Agreement No. HATS 01/2012

Study of Disinfection Dosage Control for HATS

Executive Summary

The Harbour Area Treatment Scheme (HATS) is the sewage collection and treatment scheme that serves the urban areas of Hong Kong on both sides of Victoria Harbour. The Stage 1 of HATS involves a 23.6 km-long system of deep tunnels that conveys sewage from Kowloon and the northeastern part of Hong Kong Island to the Stonecutters Island Sewage Treatment Work (SCISTW). HATS Stage 1 serves a population of around 3 million and treats 75% of the sewage from the harbour catchment. The sewage receives Chemically Enhanced Primary Treatment (CEPT), and the treated sewage flow (1.4 million m^3/d) is discharged via a 1.1 km long submarine outfall diffuser into western Victoria Harbour at a mean depth of around 12 m.

Since the full commissioning of HATS Stage 1 in 2001, the water quality in Victoria Harbour has notably improved - with increase in dissolved oxygen and decrease in ammonia nitrogen concentrations. The overall bacteria (*E. coli*) levels in eastern and central Victoria Harbour have also been reduced by 50%. However, due to the significantly more concentrated and larger sewage flow from HATS, bacterial water quality in the adjacent western harbour and coastal waters has notably deteriorated, resulting in closure of seven gazetted beaches along Tsuen Wan coast.

To improve the water quality, the Advance Disinfection Facilities (ADF) has been put into operation since March 2010 to provide disinfection to the CEPT effluent before discharging. The key elements of the ADF include: a) a chlorination system - a sodium hypochlorite solution storage and associated dosing system to the treated sewage in the Flow Distribution Chamber (FDC); b) a 1 km long effluent discharge box culvert as a chlorine contact tank; and c) dechlorination system - a sodium bisulphite storage and associated dosing system for controlling residual chlorine in Chamber 15 before discharging.

The disinfection operation has brought significant improvements to the water quality of Tsuen Wan beaches. While chlorination/de-chlorination has been effectively adopted for the disinfection, there are concerns with the high chlorine dosage currently using. It is desirable to optimize the chlorination operation - to reduce the chlorine dosage while still meeting the required beach water quality standards. It will also help to minimize the environmental impact of the chlorination, and reduce energy consumption and operation cost.

The present study has addressed the following issues:

1. <u>Relaxation of the current HATS effluent discharge standard on *E.coli* level.</u>

The current license standard for HATS effluent discharge on *E.coli* is 200,000 count/100mL for the ADF stage and 20,000 count/100mL for Stage 2A. A comprehensive study of the relationship between Tsuen Wan

beach water quality and different effluent discharge and environmental conditions has been carried out using the extensively validated WATERMAN 3D deterministic beach water quality forecast system to evaluate the possibility of relaxing the license standard for Stage 2A. The study has shown that the water quality of Tsuen Wan beaches will not be significantly affected under a relaxed HATS effluent *E.coli* level of 2×10^5 count/100mL under the HATS-2A 2014 ($Q = 1.8 \times 10^6$ m^3/s) and Ultimate conditions ($Q = 2.45 \times 10^6$ m^3/s). The geometric mean *E. coli* level for bathing season (March-October) can still meet the Hong Kong Water Quality Objective (WQO) of 180 counts/100mL without violating the beach closure criteria (610 count/100mL). It is hence recommended that the HATS effluent *E. coli* standard for Stage 2A in the bathing season can be relaxed from the current license level of 2×10^4 count/100mL to 2×10^5 count/100mL.

For the non-bathing season, as there is no statutory requirement for beach water quality, the HATS effluent standard can be further relaxed with the compliance of WQO's of other sensitive receivers (WSD flushing water intakes, fish culture zones (FCZ) and secondary contact zones). Model prediction shows that a relaxed standard of 700,000 count/100mL is a feasible option to maintain the water quality for winter beach users without violating the WQO's for all sensitive receivers.

