3$	Magnafloc 1011	0.1 mg/L
	9 mg/L $FeCl_3$	SNF DQ926	0.5 mg/L
Ferric Sulphate	> 20 mg/L $Fe_2(SO_4)_3$	No flocculant	-
	9 mg/L $Fe_2(SO_4)_3$	Magnafloc 1011	0.1 mg/L
	7 mg/L $Fe_2(SO_4)_3$	SNF DQ926	0.5 mg/L
Alum	7 mg/L Al_2O_3	No flocculant	-
	6 mg/L Al_2O_3	Magnafloc 1011	0.2 mg/L
	6 mg/L Al_2O_3	SNF DQ926	0.05 mg/L
PAC	8 mg/L Al_2O_3	Magnafloc 1011	0.01 mg/L
	8 mg/L Al_2O_3	SNF DQ926	0.01 mg/L
	3.5 - 4.0 mg/L Al_2O_3	Magnafloc 1011	0.1 mg/L
	3.5 - 4.0 mg/L Al_2O_3	SNF DQ926	0.5 mg/L
Zetag 92	Could only achieve 75-77% removal of SS		-
SNF C9012	5 mg/L	-	-

A 2.2.3.3 The jar test without chemicals achieved between 64% and 69% removal of SS. All chemical combinations achieved a removal of BOD_5 between 50% and 63% against the removal without chemicals of 38%.

A 2.2.3.4 Column tests were then conducted, in which flocculated sewage was allowed to settle in 3.4 m high columns, thus allowing tests at overflow rates (OFRs) typical of the CEPT process. The dose rates used and the performance achieved are summarised in **Table A2.2** and **Table A2.3**. Ferric chloride and alum, both with Magnafloc 1011, were predicted to achieve 80% removal of SS at a surface overflow rate three times that of the control (without chemical). The two cationic polymers also appeared to promise good performance at high surface overflow rates. It was concluded that where the target SS removal is 70-80%, the two cationic polymeric coagulants could offer a reliable alternative to ferric chloride and the other metal salts. However, if the target is 85% removal of SS, the metal salts would be the most reliable coagulants. The performance of PAC was disappointing during the column tests and this was not evaluated in the pilot plant trials.

Table A2.2 Chemicals and Doses Used in the Column Tests (SSDS Stage 1 Dosing and Disinfection Study)

COAGULANT		FLOCCULANT	
Chemical	Dose (mg/L)	Chemical	Dose (mg/L)
Ferric Chloride	9.0 (as $FeCl_3$)	Magnafloc 1011	0.10
Ferric Sulphate	11.0 (as $Fe_2(SO_4)_3$)	Magnafloc 1011	0.10
Aluminium Sulphate	5.0 (as Al_2O_3)	Magnafloc 1011	0.10
PAC	5.0 (as Al_2O_3)	Magnafloc 1011	0.10
Zetag 92	2.0	-	-
SNF C9012	5.0	-	-

Table A2.3 Comparison of Performance in Column Tests (SSDS Stage 1 Dosing and Disinfection Study)

SS Removal	Day	Ferric Chloride	Ferric Sulphate	Alum	PAC	Zetag 92	SNF C9012	Control
OFR to achieve 80% removal (m^3/m^2.d)	1	100	72	95	75	150	250	35
	2	72	38	102	-	-	-	-
OFR to achieve 85% removal (m^3/m^2.d)	1	75	65	75	-	65	80	-
	2	55	25	75	-	-	-	-
% removal at OFR 105 m^3/m^2.d	1	78%	70%	76%	68%	81%	83%	63%
	2	78%	60%	80%	59%	70%	70%	58%

Note: Chemical doses used are shown in Table A2.2
"-" cannot achieve the target % removal.

A 2.2.3.5 Based on the results of the column tests, pilot scale trials were then conducted. The pilot plant was designed by scaling down the full-scale plant at SCISTW to maintain hydraulic similarity. The pilot plant consisted of two parallel streams, one with a chemical dosing system, and one without as a control. The main components consisted of a storage tank for screened sewage, a rapid mix tank, a flocculation tank, and two primary sedimentation tanks and effluent balance tanks.

A 2.2.3.6 Most of the comparative work with chemicals was done with NW Kowloon sewage, but demonstration runs with a mixture of NW Kowloon and Kwai Chung sewage were also undertaken to give an indication of the likely effects with a mix of sewage more typical of the overall SSDS Stage 1 catchment. A summary of the pilot plant trial dosages to give 85% and 70% removal of SS at OFR of 60 m^3/m^2.d is given in **Table A2.4**.

A 2.2.3.7 SS removals at OFR of 60 m^3/m^2.d were improved from an average of 50% to 82% with the addition of chemicals. The effluent quality with CEPT was relatively constant and was generally below 50 mg SS/L for most of the test conditions up to 105 m^3/m^2.d, irrespective of the chemical combination, whereas the performance of the primary sedimentation process (without the addition of chemicals) deteriorated considerably at the higher OFR. Alum was found to give the most consistent good performance in terms of effluent quality when compared with other metal salts and cationic polymers at the dose rates tested.

Table A2.4 Doses of Chemicals to Give Different % Removal of SS at 60 m^3/m^2 d (SSDS Stage 1 Dosing and Disinfection Study)

Chemical	Unit	Dose to Give 85% SS Removal		Trial Dose	Dose to Give 70% SS Removal	
		NWK	NWK/KC		NWK	NWK/KC
Ferric Chloride	mg/L $FeCl_3$	20	<20	20	<10	n.d.
Ferric Chloride / Magnafloc 1011*	mg/L $FeCl_3$	>10	8 - 10	10	<10	<8
Ferric Sulphate	mg/L $Fe_2(SO_4)_3$	<12	<12	12	<<12	n.d.
Ferric Sulphate / Magnafloc 1011*	mg/L $Fe_2(SO_4)_3$	12	10 - 12	12	<12	<10
Alum	mg/L Al_2O_3	<10	<<10	10	<5	n.d.
Alum / Magnafloc 1011*	mg/L Al_2O_3	7.5	5	7.5	<<5	<<5
C9012	mg/L	4	2	2	2	n.d.
Zetag 92	mg/L	>3	2	2	<2	<2

* Magnafloc 1011 dosage was at 0.15 mg/L. n.d. = no data

Prototype and Commissioning Trials at Stonecutters Island STW

A 2.2.3.8 Trials were undertaken between March and May 1997 to test various chemical dosing rates against flows of 0.58 m^3/s and 0.875 m^3/s in the prototype tanks at SCISTW. The results of the trial are summarised in **Table A2.5**.

