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DRINKING WATER SAFETY ADVISORY COMMITTEE

Enhancement of Chlorination Strategy for Drinking Water Treatment in Hong Kong

Purpose

This paper aims to brief Members on (i) the successful experience in using sodium hypochlorite ("NaOCl") solution for drinking water treatment in Hong Kong and (ii) the proposed measure to enhance the reliability and stability of chlorination in water treatment through wider use of NaOCl solution.

Background

2. Chlorine (existing in the form of chlorine gas, liquid chlorine or NaOCl solution) is the most commonly used disinfectant in drinking water treatment worldwide. Before 2017, Hong Kong solely used liquid chlorine procured from the Mainland for water treatment. As liquid chlorine is a type of dangerous goods, the Water Supplies Department ("WSD") has installed On-site Chlorine Generation ("OSCG") plants at 12 large water treatment works ("WTWs")[1] to generate chlorine gas on-site to eliminate the risks associated with the transportation and storage of liquid chlorine. At the same time, NaOCl solution, a co-product generated from the OSCG plants, is used for drinking water treatment at small WTWs[2] and as a back-up for temporary application at the large WTWs during breakdown or maintenance of their OSCG plants. The relevant operational arrangements and subsequent updates were provided in DWSAC Paper numbered 8/2018[3] and 2/2023[4] respectively.

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[1] Large WTWs refer to those WTWs having a design treatment capacity ≥ 100 million litres per day ("MLD"), including Sheung Shui WTW, Silver Mine Bay WTW, Tsuen Wan WTW, Ma On Shan WTW, Yau Kom Tau WTW, Siu Ho Wan WTW, Tuen Mun WTW, Au Tau WTW, Pak Kong WTW, Sha Tin WTW, Ngau Tam Mei WTW and Tai Po WTW.

[2] Small WTWs refer to those WTWs having a design treatment capacity < 100 MLD, including Cheung Sha WTW, Tai O WTW, Red Hill WTW, Sham Tseng WTW and the decommissioned Tai Po Road WTW.

[3] https://www.devb.gov.hk/filemanager/en/content_1076/DWSAC_Paper_8_2018.pdf

[4] https://www.devb.gov.hk/filemanager/en/content_1076/DWSAC_Paper_2_2023.pdf

3. The application of chlorine in drinking water treatment in some major jurisdictions is shown in Annex for reference. In gist, the use of NaOCl solution is more commonly used than chlorine gas or liquid chlorine nowadays in many places over the world including the USA, Canada, Australia, the Middle East, Japan, the Mainland China, etc.

Control and Monitoring of NaOCl Solution in Drinking Water Treatment

4. Owing to limited local data and experience associated with the use of NaOCl solution in drinking water treatment when OSCG plants were first introduced in 2017 and the potential health concerns raised that time about the disinfection-by-products ("DBPs") linked to NaOCl solution (such as bromate, chlorate, chlorite and perchlorate), WSD has been adopting prudent control and monitoring measures in using NaOCl solution in the treatment process. Details of such measures have been given in the above DWSAC papers. In order to collect more local data to facilitate subsequent review and for the sake of prudence, the monitoring frequency of drinking water quality when NaOCl solution is used for water treatment has been set at a weekly interval, much higher than the quarterly interval associated with using liquid chlorine as a disinfectant.

5. In addition to the prudent control measures mentioned in the above DWSAC papers, WSD has also developed a prediction model for estimating precisely the chlorate level in treated water when NaOCl solution is used. Based on this model, WSD can make accurate and timely adjustment of the dosage of NaOCl solution to be applied to cope with the quality of water to be treated, taking into account different pre-set concentrations of NaOCl solution and different operating ambient temperature.

6. With several years of operating experience on application of NaOCl solution for the drinking water treatment process, WSD has not only refined the said prediction model, but also gained fruitful experience in maintaining the quality of NaOCl solution through controlling its storage condition, concentration and turnover such that the DBPs in the final drinking water of WTWs are controlled at levels well below the respective limits specified in the Hong Kong Drinking Water Standards ("HKDWS") at all times, as illustrated by the monitoring results in 2024 in the table below.