2. Study on the disinfection operation and proposed chlorine dosing strategy

Modelling and field studies have been carried out on the hydraulics and mixing of the disinfection system all the way from the FDC to the outfall. A head is required to drive the flow through a submarine sewage discharge diffuser, to overcome the friction loss in the system and the density difference between seawater and sewage. The head-discharge relation of HATS outfall is established using the measured sewage flow, tide level and water level data at the downstream of the sewage treatment work. 3D CFD model simulations have shown that, steered by the orientation of the baffle structure across the FDC, more flow is diverted towards the right-hand side (looking downstream) after passing through the baffle. Hence, non-equal flows and mass transport are resulted in the twin box culvert connecting the chambers. The flow in the ADF system is fully surcharged under high flow and becomes free surface flow during low flow, the 1D unsteady simulations reproudce the free surface and surcharge as well as the transitions between them in respond to the sewage inflow and tidal level variation.

Based on the in-plant study on disinfection efficiency, and the WATERMAN simulations, the following operation strategy is proposed:

1. Apply chlorine dosage of 10 mg/L during the non-bathing season

   To protect winter beach users and other sensitive receivers, it is considered necessary to apply a minimum chlorine dosage all the times to ensure that there is at least 1-log reduction in the CEPT effluent *E. coli* levels (2×10^6 counts/100mL). The required dosage is about 9 ~ 10 mg/L. The lower dosage is particularly applicable when the sewage temperature is less than around 21^{o}C.

2. Apply chlorine dosage of 12-14 mg/L during the bathing season under diurnal tide

   From the model simulations, it is found that the beach water quality during diurnal tide still meets the WQOs even with the effluent *E. coli* level increases to 800,000 counts/100mL, while it is not desirable to have effluent E. coli level above 200,000 counts/100mL during the semi-diurnal tide. From the results of

the diurnal survey, it is indicated that a dosage of 12-14 mg/L would be able to reduce the *E. coli* level below 800,000 counts/100mL.

3. Apply chlorine dosage of 16-18 mg/L during the bathing season under semi-diurnal tide

Improvement on plant operation is required to reduce sulphide levels in sewage inflow. As indicated by the in-plant surveys, high level of sulphide increases chloride demand and reduces *E.coli* kill. As *E.coli* kill is extremely fast in saline sewage (4-6 min), insufficient mixing will result in higher chlorine demand. To improve the disinfection efficiency, it is necessary to optimize the plant operation (including aeration and operation of treatment tanks) to ensure immediate chlorine contact with *E. coli*. Computational Fluid Dynamics modelling has shown that the present chlorine dosing unit is unable to achieve adequate mixing within the FDC, and a better design of the chlorine dosing system is proposed to improve the mixing and minimize the chlorine demand of hydrogen sulphide.

3. Assessing the water quality impact of temporal sewage diversion

In the non-bathing season of 2013-14, temporary flow diversion of HATS effluent to the Northwest Kowloon (NWK) outfall, a more onshore location, will be scheduled for about 8 weeks to facilitate the construction of effluent tunnel under HATS Stage 2A. The impact of the temporary discharge diversion on the water quality of nearby sensitive receivers (Tsuen Wan beaches, WSD seawater intakes, Ma Wan FCZ and secondary recreation contact zones) is assessed using WATERMAN 3D hydrodynamic model with the meteorological conditions of the dry season (Jan-Feb, Nov-Dec) of an average-wet year 2010.

Three scenarios of effluent *E. coli* level have been studied: (i) the current license standard (200,000 count/100mL) and two proposed relaxed standards of (ii) 700,000 count/100mL and (iii) 2,000,000 count/100mL.

Model predictions show that the water quality of the western Victoria Harbour can be significantly affected by the temporary diversion via the NWK outfall, due to its low initial dilution achieved (about 10 only) and the surface buoyant spreading of the sewage plume. The mixing zone area defined by dilution of 100 for NWK outfall is 2-5.6 km^2, which is much greater than that of HATS outfall (0-1.5 km^2).

Model predictions have shown that water quality in Tsuen Wan beaches, Ma Wan FCZ and the secondary contact zones will be negligibly affected by the temporary diversion, as they are sufficiently far away from the NWK outfall (about 10km). The water quality at the locations of the WSD seawater intakes in Victoria Harbour will be worsened, due to the greatly increased area of smaller dilution. The maximum *E.coli* level in three WSD intakes will exceed the WQO requirement of 20,000 count/100mL even under the current license discharge standard. It is recommended that the current effluent license standard of 200,000 count/100mL should be maintained to protect the WSD intakes during the temporal diversion. Stronger disinfection at the seawater intakes may be required to maintain the water quality.