

SUMMARY

Overview

A comprehensive disinfection pilot plant study was carried out for the Siu Ho Wan Sewage Treatment Works (STW) Upgrade. The study included pilot-scale testing of two most promising disinfection alternatives, i.e. UV radiation and ozonation. The objectives of the pilot study were (1) to assess their feasibility to disinfect chemically enhanced primary effluent to meet discharge standards and (2) to obtain site specific data as the basis to select the most suitable disinfection option for Siu Ho Wan.

E.Coli Discharge Standards		
Compliance Conditions		Limits
Monthly geometric mean		20,000 counts/100 mL
95-percentile		300,000 counts/100 mL

The pilot plant study took place from August to October 1999 at Stonecutters Island STW. The UV and ozone pilot plants were set up such that they could effectively reproduce full-scale operating conditions and disinfection performance. A total of more than 700 sets of effluent and influent samples were collected for E.Coli and other water quality analyses. In parallel, limited sludge dewatering tests were conducted to assess the feasibility of dewatering alum sludge using centrifuges.

Does UV work?

The UV pilot plant had a design capacity of 200 m³/h and consisted of a total of 8 medium-pressure high intensity lamps. It had identical lamp type and reactor configuration as proposed for the Siu Ho Wan STW upgrade (see Figure 1). The pilot study included 35 dose response tests, fouling tests, disinfection byproduct tests, photoreactivation tests and headloss analysis.

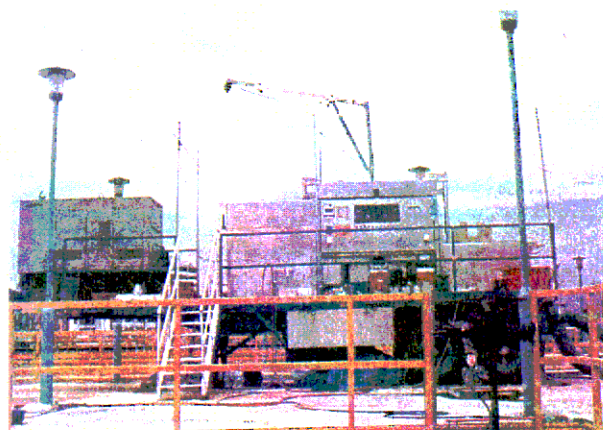


Figure 1 UV Disinfection Pilot Unit

The UV pilot tests showed that the required E.Coli standards were achievable at practical UV dose levels. As shown in Figure 2, an UV dose level less than 30 mWs/cm² was found to be sufficient to achieve the E.Coli standards at all times. The required UV dose requirements were found to increase with increasing influent TSS levels, although the trend was less apparent for some TSS range because of significant data scattering.

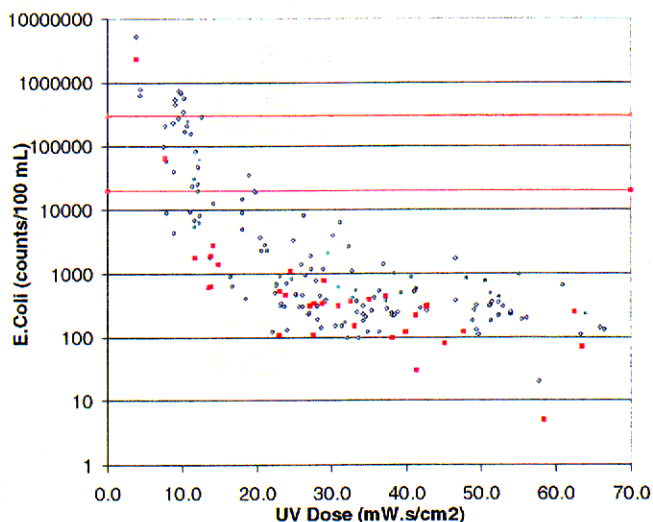


Figure 2 Effluent E. Coli vs UV Dose (All Data)

Figure 3 shows the variations of effluent E.Coli vs. UV dose under simulated design (worst-case) influent conditions. During these test periods, high TSS levels ranging from 75 to 140 mg/L and low UV transmittance levels ranging from 15 to 29 percent were simulated. It was found that UV dose levels of 14 and 21

mWs/cm² were sufficient to achieve the required standards of 20,000 counts/100 mL on average and at all times, respectively.

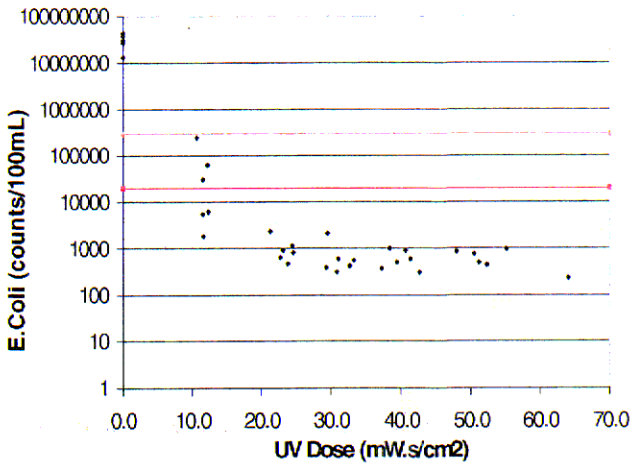


Figure 3 Effluent E.Coli vs. UV Dose (Primary Effluent plus Raw Sewage i.e. 75-140ppm TSS)

Based on a mathematical model developed by the University of California at Davis, the minimum dose requirement was estimated to be about 15mWs/cm². A design UV dose of 30mWs/cm² was selected to ensure stable disinfection performance.

