For information on
31 July 2018

DWSAC Paper No. 8/2018

DRINKING WATER SAFETY ADVISORY COMMITTEE

Enhancement of Chlorination Facilities at Water Treatment Works

PURPOSE

1. This paper briefs members on the enhancement works being implemented by the Water Supplies Department ("WSD") to eliminate the risks associated with transportation and storage of liquid chlorine[1] by (i) installation of on-site chlorine generation ("OSCG") plants at large Water Treatment Works ("WTWs")[2] to produce chlorine gas for pre-chlorination and disinfection in the drinking water treatment, and (ii) use of sodium hypochlorite ("NaOCl") solution[3] for the same purposes at small WTWs[4] as well as for serving as backup to the OSCG plants at large WTWs.

THE ENHANCEMENT

2. Currently, the WSD uses imported liquid chlorine for pre-chlorination and disinfection in the drinking water treatment. With advancement in technology, the WSD is taking steps to generate chlorine gas on-site by installation of OSCG plants at large WTWs in order to provide a more secured supply of chlorine and eliminate the risks associated with transportation and storage of liquid chlorine.

3. As small-scale OSCG plant suitable for use at small WTWs is not available in the market, the OSCG plants at large WTWs have been equipped with facilities to convert the generated chlorine gas into NaOCl solution which

[1] 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 transportation and storage of the liquid chlorine.

[2] Large WTWs are of design treatment capacity greater than or equal to 100 million litres per day ("MLD"). They include 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.

[3] NaOCl solution has been used as a long-term disinfectant in drinking water treatment in a number of overseas countries and jurisdiction such as USA, Canada, European Union and Japan.

[4] Small WTWs are of design treatment capacity less than 100 MLD. They include Cheung Sha WTW, Tai O WTW, Red Hill WTW and Tai Po Road WTW.

will be transported and used in the drinking water treatment at the small WTWs.

4. To serve as backup in case the chlorine gas and/or NaOCl solution generated from the OSCG plant is not available (e.g. during breakdown or maintenance of OSCG plant), NaOCl solution procured from the market will be used for drinking water treatment in the WTWs.

5. According to the Guidelines for Drinking-water Quality published by the World Health Organization ("WHO Guidelines"), 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 solution. In order to minimise the amount of these DBPs in the final drinking water from the WTWs, WSD has devised a stringent control and monitoring programme to ensure the quality of both the NaOCl solution (either generated from OSCG or procured from the market) and the final drinking water. A study on the use of NaOCl solution in drinking water treatment at Tai Po Road WTW has successfully demonstrated the effectiveness of the control and monitoring programme with satisfactory final drinking water quality. Details of the study and its results are summarised at **Annex 1**.

CONTROL AND MONITORING PROGRAMME FOR USING NaOCl SOLUTION IN DRINKING WATER TREATMENT

6. The raw material used for OSCG plants for generation of chlorine gas and NaOCl solution is sodium chloride salt of food-grade quality which shall comply with the specifications in **Annex 2**. It will be under strict quality control of consignment testing by WSD to confirm its compliance with the specifications before it is used.

7. For NaOCl solution procured from the market to serve a backup as mentioned in para. 4 above, it shall comply with the specifications in **Annex 3**. A quality control test certificate shall be submitted by the supplier for each batch of NaOCl solution delivered to WTW to demonstrate that its quality complies with the specifications.

8. The WSD will also conduct strict quality control of consignment testing of the NaOCl solution received at WTWs (either generated from OSCG plants

or procured from the market) to confirm its compliance with the specifications prior to use in the drinking water treatment.

9. As the levels of DBPs in the NaOCl solution may increase with the storage time, WSD will ensure that the storage time of the NaOCl solution for use in the drinking water treatment will not be more than 7 days[5] from receipt at the WTWs, beyond which the NaOCl solution will be disposed of[6]. The storage tanks for the NaOCl solution will be well shielded from direct sunlight to prevent degradation of NaOCl solution and will be completely emptied before they are re-filled by another batch of NaOCl solution. No mixing of different batches of NaOCl solution will be allowed for proper control of the storage time of the solution. Moreover, the NaOCl solution will be used on a first-in-first-out basis and the stock level of the solution will be properly controlled to minimise the storage time of the solution before it is used in the drinking water treatment.

10. Based on the consignment test results of the levels of the DBPs upon receipt of the NaOCl solution at a WTW and the required dosage of NaOCl solution in the drinking water treatment of the WTW, and assuming the storage time of the NaOCl solution is 7 days[7], the levels of the DBPs in the final drinking water from the WTW will be calculated to ensure that they are in full compliance with the Hong Kong Drinking Water Standards ("HKDWS") (which currently adopt the guideline values and provisional guideline values in the WHO Guidelines), before the batch of NaOCl solution is accepted for use in the drinking water treatment at the WTW.

11. If NaOCl solution is being used in the drinking water treatment of a WTW, the monitoring of the final drinking water quality at the WTW will be conducted at weekly intervals[8] (as compared with quarterly intervals with the

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[5] The 7-day storage limit is to meet the operational needs to provide sufficient storage at WTWs to cater for unexpected situations such as delay in delivery due to inclement weather conditions, etc.

