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DRINKING WATER SAFETY ADVISORY COMMITTEE

Updates on Use and Operation of Onsite Chlorine Generation Plants for Drinking Water Treatment in Hong Kong

PURPOSE

This paper briefs members on (i) the use of on-site chlorine generation ("OSCG") plants at 12 large water treatment works ("WTWs")[1] to produce chlorine gas/sodium hypochlorite ("NaOCl") solution for oxidation, disinfection and provision of residual disinfectant (collectively called "chlorination") for drinking water treatment in Hong Kong; (ii) the arrangement to nurture in-house expertise and experience on the operation and maintenance ("O&M") of the OSCG plants; and (iii) measures to strengthen the control on the use of NaOCl solution.

USE OF OSCG PLANTS

2. Before 2023, the Water Supplies Department ("WSD") had been importing liquid chlorine[2] for chlorination in drinking water treatment. With the advancement in technology, WSD installed OSCG plants at 12 large WTWs to generate chlorine gas on-site for direct use in drinking water treatment with a view to providing a more secured supply of chlorine and eliminating the risks associated with the transportation and storage[3] of liquid chlorine. The 12 large WTWs are classified into two groups:

Group A WTWs		Group B WTWs
Ngau Tam Mei	Pak Kong	Sheung Shui
Tai Po	Sha Tin	Silver Mine Bay
Au Tau	Tuen Mun	Siu Ho Wan
Ma On Shan		Tsuen Wan
		Yau Kom Tau

[1] Large WTWs are of design treatment capacity greater than or equal to 100 million litres per day. The installation of OSCG plants in all 12 large WTWs in Hong Kong was completed in January 2023.

[2] The import of liquid chlorine has been ceased since the expiry of the last supply contract in August 2022.

[3] Chlorine is classified as Category 2 dangerous goods under the Dangerous Goods Ordinance (Cap.295). Vigilant and complex operation procedures are required to ensure safety during the transportation and storage of liquid chlorine.

The OSCG plants at the above large WTWs, in particular those at designated WTWs[4], will also produce NaOCl solution for drinking water treatment in five small WTWs[5] and as back-up for temporary applications at the large WTWs[6].

3. As a result of the phased introduction of the OSCG plants in WTWs, WSD has formulated an O&M plan to facilitate gradual transfer of specialised O&M knowledge from overseas experts to WSD's in-house staff and to cope with WSD's planned deployment of O&M resources. Since 2021, term contractors (supported by overseas experts from the OSCG plant manufacturers) have been engaged in stages for the initial O&M of the OSCG plants at Group A WTWs. In the process, WSD found that the O&M of the OSCG plants are far more complicated than that envisaged during the formulation of the O&M plan, and consequently, it would require much more staff resources and time to train up[7] in-house staff with sufficient knowledge and competency to operate and maintain the OSCG systems on their own. At the same time, there lacks sufficient overseas experts and competent local personnel to support the running more OSCG plants concurrently.

NURTURE IN-HOUSE O&M EXPERTISE AND EXPERIENCE ON OSCG PLANTS

4. In light of the problem mentioned above, WSD has formulated and implemented the following interim O&M plan for the OSCG plants, which aims to nurture the required in-house expertise and experience for proper O&M of the OSCG plants in a defined timeframe. This will ensure timely problem-shooting of the OSCG plants under operation and enable continuous refinement to the operation processes so that a steady supply of chlorine gas/NaOCl solution can be achieved in the most cost-effective way whilst ensuring drinking water safety in the interim period:

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[4] The designated WTWs are the Sha Tin and Tai Po WTWs.

[5] Small WTWs include the Cheung Sha, Red Hill, Sham Tseng, Tai O and Tai Po Road WTWs. NaOCl solution is used for drinking water treatment at small WTWs because small-scale OSCG plant suitable for use is not available in the market.

[6] Back-up NaOCl solution dosing is required at large WTWs in case the chlorine gas generated from the OSCG plant is not available (e.g. during breakdown or maintenance of OSCG plant).

[7] The training involves comprehensive modules such as on-site demonstration and hands-on operation.