Table A2.5 Prototype Trial in Tank 33 at SCISTW

Date	Flow, m^3/s Each Stream	Ferric Chloride Dose, mg/L	Polymer Dose, mg/L	Suspended Solids % Removed	BOD % Removed
17/3/97	0.58	10	0	88	65
18/3/97	0.58	10	0	91	55
19/3/97	0.58	15	0	76	66
20/3/97	0.58	15	0	No sample	No sample
21/3/97	0.58	5	0.05	52	41
22/3/97	0.58	5	0.05	64	60
23/3/97	0.58	10	0.05	76	59
24/3/97	0.58	10	0.05	78	63
25/3/97	0.58	10	0.15	76	51
26/3/97	0.58	10	0.15	81	55
27/3/97	0.58	5	0.15	85	42
28/3/97	0.58	5	0.15	76	54
29/3/97	0.58	10	0	82	59
30/3/97	0.58	10	0	76	62
31/3/97	0.58	10	0.15	71	68
1/4/97	0.58	10	0.15	84	58
2/4/97	0.58	10	0	65	57
3/4/97	0.58	10	0	81	52
4/4/97	0.58	10	0.10	84	65
5/4/97	0.58	10	0.10	83	61
6/4/97	0.58	5	0.10	87	69
7/4/97	0.58	5	0.10	84	55
17/4/97	0.875	10	0	78	53
18/4/97	0.875	10	0	77	56
19/4/97	0.875	10	0	84	57
20/4/97	0.875	10	0.1	95	69
21/4/97	0.875	10	0.1	94	63
22/4/97	0.875	7.5	0.1	87	63
23/4/97	0.875	7.5	0.1	88	68
24/4/97	0.875	5	0.1	75	65
25/4/97	0.875	5	0.1	86	43
26/4/97	0.875	5	0.1	74	59
27/4/97	0.875	5	0.1	84	56
28/4/97	0.58	5	0.1	31	65
29/4/97	0.58	5	0.1	79	62
30/4/97	0.58	7.5	0.1	80	64
1/5/97	0.58	7.5	0.1	73	61
2/5/97	0.58	15	0.1	93	69
3/5/97	0.58	15	0.1	86	62
4/5/97	0.58	15	0.1	83	69

A 2.2.3.9 The prototype tanks provided valuable data related to equipment and process operating conditions and requirements. The main conclusion was that to ensure adequate treatment an initial dosing regime of 10 mg/L ferric chloride and 0.10 mg/L polymer would be used. Although the data suggested that 7.5 mg/L ferric chloride and 0.10 mg/L polymer may also provide consistent performance, it was agreed that the more robust of the two dosing regimes would be best for start-up.

A 2.2.3.10 On 12 May 1997 25% of the main treatment works were placed into service. All settings chosen from the trials were locked in and the initial results were consistent with what the prototype trials demonstrated. **Table A2.6** shows the initial, actual plant performance data, indicating that the process exceeded the design performance.

Table A2.6 Initial Performance Data from SCISTW after Commissioning in 1997

Parameter	Design	Actual
Ferric Chloride Dosing Rate, mg/L	20 - 40	10
Polymer Dosing Rate, mg/L	0 - 2.0	0.10
Suspended Solids Removal, %	70	82
BOD Removal, %	35	60

Ongoing Performance of Stonecutters Island STW

A 2.2.3.11 More recent data have been obtained on the performance of SCISTW based on the situation in 2000/2001 prior to commissioning of the SSDS[3] Stage 1 tunnels. The same dosing regime (10 mg/L of ferric chloride and 0.1 mg/L of anionic polymer) was being used during this period as on initial start-up of the plant. A summary of performance in 2000/01 is presented in **Table A2.7**.

Table A2.7 Performance Data from SCISTW after Commissioning

	BOD (mg/L)			SS (mg/L)		
Month	**Influent**	**Effluent**	**% removal**	**Influent**	**Effluent**	**% removal**
Oct-00	140	31	78	125	25	80
Nov-00	110	36	67	151	26	83
Dec-00	130	38	71	155	38	75
Jan-01	137	38	72	136	33	76
Feb-01	143	40	72	151	40	74
Mar-01	145	37	74	138	25	82
Apr-01	140	37	74	158	27	83
Jun-01	120	38	68	174	44	75
Jul-01	134	36	73	178	37	79
Aug-01	115	44	62	159	35	78
Sep-01	124	35	72	170	35	79

Monitored Influent Quality at San Wai STW

A 2.2.3.12 The range of values of the monitored parameters derived from the DSD sampling at San Wai STW on 19 - 29 October 2001 are summarised in **Table A2.8**. During this sampling time, sewage collected from Yuen Long Town was diverted to Yuen Long STW through Ping Shun Street Sewage Pumping Station.

[3] now known as "HATS"

Table A2.8 Monitored Influent Quality at San Wai STW (19 – 29 October 2001)

Parameter	Averages						Range (1)	
	19 Oct	20 Oct	21 Oct	27 Oct	28 Oct	29 Oct	Min	Max
TSS mg/L	140	163	157	163	140	150	90	320
TKN mg/L	33	33	33	35	35	36	24	47
NH3 mg/L	25	25	26	24	24	27	18	36
COD mg/L	368	385	202	355	355	370	150	480
BOD mg/L	149	153	150	170	171	175	74	245
TP mg/L	3.4	3.6	3.7	4.1	3.8	3.9	2.4	5.2
E.coli CFU/100 mL	8.9E+06	4.4E+06	3.5E+06	6.3E+09 (2)	3.8E+06	8.3E+06	5.0E+04	3.8E+10
Total S^{2-} mg/L	1.05	0.37	0.52	0.15	0.07	0.10	<0.01	2.38
Dissolved S^{2-} mg/L	0.19	0.03	0.15	0.01	0.03	0.04	<0.01	0.93

Note 1: "Range" provides the highest and lowest values for the samples, which each represent periods of two hours. "Averages" are arithmetic means.
Note 2: This value influenced by one very high result. All other results ≤ 6.4E+06. Geometric mean of all individual results 19-29 Oct = 2.4E+06/100mL

A 2.2.3.13 It is noted that the results represent a relatively small quantity of wastewater compared to the ultimate flows. It is possible that the characteristics will change as the catchment matures. Nevertheless, it can be concluded from the results that the wastewater is at present typical of weak domestic sewage.