The fouling rates and the required cleaning frequency were found to fall within the acceptable range for high intensity UV systems. (see Figure 4). Other UV pilot tests showed that the disinfection byproduct levels, effect of photoreactivation and hydraulic head requirements of UV disinfection were acceptable.

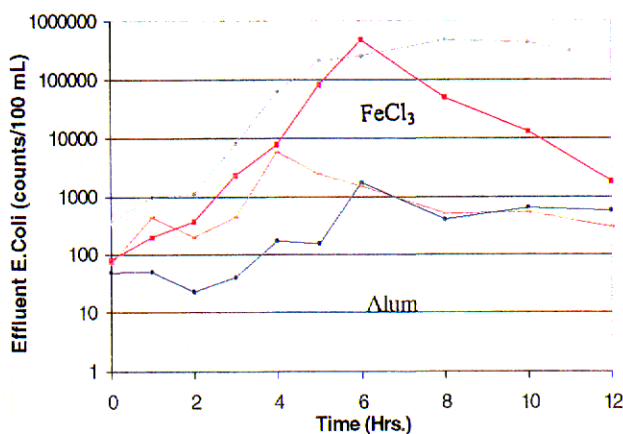


Figure 4 Effluent E. Coli vs Time During Fouling Tests

Does Ozone Work?

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 (see Figure 5). The pilot unit had the capacity of disinfecting a flow of 1.4 m³/h at 15-minute retention time. The pilot study included 26 dose response tests and disinfection byproduct tests.

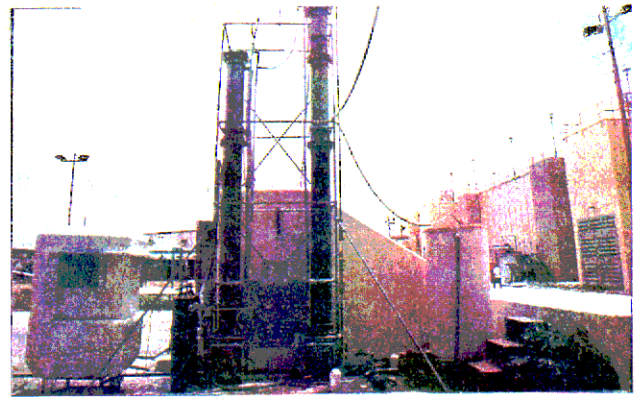


Figure 5 Ozone Disinfection Pilot Unit

The ozone pilot tests showed that the required E.Coli standards were achieved at elevated ozone dose levels. The 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. As shown in Figure 6, an ozone dose level 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. The required ozone dose levels were also found to increase with increasing TSS levels.

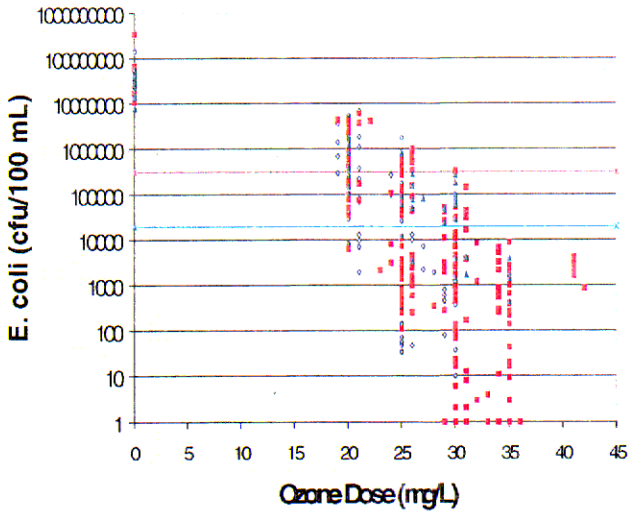


Figure 6 Effluent E. Coli vs Ozone Dose (All Data)

Figure 7 shows the variations of effluent E.Coli vs. ozone dose under simulated design influent conditions. During this period, the TSS levels ranged from 25 to 85 mg/L and COD from 180 to 300 mg/L, which were slightly lower than the design influent conditions. It was found that minimum ozone dose levels of 33 and 40 mg/L were needed to achieve the required E.Coli standards on average and at all times, respectively. An ozone dose of 40mg/L was selected for the design of the full-scale facility.