(a) concentrating the term contractors' limited resources (inclusive of those overseas experts) at the Group A WTWs, while continuing with the knowledge transfer to train up sufficient competent O&M personnel, including those of WSD and the term contractors, which is expected to be fully achieved by the end of 2025;

(b) postponing the normal operation of the OSCG plants at the Group B WTWs[8], and in the meantime use NaOCl solution for drinking water treatment in these WTWs[9]; and

(c) putting the OSCG plants at the Group B WTWs into full operation targeted from March 2025 to the end of 2025 progressively.

5. The above interim O&M plan for the OSCG plants has been formulated after balancing a host of factors, including the capacities of the OSCG plants, the potential risks of operating all OSCG plants with inadequate competent personnel, etc. The programme on the use of different chlorination agents at the 12 large WTWs is provided at **Annex 1**.

STRENGTHEN CONTROL ON USE OF NaOCl SOLUTION

6. According to the Guidelines for Drinking-water Quality published by the World Health Organization ("WHO"), the major concern for the use of NaOCl solution in drinking water treatment is the formation of disinfection by-products ("DBPs"), namely chlorite, chlorate, bromate and perchlorate, during the production process and storage of the NaOCl solution, while disinfection should not be compromised in attempting to control DBPs. In this connection, WSD has been implementing stringent monitoring and control procedures as set out in DWSAC Paper No. 8/2018 entitled "Enhancement of Chlorination Facilities at Water Treatment Works" with a view to maintaining sufficient disinfection while minimising DBPs in drinking water. The associated monitoring and control procedures are recapped and the relevant monitoring results are given at **Annex 2**.

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[8] Operation of the OSCG plants at Group B WTWs during the interim period is in fact not totally suspended due to the need to keep such plants healthy. These Group B OSCG plants will be operated on rotational basis (i.e. each OSCG plant will run for one month and suspend operation in the following four months). The OSCG plants under suspension can be put back into operation immediately when needed.

[9] The Group B WTWs serve a total population of about 1.5 million.

7. It is worth mentioning that in 2020, WSD took additional measures (see **Annex 2**) to further tighten up the control of DBPs including the introduction of an action level of 100 μg/L for chlorate in drinking water treatment[10].

8. With the introduction of the above additional measures, the monitoring results (also at **Annex 2)** indicated that the average levels of DBPs and residual chlorine in the final drinking water from the WTWs when NaOCl solution was dosed have been effectively controlled at levels well below the Hong Kong Drinking Water Standards ("HKDWS") while maintaining sufficient chlorination. In particular, the average chlorate level in drinking water has been reduced by 45% (from 64 μg/L to 35 μg/L) and the other DBPs have been continuously maintained at very low levels.

9. WSD will continue to implement stringent monitoring and control measures whenever NaOCl solution is used for drinking water treatment so as to control the amount of DBPs in the final drinking water supplied by WTWs at levels well below HKDWS, whilst ensuring proper disinfection in the drinking water treatment process as well as maintaining sufficient amount of residual chlorine in drinking water supplied by WTWs.

Development Bureau
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[10] The standard value in the Hong Kong Drinking Water Standards and WHO's provisional guideline value for chlorate is 300 μg/L and 700 μg/L respectively. The enhanced measures at **Annex 2** aim to control the chlorate level in drinking water leaving the WTWs at or below 100μg/L which is well below the aforesaid standard value or provisional guideline value.

Annex 1

Programme on Use of Different Chlorination Agents at 12 Large Water Treatment Works

<table>
<tr><th>Items</th><th>Water Treatment Works</th><th>2023</th><th>2024</th><th colspan="2">2025</th><th>2026 onwards</th></tr>
<tr><td>1</td><td><u>Group A WTWs (7 nos.) :</u>
Ngau Tam Mei, Tai Po
Au Tau, Tuen Mun, Sha Tin, Ma On Shan, Pak Kong</td><td colspan="5">Chlorine gas^ from OSCG plant</td></tr>
<tr><td>2</td><td><u>Group B WTWs (5 nos.) :</u>
Tsuen Wan, Yau Kom Tau, Sheung Shui, Siu Ho Wan, Silver Mine Bay</td><td colspan="2">Sodium hypochlorite solution for temporary use</td><td colspan="2">Migration from sodium hypochlorite solution to chlorine gas from OSCG plant
(Progressive operation of OSCG plants targeted from March 2025 to end of 2025 *)</td><td>Chlorine gas from OSCG plant</td></tr>
</table>

Remarks:

^ After depletion of liquid chlorine stock.

