Case	Powdered activated carbon and intermediate chlorination to control musty odor in the Tama River			
water utility	Bureau of Waterworks Tokyo Metropolitan Government			
General information of the utility (as of 2022)				
Operation type	Public (retail & industrial water supply※) (※ Industrial water supply discontinued at the end of March 2023.)	Service area (km^2)	1239.23	
Population served	13,695,575	Distribution (m^3/d)	4,155,200	
Service coverage (%)	100	Pipe length (km)	27,466	
NRW (%)	4.3	Number of staff	3,630	
Number of water sources	Surface water (4), Groundwater (278), Others (0)			
Water rates (JPY)	1,067	(in case of $10m^3$ of water per month for residential customers with 13mm diameter)		
Summary	The Ozaku Water Treatment Plant, which uses the Tama River as its water source, has long been blessed with excellent raw water quality and has conducted water treatment using a rapid filtration system based on pre-chlorine injection. Around 2011, the concentration of 2-Methylisoborneol (2-MIB), a substance that causes musty odor in raw water, began to rise sharply, and the plant responded by increasing the powdered activated carbon (PAC) injection facilities. However, the pre-chlorination method had low 2-MIB removal efficiency of PAC, and faced problems such as increased chemical costs and reduction in the volume of treated water. Therefore, in order to implement more efficient PAC treatment, the Bureau of Waterworks Tokyo Metropolitan Government verified the introduction of intermediate chlorination through facility upgrades, and completed the facility upgrades in 2016. The facility has been used in combination with pre-chlorination facility and operating without any problems up to the present, maintaining good water quality.			

Current Status & Challenges

1) Overview of the Ozaku Water Treatment Plant

The Ozaku Water Treatment Plant is located in the upper reaches of the Tama River and has a treatment capacity of 280,000 m^3/day. Raw water is all surface water from the Tama River, which is taken at the Hamura intake weir located approximately 3km from the treatment plant and is led to the plant by the water pump. The water is treated by a rapid filtration system and is delivered to the western part of the Tama area.

2) 2-MIB in raw water

2-MIB in raw water of the Ozaku Water Treatment Plant bigan to rise sharply around 2011 , reaching to a maximum of 220 ng/L in August 2013. Surveys have confirmed that this increase in 2-MIB concentration was caused by the mass proliferation of *Microcoleus autumnalis* (*Phormidium autumnale*) (Figure 1), a type of cyanobacteria attached to riverbeds, and that the concentration of 2-MIB increases as water temperature rises.

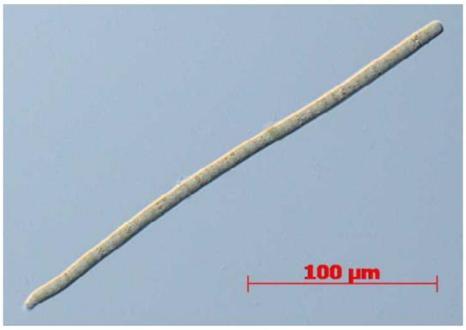

Figure 1. *Microcoleus autumnalis* (*Phormidium autumnale*)

3) PAC injection facilities

At the time of 2011, the plant had activated carbon injection facilities at the Hamura Water Supply Pump Station and in the plant. To cope with the rise in raw water 2-MIB after 2011, a temporary injection facility was installed (2012), and then an injection facility was added at the pump station (2014).

4) issues

The Ozaku Water Treatment Plant did not have an intermediate chlorine facility, and sodium hypochlorite ("hypochlorite") was injected in the flush mixing tank which was placed before the sedimentation water culvert. In the pre-chlorination process, PAC reacts with hypochlorite, releasing some of the 2-MIB adsorbed on the PAC released (Figure 2) and the removal rate decreases, forcing an increase in the amount of PAC injected and a reduction

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in the water volume.