A 2.2.3.14 **Table A2.7** shows that the sewage received at SCISTW during 2000/01 was also relatively weak. The performance of Stonecutters Island STW up to late 2001 should thus be very relevant to the likely performance of CEPT at San Wai STW.

A 2.2.4 *Effects on Disinfection*

SSDS Stage 1 Dosing and Disinfection Study

A 2.2.4.1 The SSDS Stage 1 Dosing and Disinfection Study found that alum gave the best effluent unfiltered UV transmittance (measured at 253.7nm) , exceeding the target of 35%. Values as high as 50% transmittance were recorded. On the other hand it was concluded that it would be difficult to achieve an unfiltered transmittance of 35% with ferric salts, at the doses of chemicals used.

A 2.2.4.2 The laboratory-scale study for chlorination using sodium hypochlorite (termed "hypochlorination") did not show any apparent differences in chemical requirements for CEPT effluent using different coagulants.

SSDS Stage 2 PPFS

A 2.2.4.3 Under the trials carried out for the SSDS Stage 2 PPFS, tests were carried out to evaluate the influence of ferric chloride and alum on UV transmittance (unfiltered and filtered) on CEPT effluent at varying chemical dosage rates.

Ferric Chloride Based Coagulation

A 2.2.4.4 Tests were conducted on effluent from the CEPT process simulations using ferric chloride on wastewaters from various SSDS catchments and on a "SSDS Representative Mix". All tests were conducted at times of peak diurnal concentration. The findings from these tests were as follows:

- the response to ferric chloride addition varied significantly from catchment to catchment in terms of unfiltered transmittance and effluent turbidity.
- for all catchments unfiltered UV transmittance increased with an increase in chemical dosage.
- there was a very strong relationship between unfiltered UV transmittance and effluent turbidity.
- the response in terms of unfiltered transmittance associated with North West Kowloon wastewater exceeded that of the other catchments. Wastewaters from Kwun Tong and Kwai Chung catchments, with a greater industrial component, gave much lower transmittances.
- At the current chemical dosage employed at SCI STW of 10 mg/L $FeCl_3$ (i.e. 3.5 mg/L as Me^{3+}), effluent transmittance (as determined from the jar tests) over the peak diurnal concentration period would be expected to vary as follows for each PTW and the SSDS Representative Mix :
  - Central PTW: 16% to 20%, median 17%
  - Kwai Chung PTW: 10% to 17%, median 12%
  - Kwun Tong PTW: 10% to 15%, median 10%
  - North West Kowloon PTW: 22% to 26%, median 24%
  - SSDS Representative Mix: 12% to 20%, median 13%
- The performance of the CEPT process at SCI STW (which was receiving influent from NW Kowloon) over the peak diurnal concentration period was somewhat better than the jar test result for NW Kowloon (typically between 26% and 30%).

Alum Based Coagulation

A 2.2.4.5 Tests were conducted on effluent from the CEPT process simulations using alum on wastewaters from various SSDS catchments and on a “SSDS Representative Mix”. All tests were conducted at times of peak diurnal concentration. The findings from these tests were as follows:

- the response to alum addition differed significantly on a catchment by catchment basis both in terms of unfiltered transmittance and effluent turbidity.
- for all PTWs there was an increased response to chemical addition as a function of chemical dose.
- there was a very strong relationship between unfiltered UV transmittance and effluent turbidity.
- the response to alum addition in terms of unfiltered transmittance associated with North West Kowloon PTW exceeded that found all other PTWs. The industrialised catchments of Kwai Chung PTW and to a lesser extent, Kwun Tong PTW showed a lower response (measured in terms of unfiltered UV transmittance) as compared to the more residential/commercial sites;
- At the optimum chemical dosage employed during the previous pilot plant studies conducted at SCI STW of 7.5 mg/L Al_2O_3 (i.e. 4.0 mg/L as Me^{3+}) effluent unfiltered transmittance (as determined from the jar tests) over the peak diurnal concentration period would be expected to vary as follows:

- Central PTW: 27% to 33%, median 29%
- Kwai Chung PTW: 15% to 21%, median 18%
- Kwun Tong PTW: 19% to 22%, median 21%
- North West Kowloon PTW: 32% to 52%, median 36%
- SSDS Representative Mix: 18% to 30%, median 23%

A 2.2.4.6 The study concluded that effluent unfiltered transmittance at the previously optimised dose rates for ferric chloride and alum is not the overriding factor in the choice of chemical because:

- the costs of alum and ferric chloride are different[4];
- at the 7.5 mg/L dose rate, alum would produce more sludge than ferric chloride at 10 mg/L. This is due to the improved solids capture and the increased dose of coagulant (when expressed on a metal ion basis).
- the UV transmittance using ferric chloride can be improved by increasing the dose rate of ferric chloride (although the savings in power costs would be offset by increased chemical and sludge costs).

A 2.2.4.7 The study also noted that ferric chloride has also been found to help suppress hydrogen sulphide generation. Use of alum may necessitate the provision of separate facilities to dose ferric chloride into the sludge, to reduce to generation of hydrogen sulphide.

A 2.2.5 *Effects on Sludge Treatment*

SSDS Stage 1 Dosing and Disinfection Study

A 2.2.5.1 The SSDS Stage 1 Dosing and Disinfection Study conducted preliminary trials to assess the chemical sludge characteristics, such as sludge volume, mass and conditionability for dewatering using different chemicals in CEPT.