[6] The NaOCl solution to be disposed of will be delivered to the seafront salt water pumping stations of WSD for use in the disinfection of the salt water for flushing or to the sewage treatment works of the Drainage Services Department for use in the sewage treatment.

[7] The actual storage time of the NaOCl solution prior to use in the drinking water treatment should be much less than 7 days in normal operation.

[8] At the initial stage, WSD will collect daily monitoring data on the concerned DBPs from one to two WTWs operating in real-life situations with storage of NaOCl solution of up to 7 days under the worst case scenario (for example carrying out the trial during the hot summer period) for a certain period of time, say one to two months. When the level of the DBPs shows consistent compliance throughout the monitoring period, the monitoring frequency will be stepped down to weekly for application at all WTWs when NaOCl solution is used.

use of liquid chlorine) to ensure that the levels of DBPs in the final drinking water are in full compliance with the HKDWS. Nevertheless, the monitoring frequency will be subject to further review when more data are available after implementation of the control and monitoring programme.

Development Bureau
Water Supplies Department
July 2018

Annex 1

Study on the Use of NaOCl Solution in Drinking Water Treatment at Tai Po Road WTW

1. A study on the use of NaOCl solution in the drinking water treatment was conducted at Tai Po Road WTW to verify the effectiveness of the control and monitoring programme devised by WSD to ensure that the levels of DBPs in the final drinking water is in full compliance with the HKDWS. Imported NaOCl solution with active chlorine content of 7.5-9.0 % w/w (weight/weight) was used in the study.

2. Under the study, two batches of NaOCl solution consignment were delivered to Tai Po Road WTW on 19 June 2018 and 25 June 2018 respectively with each batch used for 7 days in the drinking water treatment. Quality control test certificates were submitted by the supplier as in **Appendix 1 to Annex 1** for the batches to demonstrate that its quality had fully complied with the specifications.

3. WSD conducted consignment testing for the NaOCl solution to confirm its compliance with the specifications. The consignment test results are at **Appendix 2 to Annex 1**.

4. The NaOCl solution was used in the pre-chlorination and disinfection in the drinking water treatment at Tai Po Road WTW under real life operation mode during the period from 19 June 2018 to 2 July 2018[1].

5. The plant data of Tai Po Road WTW during the study period are summarised below:

	Maximum	Minimum	Average
Plant Output (MLD)	9.1	7.7	8.8
NaOCl Dosage (mg/L)	2.9	2.4	2.6

[1] During the study period, the final drinking water from the WTW was not supplied to the public.

6. Based on the consignment test results of the levels of the DBPs of the NaOCl solution and the required dosage of NaOCl solution in the drinking water treatment of Tai Po Road WTW, the levels of the DBPs in the final drinking water from the WTW were calculated, as shown below which were in full compliance with the HKDWS.

Parameter	Standard Values in HKDWS	Estimated levels of DBPs in the final water[2,3,4]	
		1st batch of NaOCl	2nd batch of NaOCl
Bromate (μg/L)	10	< 2.5	< 2.5
Chlorate (μg/L)	700	180	200
Chlorite (μg/L)	700	< 25	< 25
Perchlorate (μg/L)	70	< 2.5	< 2.5

7. The levels of DBPs in the final drinking water from the Tai Po Road WTW were monitored daily during the study period and the monitoring results are summarised in the table below. The levels of DBPs in the final drinking water from the WTW were all well below the respective standard values in the HKDWS. The free residual chlorine level in the final drinking water also complied with the established guideline of WSD during the study period.

[2] The estimated bromate and chlorite contents are calculated based on the consignment test results upon receipt at WTW and the required dosage. According to a previous study, their levels had shown no significant change with storage time of NaOCl solution over a period for about a month.

[3] The projected maximum chlorate content in the final water on day 7 of the storage time of the NaOCl consignment after receipt at WTW, which are calculated from the consignment test results and the required dosage using a linear regression model based on a previous bench-scale study on formation of chlorate in NaOCl solution with storage time for about a month.

[4] The estimated perchlorate contents are calculated based on the consignment test results upon receipt at WTW and the required dosage. It is expected that its content would remain at a relatively low level with implementation of the strict quality control measures and storage conditions for the NaOCl solution.

Parameter	Standard Values in HKDWS	Final Drinking Water from Tai Po Road WTW[5] (19 June 2018 – 2 July 2018)		
		Maximum	Minimum	Average
Bromate (μg/L)	10	< 2.5	< 2.5	< 2.5
Chlorate (μg/L)	700	91	61	79
Chlorite (μg/L)	700	< 25	< 25	< 25
Perchlorate (μg/L)	70	< 2.5	< 2.5	< 2.5
Free Residual chlorine (mg/L)	5	1.1	0.9	1.0

[5] The levels of quantitation for bromate, chlorate, chlorite and perchlorate are 2.5 μg/L, 25 μg/L, 25 μg/L and 2.5 μg/L respectively.