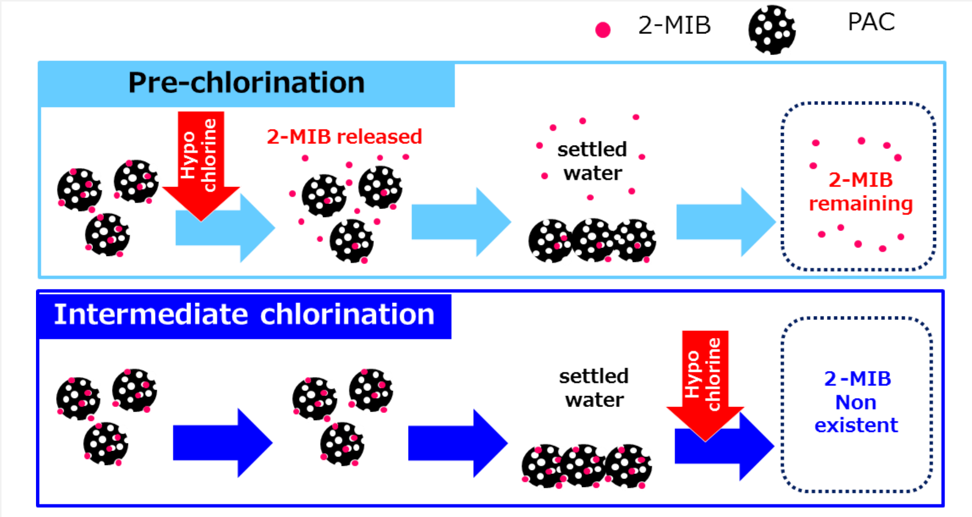

Figure 2. Effect of hypochlorite injection on 2-MIB treatment

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<td>Measures & Solutions</td>
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In order to improve the 2-MIB removal rate by PAC, intermediate chlorination in which hypochlorite is injected after coagulation sedimentation process was considered to be effective. Therefore, the Bureau examined the possibility of introducing this method by improving the facility and verified the effectiveness of the introduction.

<u>**1) Investigate feasibility of introducing facility improvements**</u>

Since this water treatment plant was designed on a narrow site and it was difficult to incorporate new facilities and processes, it was decided to inject and mix hypochlorite in the existing sedimentation water culvert and conduct the following experiments and verifications.

<u>1.1) experiment in practical facilities</u>

A temporary hypochlorite injection facility was installed at the site to investigate the state of hypochlorite mixing. Hypochlorite was injected at one injection point in each group (four injection points per system) at the inlet of the sedimentation basin, aiming for mixing by water flow.

The results of the investigation showed that the mixing of hypochlorite in the sedimentation water culvert was insufficient, resulting in fluctuations in the residual hypochlorite concentration in the treated water. In addition, multiple hypochlorite injection pumps and injection piping were required, and facility management

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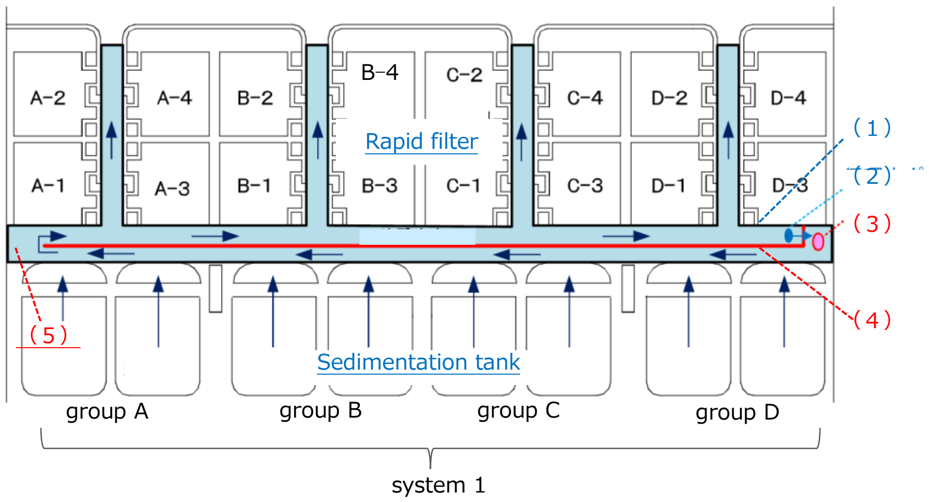
	issues were also identified. <u>1.2) hydraulic model experiments</u> To solve the problems identified in the previous experiment (1.1), it was considered effective to install separation walls in the existing sedimentation water culvert and use a one-point injection system per system. However, the installation of these facilities could cause a rise in the water level and an imbalance in the water flow to each filtration pond, so the shape of separation walls, etc. was considered through a hydraulic model experiment (1/5 scale of the actual facility). As a result of the investigation, it was found that a system with separation walls, circulating water pump, and hypochlorite injection point, as shown in Figure 3, and diversion wall at the opening of separation walls is optimal in terms of water level, water volume balance, and hypochlorite mixing.  **Figure 3.** Overview of the adopted sedimentation water culvert improvement plan (1) sedimentation water culvert (2) circulating water pomp (3) hypochlorite injection point (4) separation walls (5) diversion wall installation position <u>1.3) Improvements and Verification in actual facility</u> Based on the results obtained from the hydraulic model tests, the construction work related to intermediate chlorination facility ,

including sedimentation water culvert modification, hypochlorite injection facility installation, and monitoring and control modification, were carried out and the hypochlorite injection facility started operation in July 2016 (Figure 4,5). There were no problems with the water level in the sedimentation canal, and the residual chlorine concentration was uniform after the diversion wall, indicating proper mixing.