A 2.2.5.2 NWK and KC mixed sewage was used for the study. The optimum chemical dose to achieve 85% SS removal was used in the CEPT stream. The plant was run at a surface overflow rate of 60 m^3/m^2.d for 5 hours to generate sufficient volume of sludge for characterisation tests. Day 1 was repeated on Day 5 to give some measure of variability.

A 2.2.5.3 The sludge production rate at a SS removal rate of 85% from CEPT (**Table A2.9**) was found to be in the order of 220 kg DS/1,000 m^3 of sewage treated for NWK/KC sewage, compared with 180 kg DS/1,000 m^3 of sewage treated without chemicals. The volume of sludge produced from CEPT was in the order of 8 - 9 m^3/1,000 m^3 of sewage treated for NWK/KC sewage, compared with 6 m^3/1,000 m^3 of sewage treated without chemicals.

[4] The SSDS Stage 1 Dosing and Disinfection study and the SSDS Stage 2 PPFS both found that alum would be more expensive than ferric chloride. A recent quote from a single supplier yielded

- for $FeCl_3$: HK$1,500/tonne for liquid at 40%, or HK$4,500/tonne for solid containing 99% $FeCl_3$
- for Al_2O_3: HK$1,500/tonne for solid form containing 15% Al_2O_3

Table A2.9 Calculated Sludge Quantities Assuming 85% SS Removal (SSDS Stage 1 Dosing and Disinfection Study)

Day	Chemical	Suspended Solids % Removal %	Quantity of Sludge from SS Removed kg	Quantity of Sludge from SS Removed adjusted to 85% removal kg	Sludge Production Rate adjusted to 85% removal kg DS / 1,000m^3sewage
Day 1	Ferric Chloride	75	19.5	22.0	220
Day 2	Ferric Sulphate	79	21.0	22.5	225
Day 3	Alum	88	23.0	22.3	223
Day 4	Zetag 92	85	23.9	23.8	238
Day 5	Ferric Chloride	82	20.7	21.5	215

A 2.2.5.4 Sludge conditioning tests were carried out by the measurement of the ease of filtration using the Capillary Suction Time (CST) after conditioning with a cationic polyelectrolyte, Zetag 57 (a sludge conditioner). The control sludge could be conditioned with a low concentration (less than 0.1 kg/tonne dry solids) of Zetag 57. The sludges produced after chemical coagulation with ferric salts or Zetag 92 could be conditioned using a dose of Zetag 57 in the range of 0.15 - 0.35 kg/tonne dry solids. Alum sludge required a higher dose of 0.40 - 0.45 kg/tonne dry solids to achieve the same level of conditioning.

Siu Ho Wan STW Disinfection Study

A 2.2.5.5 Sludge Dewatering Tests were undertaken as part of the above study to check the dewaterability of alum sludge from CEPT. These pilot tests took place on 10 days in parallel with the UV and ozone pilot tests. A full-scale centrifuge at SCISTW of 100m^3/h capacity was used. The main conclusions were:

- There was no significant technical difficulty to dewater alum sludge to achieve the required 30% solids content. The dry solids content of the sludge in the trials ranged from 33 to 42 percent. The solids recovery also exceeded 95 percent when the appropriate polymer dose and centrifuge operating conditions were established.
- The required sludge cake solids and centrate TSS levels were achievable at the feed rate of only 10 to 20% lower than those for dewatering ferric chloride sludge. A polymer dose of 5 kg/ton dry solids was found to be sufficient.

Ongoing Performance of Stonecutters Island STW

A 2.2.5.6 Information provided by DSD indicates that Stonecutters Island STW produced about 140 tonnes of dewatered sludge at 37% dry solids in 2000, during which the sewage flows from NW Kowloon averaged about 360,000 m^3/day.

A 2.2.6 *Summary*

Treatment Performance

A 2.2.6.1 Removal requirements for BOD and SS at San Wai STW are likely to be approximately 50% and 70% respectively. Even allowing for an increase in wastewater strength, such removals would produce typical effluent quality of <100 mg BOD/L and <55 mg SS/L. Previous studies have shown that various chemicals can readily achieve these objectives, based on laboratory tests and pilot trials on effluents from several different catchments. These include ferric chloride, ferric sulphate, alum, and cationic polymeric coagulants, although the latter were found to be relatively expensive.

A 2.2.6.2 Experience over several years has shown that the use of ferric chloride at Stonecutters Island STW in moderate doses (10 mg/L as $FeCl_3$ (i.e. 3.5 mg/L as Me^{3+}) together with 0.1 mg/L of anionic polymer) consistently produces higher removals than the expected requirements for San Wai STW. The required dose rate for alum to achieve equivalent BOD and SS removal is likely to be around 7.5 mg/L Al_2O_3 (i.e. 4.0 mg/L as Me^{3+}).

Chemical Supply

A 2.2.6.3 Availability of supply of chemicals such as ferric chloride, ferric sulphate or alum in the quantities required for this project is not expected to be a constraint on options.

Sludge Treatment

A 2.2.6.4 Sludge dewatering has been demonstrated to be without major technical difficulties for both the ferric chloride (pilot and full-scale) and alum (pilot scale) options.

UV Transmittance

A 2.2.6.5 San Wai STW's catchment is almost entirely domestic, although there are small "industrial" zones, e.g. in Tung Tau (the Yuen Long Industrial Estate will continue to discharge to Yuen Long STW). Transmittances after CEPT might therefore be expected to be similar to those found for NW Kowloon wastewater. The results from jar tests were as follows:

≥ 24% at a dose of 10 mg/L $FeCl_3$

≥ 36% at a dose of 7.5 mg/L Al_2O_3

A 2.2.6.6 It is noted that, however, SCI STW produces a transmittance slightly better than the jar tests with ferric chloride – typically in the range 26 to 30%.

A 2.2.6.7 The enhanced UV transmittance when using alum suggests that, based on the dose rates described above, lower power costs will be incurred for this option if UV is selected for disinfection. However, most studies suggest that ferric chloride is cheaper than alum for CEPT at these dose rates. For the ferric chloride option it may therefore be possible to improve effluent transmittance by increasing the coagulant dose to produce a more cost-effective option overall.