Parameter	Unit	HKDWS limit	Monitoring results Period: 1/1/2024 – 31/12/2024			
			Minimum	Average	Maximum	95 percentile
Bromate	µg/L	≤10	< 1	< 1	1.5	<1
Chlorate	µg/L	≤300	< 10	29	98	66
Chlorite	µg/L	≤700	< 10	< 10	< 10	<10
Perchlorate	µg/L	≤70	< 1	<1	3.9	2.1
Residual Chlorine	mg/L	≤ 5	0.6	1.2	1.5	1.4

Table – Overall levels of DBPs in final drinking water in 2024, using NaOCl solution as a disinfectant

7. Since all DBPs in the treated water have been continuously maintained at a very low level, WSD will reduce the monitoring frequency of DBPs in treated water **from weekly to monthly**, which tallies with the arrangement when chlorine gas is used as a disinfectant and in no way diminishes the effectiveness of the monitoring regime.

Proposed Measure to Enhance the Reliability and Stability of Chlorination through Wider Use of NaOCl Solution

8. Currently, NaOCl solution serves only as a backup for chlorination in large WTWs when there is sudden breakdown of chlorine gas production in the OSCG plants. In the process, a 30-minute start-up time is generally required for switching the NaOCl system from the idling mode to the operation mode, and fluctuations or transient drops in residual chlorine levels in the treated water may be experienced. To tackle the problem, WSD proposes to have wider adoption of NaOCl solution in the treatment process of the large WTWs, viz. either using chlorine gas and NaOCl solution alternately or simultaneously ("hybrid mode") or using NaOCl solution alone similar to that of the small WTWs ("sole mode"). Under both the hybrid and sole modes, the reliance on chlorine gas production will be reduced and the NaOCl system will be running at all times, thus eliminating the need to go through the 30-minute start-up process. In so doing, a continuous, reliable and stable chlorination process can be achieved at all times, thereby further safeguarding the quality of drinking water.

9. Riding on the successful experience on application of NaOCl solution for the drinking water treatment process as mentioned in paragraph 6 above and coupled with a robust monitoring regime that has standardised the monitoring frequency of DBPs in

treated water for both NaOCl solution and chlorine gas (viz. at monthly intervals), WSD is confident to produce drinking water that can fully meet the HKDWS under the hybrid or sole mode arrangement.

Conclusion

10. With effective control and monitoring measures in place, the DBPs in treated drinking water from the WTWs in Hong Kong using NaOCl solution under the hybrid or sole mode will be well controlled at levels that will give no adverse effect on drinking water safety. Such arrangement is in line with the practice being adopted by many leading jurisdictions in the world using NaOCl solution for chlorination of drinking water.

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Annex

Chlorination in Drinking Water Treatment in Various Jurisdictions

USA (Ref 1)

In the 2017 American Water Works Association survey, it was revealed that free chlorine and chloramines were the two most commonly used disinfectants, used by about 70% and 21% of the survey respondents respectively. Among the free chlorine users, more than 50% of them used NaOCl solution as disinfectants while 48% of them used chlorine gas. Since 2017, more than 35% of the chlorine gas systems have been switched to use NaOCl solution for safety reasons. As such, NaOCl solution is more widely used than chlorine gas in drinking water treatment in the USA now.

Canada (Ref 2)

According to 2005 data, 3 590 drinking water facilities located in nine provinces and territories indicated that NaOCl solution was the most common disinfectant used for disinfection in 78% of the plants, while 19% used chlorine gas, 1.4% used calcium hypochlorite and less than 0.5% used alternative disinfectants.

Australia (Ref 3)

In 1983, NaOCl solution was endorsed by the National Health and Medical Research Council for use as a drinking water treatment chemical. Subsequent revision made in 2006 did not change the status of this chemical for the treatment of drinking water. Although NaOCl is more expensive than chlorine gas, its use is becoming more widespread in Australia because of concerns about the safe transportation and handling of hazardous gaseous chlorine in pressurized tanks.

New Zealand (Ref 4)

The most common disinfectant used in water supply is still chlorine, as the gas or hypochlorite, but other chemical disinfectants such as chloramine, chlorine dioxide, and ozone are also used.

Europe (Ref 5a – 5c)

In 2012, among the EurEau member countries, 88% of the drinking water production schemes has applied a disinfection method. In case surface water is disinfected, chlorine gas or hypochlorite disinfection are applied for 44% (Ref 5a). In 2020, the vast majority of the participating countries used chlorination (chlorine gas or hypochlorite) as the main disinfection method alone (Ref 5b) and in the same period in Nordic countries, the most commonly used drinking water disinfectant in Finland (48% out of 153 treatment plants), Norway (53% out of 106 treatment plants) and Sweden (43% out of 80 treatment plants) was active chlorine (hypochlorite or chlorine gas) (Ref 5c).