* With additional resources and measures (including nurturing in-house and local OSCG O&M specialists, knowledge transfer to WSD in-house staff, continuous enhancement to the OSCG systems) for the targeted operation of OSCG plants at Group B WTWs.

Annex 2

Control and Monitoring Programme for Using NaOCl Solution in Drinking Water Treatment

1. Measures to control and monitor levels of DBPs for using NaOCl solution as set out in DWSAC Paper No. 8/2018 are as follows:

- Perform consignment testing on the edible salt (i.e. the raw material for chlorine gas and NaOCl solution generation) to confirm its compliance with the specifications including arsenic, cadmium, mercury, lead, bromide and iodide before being used by the OSCG plants.

- Perform consignment testing on each batch of NaOCl solution to confirm its compliance with the specifications prior to use.

- Keep the NaOCl solution out of direct sunlight, use it on a first-in-first out basis, no mixing of different solution batches and clean the storage tank before refilling the solution to minimise degradation of NaOCl solution.

- Estimate the levels of DBPs in final drinking water over the course of dosage to ensure that they are in full compliance with HKDWS.

- Storage time of the NaOCl solution will not be more than 7 days from receipt at the WTWs.

- Step up monitoring of DBPs in final drinking water at the WTWs from monthly (or quarterly before 2022) to weekly interval.

2. The annual statistics for DBPs and residual chlorine levels in final drinking water of WTWs when NaOCl solution was dosed in 2019[i] are summarised below.

Parameter	Unit	HKDWS value	1/1/2019 – 31/12/2019			
			Minimum	Average	Maximum	95%tile
Bromate	µg/L	≤10	<2.5	<2.5	<2.5	<2.5
Chlorate	µg/L	≤300	<25	64	150	120
Chlorite	µg/L	≤700	<25	<25	<25	<25
Perchlorate	µg/L	≤70	<2.5	<2.5	6.7	<2.5
Residual Chlorine	mg/L	≤5	0.8	1.0	1.2	1.2

[i] Chlorination by NaOCl solution was implemented during the installation of OSCG plants and the trial periods of using NaOCl solution at WTWs.

3. A chlorate action level of 100 µg/L in final drinking water and the following enhanced measures to minimise DBPs levels in final drinking water at WTWs were introduced in Q3 2020.

- Each batch of NaOCl solution will expire in 7 days or on the day when the estimated chlorate content in final drinking water is greater than 100 µg/L, whichever is the earlier.

- Monitor the NaOCl solution temperature daily and dilute the current batch of NaOCl solution to extend the usable period if necessary.

- Expedite replacement of the expiring batch of NaOCl solution via necessary production and/or delivery arrangement.

4. After introducing the chlorate action level and enhanced measures in paragraph 3 above, the recent annual statistics on DBPs and residual chlorine levels in final drinking water of WTWs when NaOCl solution was used[ii] are summarised below.

Parameter*	Unit	HKDWS value	16/2/2022 – 15/2/2023			
			Minimum	Average	Maximum	95%tile
Bromate	µg/L	≤10	<1	<1	<1	<1
Chlorate	µg/L	≤300	<10	35	110	76
Chlorite	µg/L	≤700	<10	<10	<10	<10
Perchlorate	µg/L	≤70	<1	1.0	10	3.3
Residual Chlorine	mg/L	≤5	0.8	1.2	1.4	1.3

* From 1 April 2020, the detection sensitivities of bromate, chlorate, chlorite and perchlorate have been improved to 1, 10, 10 and 1 µg/L respectively.

[ii] Chlorination by NaOCl solution was implemented during the testing of NaOCl solution dosing system, installation or breakdown of OSCG plants, as well as for interim use at Group B WTWs and long term use at small WTWs after depletion of liquid chlorine stock.