A 2.3 Review of Potential Disinfection Options

A 2.3.1 *Introduction*

A 2.3.1.1 This section makes use of the reviews and trials carried out under several recent projects in Hong Kong. The scopes of these studies are briefly described in **Section A2.1** and their findings on the potential disinfection options are reviewed in this section. Where relevant, information on developments elsewhere is also included in this section.

A 2.3.2 *Previous Studies and Current Projects*

SSDS Stage 1 Dosing and Disinfection Study

A 2.3.2.1 For the purpose of the SSDS Stage 1 Dosing and Disinfection Study a minimum of three log (i.e. 99.9 percent) inactivation of *E.coli* bacteria was selected as the target in the absence of a specific discharge standard or water quality objective for general marine waters.

A 2.3.2.2 An initial evaluation of the long list of options yielded the results and weightings given in **Table A2.10**. Based on this review, the following disinfection methods were retained for further evaluation:

- Gaseous chlorination and dechlorination
- Hypochlorination and dechlorination
- UV Irradiation
- Ozonation
- Microfiltration

Table A2.10 Comparison of Disinfection Alternatives (from SSDS Stage 1 Dosing and Disinfection Study)

	Chlorine	Sodium Hypochlorite	UV	Ozone	Chlorine Dioxide	Bromine Chloride	Peracetic Acid	Lime Treatment	Microfiltration
Ability to meet target	0	0	0	0	0	0	+	-	+
Environmental degradation	-	-	+	0	-	-	-	0	+
Safety/use of hazardous materials	-	0	+	0	-	-	-	0	+
Flexibility	+	+	-	0	0	0	0	-	0
Equipment reliability	+	+	0	+	0	0	0	0	0
Process reliability	+	+	0	0	0	0	0	-	0
Track Record	+	+	+	0	-	-	-	-	-
TOTAL	**+2**	**+3**	**+2**	**+1**	-3	-3	-2	-4	**+2**

A 2.3.2.3 Of the five disinfection technologies, hypochlorination and dechlorination and UV irradiation were considered to be the most promising systems. The other alternatives were eliminated for further study because of site specific hazards, environmental impacts and costs. It was also concluded that microfiltration and ozonation would require a much greater area then chlorination or UV irradiation.

A 2.3.2.4 The two most promising disinfection alternatives were further studied using laboratory-scale tests to confirm feasibility when used with CEPT effluent and to assess the dose levels to achieve the required bacterial inactivation. Different dosages of ferric chloride, alum and cationic polymer were added and CEPT effluent of different qualities was produced. The dose response curves obtained using collimated beam apparatus indicated that to achieve the required 3 log inactivation of *E. Coli*, the UV dose levels ranged from 8 to 10 mWs/cm^2, depending on the concentration of suspended solids. To ensure stable disinfection performance, the dose requirements were found to be in the range of 20 to 40 mWs/cm^2.

A 2.3.2.5 The laboratory-scale study for hypochlorination indicated that, for 3-log inactivation and to ensure stable disinfection performance, the chlorine dose requirements were in the range of 17 to 22 mg/L at 15 minutes contact time.

A 2.3.2.6 A pilot plant study was conducted to study the feasibility of the UV disinfection for CEPT effluent. The objectives were:

i. To confirm UV dose requirements established from the UV laboratory-scale study.

ii. To assess whether UV laboratory-scale studies can be used to predict pilot-scale performance.

iii. To conduct preliminary assessment of the fouling rate of the UV lamps at SCISTW.

A 2.3.2.7 The UV pilot study was conducted using medium pressure high intensity lamps and the effluent produced from the chemical pilot plant. During the study period, different dosages of ferric chloride or alum were added and CEPT effluent of different qualities was produced. The results correlated well with the collimated beam tests results. As before, the UV dose requirements did not seem to be dependent on the choice of coagulants, and a dose of 20 to 40 mWs/cm^2 was found to be adequate to achieve the required 3 log inactivation of *E. Coli*. The limited fouling test program (up to 6 hours) did not show significant impact on disinfection of the effluent due to lamp fouling.

<u>SSDS EIA</u>

A 2.3.2.8 The SSDS EIA Study reviewed options for provision of disinfection after CEPT for the SSDS, based on the outcome of the previous pilot studies described above. In addition, the EIA Study conducted a review[5] of the environmental implications of chlorination, the findings of which are summarised below.

Chlorination By-Products

A 2.3.2.9 The literature search revealed numerous publications on the formation of chlorination by-products but limited scientific information on the aquatic life and human health impacts of chlorinated by-products in wastewater effluent discharged to the sea. Available data indicated that chloramines are the most toxic to aquatic life, compared to trihalomethanes and haloacetic acids, with LC50 values below 1 mg/L. Upon chlorination of CEPT effluent, chloramines (predominantly monochloramine) would also be the dominant by-products formed. However, the concentration of chloramines in the effluent is unlikely to be a key issue. The concentration will be dependent upon the contact time employed for disinfection and the chlorine dose/demand of the wastewater at the time. If decay is insufficient to meet treatment requirements, dechlorination can be practised to control residual.

A 2.3.2.10 The monitoring of dissolved organic halogen (DOX) levels has been used to indicate potential total organic halogen (TOX) levels in effluent. Approximately 1% of the chlorine dose would form TOX. Based on pilot test results of chlorine dose ranging from 17-22 mg/L for CEPT effluent from the SCISTW, TOX formed would be in the range of 0.17-0.22 mg/L. The DOX fraction, mainly made up of THM and HAA, would be smaller. It was further determined that the formation of THM would be unlikely. DOX levels should be less than 0.2 mg/L, the

[5] SSDS EIA Study Final Report Volume 2, Appendix A2.7.4 (Jan 2000)

standard established by the Industrial Sector Working Group of the Paris Commission for discharging of textile industry effluent directly into surface water.

Dechlorination

A 2.3.2.11 With dechlorination, chloramine levels would be eliminated. Chemicals such as sulphur dioxide, sodium sulphite, sodium metabisulphite and activated carbon have been used as dechlorination agents. Sulphur dioxide gas could remove free chlorines, monochloramine, dichloramine, nitrogen trichloride, and poly-n-chlor compounds. It has been found that about 1.0 mg/L of sulphur dioxide was required for the dechlorination of 1.0 mg/L of chlorine residue and the reactions were instantaneous. Therefore by adoption of dechlorination in the CEPT effluent, removal of chloramines could be achieved. Considering the initial dilution that is available at Urmston Road, impacts to aquatic life and human health are expected to be small.