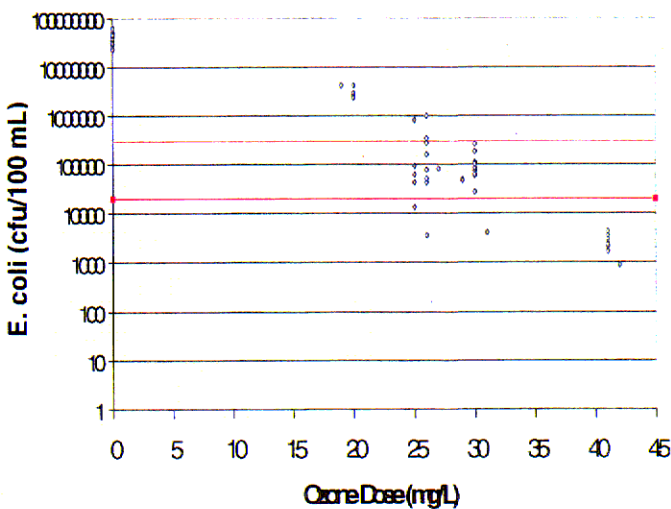


Figure 7 Effluent E. Coli vs. Ozone Dose (Primary Effluent)

Disinfection byproduct tests were conducted for both ferric chloride- and alum-treated effluents at a dose level of 37.5 mg/L. Higher dose levels were not practical because of capacity constraint of the ozone generator. Elevated levels of bromoform, which is a carcinogen, were found in the effluents after ozonation. At present, there are no standards regulating the discharge of this compound to North Western Water Control Zone.

Bromoform Levels $\mu\text{g/L}$		
Coagulants	Before Ozonation	After Ozonation
Alum	Not Detected	45
FeCl_3	Not Detected	170

How About Dewaterability of Alum Sludge?

The sludge dewaterability pilot tests took place on 10 days in parallel with the UV and ozone pilot tests. A full-scale centrifuge at SCISTW of 100m³/h capacity was used. A total of 44 sets of feed sludge, sludge cake and centrate samples were collected for solids and other water quality analyses.

The pilot study showed it was feasible to dewater alum sludge to meet the required 30% solids content requirement (See Figure 8). The solids content of alum 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 centrate TSS concentration ranged from 410 to 1800 mg/L.

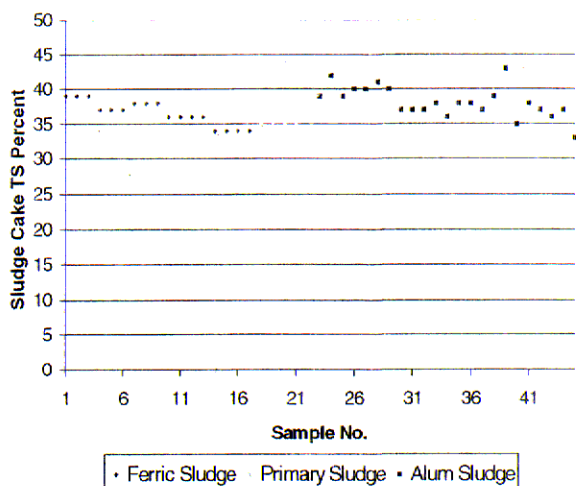


Figure 8 Sludge Cake Solids Content (All Data)

Which Option Is More Economical?

A detailed cost comparison was undertaken for the two disinfection options, using the design basis established during the pilot plant study. Capital, O&M and life-cycle costs were estimated, after preliminary equipment sizing and layout plans for the two options were developed.

Comparative Cost Comparison		
Costs (\$M)	UV Radiation	Ozonation
Capital	61.2	148.5
Annual O&M	11.9	28.6
Life-cycle	157.3	379.5

Notes: Comparative costs only.

The UV disinfection option was found to be significantly more economical than the ozone option, in terms of capital, O&M and life-cycle costs. Both the capital and O&M costs of ozone option were estimated to be more than 200% higher than those of UV option.

Other Nonmonetary Considerations

The comparison of two options based on non-monetary considerations was shown as below. The UV option was considered more favourable in terms of land requirements, schedule implications, environmental impact and safety. A recent concern of using UV disinfection is the disposal of spent mercury

lamps. This concern was found to be minor because of the expected small lamp number and can be mitigated by a waste lamp recycle plan.

Nonmonetary Considerations		
	UV Option	Ozone Option
Land Requirements	Small	Large
Schedule Implications	Shorter	Longer
Environmental Impact	Pros: No toxic residuals and harmful byproducts. Cons: Disposal of spent mercury lamps.	Pros: Increased effluent D.O. and possibly reduced COD. Cons: Toxic residuals and harmful byproducts
Safety Concern	Low	Higher, due to toxicity of ozone gas

Conclusions and Recommendations

The comprehensive disinfection pilot plant study indicated that both UV and ozone disinfection were feasible options to disinfect CEPT effluent to the required E.Coli standards.

Detailed cost comparison showed that the UV option was significantly more economical than the ozone option, using the design basis established during the pilot study, in terms of capital, O&M and life-cycle costs. The UV option was also found to be more favourable when considering non-monetary factors including land requirements, schedule implications, environmental impact and safety.

Based on both cost and nonmonetary considerations, we recommend that UV radiation should be selected as the disinfection method for the Siu Ho Wan STW upgrade.