Russia (Ref 6)

On-site NaOCl generation has been used in drinking water treatment.

South Africa (Ref 7)

From 2004 to 2006, a survey of 181 drinking water plants across seven provinces of South Africa indicated that chlorination was the predominant type of disinfection. Approximately 69% of the treatment plants use chlorine gas, about 15% use NaOCl solution and about 14% use calcium hypochlorite.

Middle East (Ref 8)

NaOCl solution was widely used for chlorination of drinking water.

Japan (Ref 9a – 9b)

According to a presentation made by the Department of Water Supply Engineering of the National Institute of Public Health of Japan in 2009, NaOCl solution was a major disinfectant used in 85% of water treatment facilities in Japan (Ref 9a). In 2023, NaOCl continued to be the main chlorine disinfectant for drinking water treatment (Ref 9b) .

Singapore (Ref 10a – 10c)

Chlorine was used to destroy bacteria and viruses in drinking water treatment. Ozone and chlorine were used in Choa Chu Kang and Bedok Waterworks. Ammonia was added in the treated water containing free chlorine to form chloramines, a more stable chlorine residual (Ref 10a). Singapore's Public Utility Board opted for NaOCl over chlorine gas for its new desalination facilities in Tuas and waterworks treatment plant in Lower Seletar in 2011 (Ref 10b). In 2021, Singapore started replacing the existing liquid chlorine and ammonia systems at Johor River Water Works with on-site hypochlorite generation systems(Ref 10c).

Mainland China (Ref 11a – 11e)

The majority of water treatment works employed chlorine, including liquid chlorine, NaOCl and chlorine dioxide(Ref 11a). In rural area, on-site NaOCl generation was the major disinfectant (Ref 11b). For some major cities, such as Fuzhou (Ref 11c), Shanghai, Pujiang, Nanping and Xiangshan (Ref 11d), NaOCl was used for drinking water treatment. 13% of water treatment works in Guangdong (Ref 11e) also used NaOCl for drinking water treatment.

References:

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Ref 3 Nation Water Quality Management Strategy, Australian Drinking Water Guidelines 6, 2011, Version 3.9, Updated December 2024 – Fact Sheets,

Drinking Water Treatment Chemicals, Sodium hypochlorite, page 1145. (https://www.nhmrc.gov.au/about-us/publications/australian-drinking-water-guidelines#block-views-block-file-attachments-content-block-1)

Ref 4 Guidelines for Drinking-water Quality Management for New Zealand 2019 Chapter 4: Selection of Water Source and Treatment.

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Ref 5b Trihalomethanes in Drinking Water and Bladder Cancer Burden in the European Union (https://doi.org/10.1289/EHP449)

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Ref 9a “Emerging Contaminants in Drinking Water and Future Directions” paper presented in a Conference on Drinking Water Quality Management and Wastewater Control in 2009 by Department of Water Supply Engineering, National Institute of Public Health, Japan.

Ref 9b Japan Water Works Association (http://www.jwwa.or.jp/houkokusyo/pdf/202303_suidouyou_guideline_v2.pdf)

Ref 10a Water Treatment, Public Utilities Board, Singapore's National Water Agency. (https://www.pub.gov.sg/Public/WaterLoop/Water-Treatment#)

Ref 10b Eastern Growth Shows Shift in Chlorination Technologies, January 2011. (https://www.waterworld.com/drinking-water-treatment/article/16209387/eastern-growth-shows-shift-in-chlorination-technologies)

Ref 10c De Nora awarded one of Asia's largest Water Disinfection Projects at Singapore's Johor River Water Works. 26 November 2021. (https://www.denora.com/media/press-release/2021/De-Nora-awarded-one-of-Asia-s-largest-Water-Disinfection-Projects-at-Singapore-s-Johor-River-Water-Works.html)

Ref 11a 如何控制氯酸盐消毒副产物，让饮用水更安全. Jul 2020. (https://www.h2o-china.com/news/311416.html)

Ref 11b Lu J, Yue YL and Zhang L. (2017). Overseas and domestic research progress in application and optimization of drinking water disinfection technology. Chin J Public Health, 33(3);428-432. (https://www.zgggws.com/en/article/doi/10.11847/zgggws2017-33-03-23)

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