SSDS Stage 1 Ozone Trials

A 2.3.2.12 In this study by HKUST for DSD, tests were conducted to determine the appropriate ozone dose and contact time to achieve three different disinfection targets using one counter-current ozone bubble column.

A 2.3.2.13 Based on the study results, the ozone demand of the CEPT wastewater at SCISTW is around 19 g/m^3. Therefore, effective disinfection is possible only at ozone doses above this concentration. Almost all of the ozone applied, regardless of the dose used (up to 40 g/m^3), was consumed, as attested by the low residual dissolved ozone concentration in the effluent. The tests suggested that the results were more sensitive to ozone dose than to contact time.

A 2.3.2.14 The study concluded that ozone effectively disinfects CEPT effluent at SCISTW. For the three targets, the corresponding ozone conditions were as follows:

- 3-log reduction of *E.coli* was achieved on 100-percentile basis with an ozone dose of 20 g/m^3 and contact time of 10 minutes.
- an *E. coli* count of 5000/100 ml or less was achieved on a 97-percentile basis with an ozone dose of 20 g/m^3 and a contact time of 10 minutes.
- an *E. coli* count of 1000/100 ml or less was achieved on a 97-percentile basis with an ozone dose of 20 g/m^3 and a contact time of 15 minutes.

A 2.3.2.15 It should be noted that these trials were undertaken using NW Kowloon effluent. It is not known how representative these results would be for the effluent from San Wai STW and Yuen Long STW.

A 2.3.2.16 It was also reported that ozone treatment did not negatively affect the quality of the effluent in terms of BOD, COD, halides, total iron, total organic carbon, and total suspended solids. Due to chemical interference in the analytical procedures, the effects of the ozone treatment on effluent quality with regard to bromate and free chlorine could not be determined with certainty, but were thought to be insignificant.

A 2.3.2.17 No information was found on aldehydes in the report.

<u>SSDS Stage 2 PPFS</u>

UV Transmittance

A 2.3.2.18 Based on data from previous studies, a UV dose was adopted to compare the requirements for UV facilities for ferric chloride or alum based upon the transmittance data obtained during the study. The main outcome of the UV tests was to ascertain the diurnal variation in the UV transmittance of various wastewaters after CEPT with ferric chloride or alum. The results are summarised in **Section A2.2.4**.

A 2.3.2.19 A UV dose of 30 mW-s/cm^2 was found to be applicable to ensure disinfection of CEPT effluent. For an effluent from CEPT using ferric chloride with a mean UVT of 15%, 65% more lamps would be needed than for an effluent from CEPT using alum with a mean UVT of 25%.

Chlorination Trials

A 2.3.2.20 The trials included:

- chlorine demand assessments
- dose-response assessments
- potential impact of sulphide
- disinfection by-product testing.

A 2.3.2.21 The findings of these trials suggested that the dosing capacity of a potential chlorination system would need to be at a level equivalent to 25 to 30 mg/L as Cl_2. Target dosages would typically be in the range 12-15 mg/L to achieve a redox of around 300 mV.

A 2.3.2.22 The results of the trials suggested that a minimum contact time of 30 minutes would be required to ensure adequate disinfection at times of peak diurnal concentration. The occurrence of peak diurnal concentration was found to be coincident with peak diurnal flows. Therefore, a 30 minute contact time would be required at peak diurnal flow. For example, if the peak diurnal flow is 1.5 times the average design flow, the minimum contact time required at average design flow would be 45 minutes.

A 2.3.2.23 An assessment of potential disinfection by-products arising from the use of chlorine as disinfectant was based upon the formation of:

- trihalomethanes (THM).
- haloacetic acids (HAA).
- dissolved organic halide (DOX). DOX represents a useful "catch-all" to indicate the concentration of all chlorinated organics which are not specifically identified either as trihalomethanes or haloacetic acids.

A 2.3.2.24 A summary of the concentration of disinfection by-products produced at a contact time of 60 minutes and applied chlorine dose of 15 mg/L is presented in **Table A2.11**.

A 2.3.2.25 The trials determined the concentration of combined chlorine residual as a function of chlorine dose and contact time. The results indicated that the concentration of combined residual would be around 1-4 mg/L at a contact time of 60 minutes and a chlorine dose of 12 to 15 mg/L, dependent upon the catchment being evaluated. At increasing contact time the residual decays. If decay is insufficient to meet treatment requirements dechlorination can be practised to control residual.

A 2.3.2.26 The low concentration of disinfection by-products such as THM, HAA and DOX formed during the chlorination of CEPT effluents from these catchments was not unexpected since chlorination would be achieved using a combined residual as a result of the reactions with ammonia present in the wastewater. The potential to form by-products under these conditions is greatly reduced when compared to disinfection using a free chlorine residual.

Table A2.11 Formation of Disinfection By-products in Chlorination

Parameter	Catchments			
	Central	Kwai Chung	Kwun Tong	SSDS Mix
Number of Samples	5	5	4	2
Total Residual Chlorine (mg/L)	3.2 to 7.5	0.1 to 7.4	1.8 to 6.2	2.5 to 3.0
Dissolved organic halide	1,900 to 2,600	2,500 to 4,300	2,300 to 3,400	1,600 to 2,300
Total trihalomethanes	21 to 41	11 to 12 (62)	8 to 9 (39)	30 to 57
Haloacetic acids (HAA_5)	67 to 90	63 to 81	61 to 83	37 to 76

1. Tabulated values are expressed in µg/L
2. Figure in parentheses represent the maximum value recorded and was generally as a result of an atypically high value for bromodichloromethane.
3. Source: SSDS Stage 2 PPFS

A 2.3.2.27 Although the sulphide trials were limited, a consistent relationship between the amount of sulphide addition and its impact upon initial chlorine demand was apparent in that 1 mg of sulphide added resulted in an increase in initial chlorine demand of about 1 mg.