Appendix 1 to Annex 1

Quality Control Certificate for NaOCl Consignment
(1st Batch)

惠州市深华化工有限公司

化验报告单

日期：2018 年 6 月 18 日　　检验批号：

样品名称	次氯酸钠Great Value Bleach	送样部门	生产部
检验依据	GB19106-2013(和水务署标准)	取样日期	6 月18日
生产数量	吨	化验日期	6 月18日
指标名称	指标值	化验结果	
有效氯	7.5-9%	8.46 %	
游离碱	0.1 - 1.0%(w/w)	0.22 %	
铁含量	≤0.005%(w/w)	0.0005 %	
重金属（以铅计）含量	≤0.001%(w/w)	0.0002 %	
砷含量	≤0.0001%(w/w)	0.00002 %	
P.H值	≥10.0	12.6	
氯酸钠	≤有效氯含量的5.4%（w/w）	2.1 %	
溴酸钠	≤有效氯含量的2.5 g/Kg	0.8 g/Kg	
外观说明	浅黄色	结论	合格

惠州市深华化工有限公司 质量检测章

审核：　复核：杨开云　化验员：罗来涛

Appendix 1 to Annex 1

Quality Control Certificate for NaOCl Consignment
(2nd Batch)

惠州市深华化工有限公司

化验报告单

日期：2018 年 6 月 14 日　　检验批号：

样品名称	次氯酸钠 Great Value Bleach	送样部门	生产部
检验依据	GB19106-2013(和水务署标准)	取样日期	6月14日
生产数量	吨	化验日期	6月14日
指标名称	指标值	化验结果	
有效氯	7.5-9%	8.52 %	
游离碱	0.1 - 1.0%(w/w)	0.16 %	
铁含量	≤0.005%(w/w)	0.0005 %	
重金属（以铅计）含量	≤0.001%(w/w)	0.0003 %	
砷含量	≤0.0001%(w/w)	0.00003 %	
P.H值	≥10.0	12.7	
氯酸钠	≤有效氯含量的5.4%（w/w）	2.3 %	
溴酸钠	≤有效氯含量的2.5 g/Kg	0.88 g/Kg	
外观说明	淡黄色	结论	合格

惠州市深华化工有限公司 质量检测章

审核：　　复核：　　化验员：

Appendix 2 to Annex 1

NaOCl Consignment Test Results

Parameter	Requirements	1st Batch	2nd Batch
Appearance	Visibly free from deposits or suspended matter	Visibly free from deposits or suspended matter	Visibly free from deposits or suspended matter
Active Chlorine Content	7.5 – 9.0% (w/w)	7.8 %	8.6 %
Free Caustic Alkali (as NaOH)	0.1 – 1.0% (w/w)	0.3 %	0.4 %
Iron (Fe)	Not more than 0.005% (w/w)	<0.0004%	<0.0004%
Total Heavy Metal (as Pb)	Not more than 0.001% (w/w)	<0.001 %	<0.001 %
Arsenic (As)	Not more than 0.0001% (w/w)	< 0.00001 %	< 0.00001 %
Sodium Bromate	Not more than 2.5 g/kg of available chlorine	< 0.29 g/kg	< 0.27 g/kg
Sodium Chlorate	Not more than 5.4% (w/w) of available chlorine	3.5 %	2.4 %

Annex 2

Specifications for NaCl Salt

The specifications for NaCl salt is based on the National Standard of Mainland China GB/T 5461-2016 (food grade salt) with 2 additional parameters calcium and magnesium and bromide as shown below.

Parameter	Specifications
Sodium Chloride	≥ 99.1 % w/w
Aesthetic requirement	White, non-odourous and visually free of contaminant
Whitness degree	≥80 degree
Gradularity	Small: 0.15mm to 0.85 mm
Iodizing agent as Iodide	<5mg/kg
Sulphate	≤ 0.40 % w/w
Moisture	≤ 0.30 % w/w
Water insoluble matter	≤ 0.03% w/w
Arsenic (As)	≤ 0.5 mg/kg
Cadmium (Cd)	≤ 0.5 mg/kg
Mercury (Hg)	≤ 0.1 mg/kg
Barium (Ba)	≤ 15 mg/kg
Lead (Pb)	≤ 2 mg/kg
Anti-caking agent as $[Fe(CN)_6]^{4-}$	≤10 mg/kg
Bromide	≤150 mg/kg
Calcium and Magnesium	≤60 mg/kg

Annex 3

Specifications for NaOCl Solution

The specifications for NaOCl solution for drinking water treatment is based on the National Standard of Mainland China GB 19106-2013 NaOCl solution Type A II with 2 additional parameters of sodium bromate and sodium chlorate referenced from British Standard BS EN 901:2013 Type 1 as shown below.

Parameter	Specifications
Appearance	Visibly free from deposits or suspended matter
Active Chlorine Content	10.0% (w/w)
Free Caustic Alkali (as NaOH)	0.1 – 1.0% (w/w)
Iron (Fe)	Not more than 0.005% (w/w)
Total Heavy Metal (as Pb)	Not more than 0.001% (w/w)
Arsenic (As)	Not more than 0.0001% (w/w)
Sodium Bromate	Not more than 2.5 g/kg of available chlorine
Sodium Chlorate	Not more than 5.4% (w/w) of available chlorine