Ozonation Trials

A 2.3.2.28 The trials included:

- ozone demand assessments
- dose-response assessments
- potential impact of sulphide
- disinfection by-product testing.

A 2.3.2.29 It was found that disinfection is rapid once the initial ozone demand has been satisfied. The effectiveness of disinfection was variable and very much dependent upon effluent quality. Based on the findings of these trials, ozonation facilities would need to maintain a design dose of at least 30 mg/L. To ensure sufficient flexibility and security it was recommended that the facilities should be capable of dosing at up to 40 mg/L on a short-term basis. The design contact time was 20 minutes at peak diurnal flows.

A 2.3.2.30 The analysis of disinfection by-products arising from ozonation focussed on the formation of:

- Trihalomethanes.
- Aldehydes.
- Bromate.

A 2.3.2.31 A summary of the concentration of disinfection by-products produced, based on only a limited number of analyses at each site, at a contact time of 10 minutes and applied ozone dose of 40 mg/L is presented in **Table A2.12**.

Table A2.12 Formation of Disinfection By-products in Ozonation

Parameter	Catchments			
	Central	Kwai Chung	Kwun Tong	SSDS Mix
Number of Samples	3	3	2	2
Ozone residual (mg/L)	0.15 to 0.39	0.01 to 0.06	0.04 to 0.13	0.06 to 0.08
Bromate (µg/L)	8 to 23	16 to 43	n.d to 32	10 to 30
Bromide (mg/L)	0.9 to 3.1	4.9 to 7.5	1.0 to 7.3	1.0 to 2.2
Aldehydes (µg/L)	220 to 460	360 to 440	360 to 390	200 to 410
Total trihalomethanes (µg/L)	3 to 23	5 to 31	19 to 23	2 to 11

Source: SSDS Stage 2 PPFS

A 2.3.2.32 The concentration of trihalomethanes is typically very low (were well below the maximum contaminant levels regulated by the US EPA for the protection of drinking water), in all instances being less than 40 µg/L. The predominant trihalomethane was bromoform. The concentrations of the aldehydes in ozonated effluents were significantly higher than in the CEPT effluent. The major components within the aldehyde group were acetaldehyde, formaldehyde and glyoxal. Bromate concentrations were consistently reported in concentrations significantly higher than that regulated through the Stage I D/DBP Rule for drinking water.

Overall Conclusions

A 2.3.2.33 The conclusions from the SSDS Stage 2 PPFS on a number of disinfection options are sumamarised in the following paragraphs.

A 2.3.2.34 ***Gaseous Chlorination and Dechlorination*** : This technology was considered inappropriate for Hong Kong given the large quantities of gaseous chlorine and sulphur dioxide involved.

A 2.3.2.35 ***Hypochlorination and Dechlorination*** : This technology is well proven, and has substantially lower operating risks than gaseous chlorine. The disinfection trials confirmed that chlorination is a suitable disinfection method that will consistently achieve the required levels of *E.coli* inactivation with CEPT effluent. Formation of by-products such as trihalomethanes and haloacetic acids is would probably be within acceptable levels. Commercial liquid supply at a concentration of 10-12% of available chlorine was considered most appropriate. Onsite generation was not considered cost effective at this scale.

A 2.3.2.36 ***UV Irradiation*** : Effluent UVT is the most important determining factor with respect to the feasibility of using UV methods to disinfect CEPT effluent. UVT is also a critical parameter with respect to facility sizing. The results of the disinfection trials suggest that UV irradiation is a technically feasible option for disinfection of CEPT effluent in Hong Kong, irrespective of the coagulant selected, given appropriate design and the application of an appropriate UV dose. However, it was noted that there was a lack of operating experience with low-pressure high intensity (LPHI) UV lamp technology with effluents of relatively low UVT. Further evidence was considered to be needed to confirm the applicability of LPHI systems on CEPT effluent. It was noted that further increases in lamp intensity are possible as the technology continues to develop. More operating experience exists for medium pressure systems, including some experience with lower CEPT effluents. Based on current technology, a medium pressure solution requires significantly less lamps than a low pressure solution and as a consequence occupies far less site area. However, a low pressure high intensity system would be significantly cheaper to operate due to reduced power demand.

A 2.3.2.37 ***Ozonation*** : Ozonation has become a well developed technology and whilst there have been some increases in equipment size and overall efficiency in recent years, there is little likelihood of significant reductions in the overall cost of ozone disinfection in the short to medium term. Based on the dose rate derived from the trials of up to 40mg/L with a contact time of 20 minutes to ensure effective disinfection under all conditions, the large capital and annual costs would be a significant disadvantage. Furthermore, the area requirements for ozone disinfection would far exceed those for either hypochlorination/dechlorination or UV Irradiation.

A 2.3.2.38 ***Microfiltration*** : Microfiltration will achieve 100% removal of *E-coli* and coliforms, but is less effective against viruses. The very large site area requirements for this process are a significant disadvantage for disinfection of primary effluent. microfiltration also introduces a significant additional solids handling requirement including sludge dewatering and disposal. This requirement is considered a significant drawback considering that the process requirement relates simply to bacterial inactivation of the effluent. This process is not considered cost effective as a disinfection technology but may be a viable technology if a reduction in the effluent suspended solids concentration is required in the longer term.

A 2.3.2.39 The overall conclusion was therefore that the leading options for disinfection of CEPT effluent in Hong Kong are:

- Chlorination and dechlorination (using sodium hypochlorite and sodium bisulphite);
- UV irradiation using medium pressure high intensity lamps, or
- UV irradiation using low pressure high intensity lamps (subject to future trials).

<u>Siu Ho Wan STW Disinfection Study</u>

A 2.3.2.40 Although comparisons of disinfection options were made for this study, no trials on chlorination were undertaken. The study included tests of both UV radiation and ozonation to assess their feasibility to disinfect CEPT effluent to meet discharge standards similar to those postulated for San Wai STW. Effluent from Stonecutters Island STW was used in the tests.

1999 UV Trials

A 2.3.2.41 The UV pilot test in 1999 used medium pressure high intensity lamps. The results showed that the required *E.coli* standards are achieved at practical dose levels. UV dose levels less than 30 mWs/cm^2 were found to be sufficient to achieve the *E.coli* standards of 20,000 counts/100mL over a wide range of influent conditions. These included high TSS levels ranging from 75 to 140 mg/L and low UV transmittance levels ranging from 15% to 29%.

A 2.3.2.42 The results of the pilot trials were found to be consistent with parallel collimated beam test work.

A 2.3.2.43 The fouling rate for the ferric chloride-treated effluent would be approximately four hours, whereas the rate if alum is used as the coagulant would be approximately twelve hours. The study concluded that the expected fouling rate and required frequency of cleaning should be acceptable using the UV systems with automatic wipers.

A 2.3.2.44 There were no apparent increases in harmful disinfection by products for UV dose levels up to 3 times of the design dose.

A 2.3.2.45 The photoreactivation tests showed that photoreactivation did occur under laboratory conditions, but it was concluded that this effect would be offset by the natural die-off under field conditions. It should be noted that:

- the trials were designed to simulate photoreactivation or dark repair for Siu Ho Wan conditions (submerged pipeline outfall) and might not be indicative of potential regrowth in the much longer tunnel from NWNT to Urmston Road outfall;
- the trials were limited and therefore may not be conclusive. Significant regrowth has been reported where long travel times are required after UV disinfection to the outfall or effluent reuse point, as noted in the Review of Yuen Long and Kam Tin Sewerage and Sewage Treatment Requirements. For example, at the Chapel Street WWTP in Tauranga, secondary effluent is disinfected by UV and then pumped 7 km to Te Maunga. Significant regrowth of faecal coliforms and enterococci is observed at a golf course abstraction point at about 4½ km.

2001 UV Trials

A 2.3.2.46 As noted in **Section A2.1.2**, a further series of tests was undertaken using a low pressure high intensity (LPHI) UV system in 2001. Both ferric chloride and alum were used as coagulants. The Draft Report (Dec 2001) concluded the following:

- it was difficult to achieve the *E.coli* standards of 20,000 counts/100mL consistently using a one-bank LPHI UV system, although two different lamp spacings were tested (note: this is not unexpected – all proposals for this duty are likely to include at least two banks in series);
- with a three-bank LPHI pilot UV reactor, a UV dose of about 35 mWs/cm^2 was found to achieve *E.coli* standards of 20,000 counts/100mL on average. A dose of 40 mWs/cm^2 may be required to ensure consistent performance.

A 2.3.2.47 In order to review the validity of these results, it is necessary to compare the results obtained on the pilot plant to those obtained in parallel collimated beam tests. These showed significant differences between the different coagulants: the UV irradiation of an alum based effluent yields significantly lower bacterial concentration in the UV irradiated effluent when compared to a ferric based coagulant particularly at transmittances. It also shows that there may be some difficulty in consistently meeting a requirement of 20,000 cfu/100 mL with a ferric based coagulant if the transmittance of the effluent is in the range 9%- 15%. However, only a limited number of collimated beam test work was conducted during these trials under the critical conditions.

A 2.3.2.48 The differences between the collimated beam data and the results obtained from the pilot reactor suggest hydraulic deficiencies within the pilot reactor. A review of operating conditions described in the report indicates that channel velocities were not within the recommended ranges[6] (a complete appraisal of the results cannot be conducted as a substantial proportion of required information is not presented in the report). The key point to note is that such hydraulic deficiencies will not be apparent in a full scale unit, as this will be designed for optimum conditions such that potential problems associated with low velocities and high head losses are eliminated.

A 2.3.2.49 The Draft Report (Dec 2001) implies that, although disinfection of CEPT effluent with LPHI systems is feasible, the theoretical advantage of LPHI over MPHI systems in terms of power requirements may not be achievable currently in practice. Because of the hydraulic deficiencies in the pilot reactor described above, we do not concur with these conclusions. Side-by-side trials of medium pressure and low pressure technologies within the recommended velocity and head loss ranges would be preferable to produce firm conclusions on the overall power requirements of each system.

Ozone Pilot Study

6 The head loss across the LPHI banks should be limited to 40mm to prevent streamlining, but head losses in the trials were reported to be over 140 mm across the UV lamps in some instances. Hence, there would be a significant proportion of the top layer that does not receive adequate disinfection.

A 2.3.2.50 The ozone pilot plant consisted of two contact columns of 5.5 m high and an on-site ozone generator of 100 g/h capacity. A contact time of 15 minutes was used in the trials.

A 2.3.2.51 An ozone dose level of 20 mg/L or lower, as recommended by some ozone suppliers, was found to be insufficient to achieve the required *E.coli* standards. An ozone dose of about 35 mg/L was necessary to ensure that the required *E.coli* standards of 20,000 counts/100 mL were achieved at all times, based on the collected data. It was recommended that a design dose level of at least 40 mg/L should be used in the design of a full-scale facility for this type of effluent.

A 2.3.2.52 Disinfection by product tests were conducted for both ferric chloride and alum-treated effluent at a dose level of 37.5 mg/L. Elevated levels of bromoform, bromodichoriomethane and chlorodibromomethane were found in the effluent samples. The effluent bromoform levels were found to be 45 and 170 μg/l for CEPT effluent with alum and ferric chloride, respectively. The residual ozone levels were generally low but elevated levels from 0.11 to 0.21 mg/L might also be encountered at high ozone levels. There appeared to be no significant changes in BOD and COD levels due to ozonation.

Conclusions

A 2.3.2.53 The Siu Ho Wan STW Disinfection Study concluded that both UV and ozone disinfection would be feasible to disinfect CEPT effluent to the required *E.coli* standards. The design UV and ozone dose requirements for the full-scale facilities were deemed to be 30 mWs/cm^2 and 40 mg/L respectively.

A 2.3.2.54 Cost estimates showed that both the capital and O&M costs of the ozone option would be more than 200% higher than those of UV option. The UV option was also found to be more favourable when considering land requirements, schedule implications, environmental impact and safety.

A 2.3.2.55 Based on a review of all the above considerations, UV radiation was recommended as the disinfection method for the Siu Ho Wan STW upgrade.