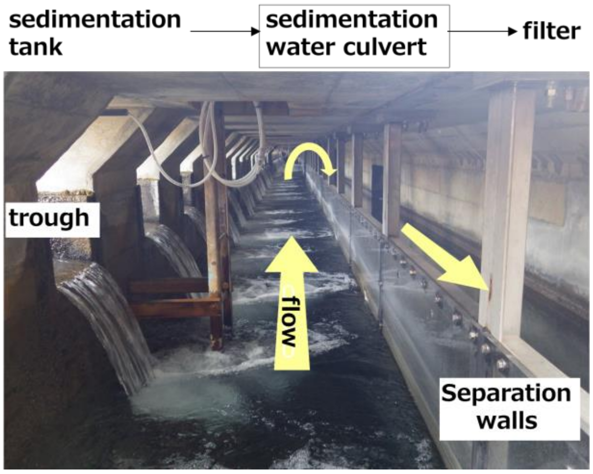


Figure 4. sedimentation water culvert after improvement work

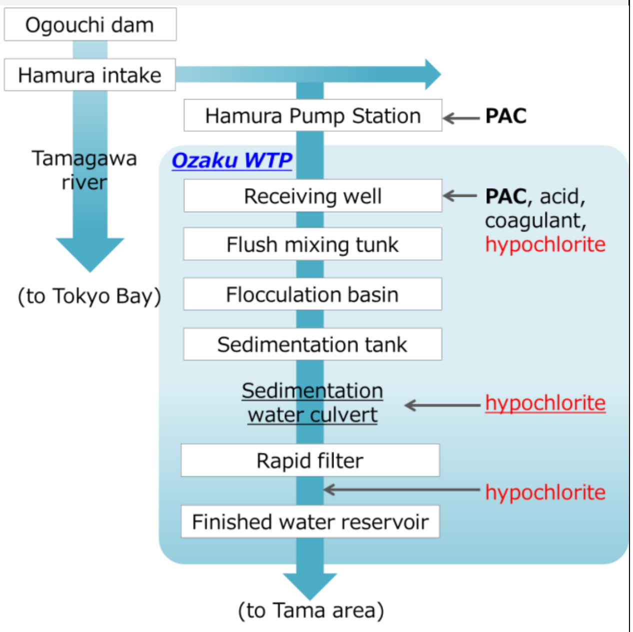
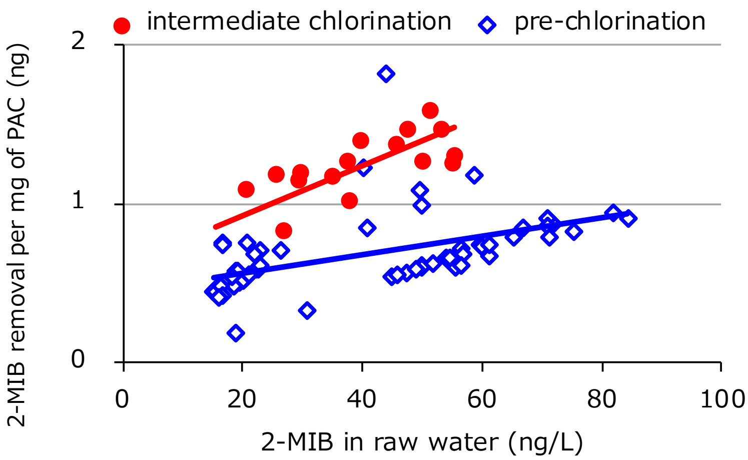


Figure 5. Treatment process at Ozaku WTP (after improvement work)

2) Verification of 2-MIB removal performance

To evaluate the removal performance of 2-MIB by PAC, the "amount of 2-MIB removed per 1 mg of PAC (ng)" were compared between pre-chlorination and intermediate chlorination. As a result, when the raw water 2-MIB concentration was about 50 ng/L (the maximum in FY 2016), the amount of 2-MIB removed was 0.73 ng in pre-chlorination, while it was 1.4 ng in the intermediate chlorination, confirming that the amount of PAC used could be reduced by intermediate chlorination (Figure 6).

	 **Figure 6.** Comparison of 2-MIB removal of activated carbon
Future Plans	This case study shows that intermediate chlorination is possible by improving existing pre-chlorination facilities, and that the amount of PAC injection can be reduced by intermediate chlorination. However, there are cases where pre-chlorination is effective, such as when dealing with biological turbidity and manganese, so it is necessary to devise flexible operation and management according to the raw water quality. The Bureau will continue to strive for a stable supply of safe, good-tasting, high-quality water by conducting appropriate water treatment according to the quality of raw water.
References	○Tsunoda. T et al., “Results of genetic analysis of musty odor-producing cyanobacteria in the upper reaches of the Tama River”, Journal of the Japan Society of Water Environment, vol. 37, No. 1, pp. 9-13, 2014 (in Japanise) ○Koda. T et al., “Investigation on musty odor-producing cyanobacteria in the upper reaches of the Tama River: distribution status and growth characteristics of *Phormidium autumnale*”, Proceedings of the 2018 JWWA National Waterworks Conference, pp. 186-187, 2018 (in Japanise) ○Watanabe. A et al., “Measures to remove musty odor by introducing intermediate chlorination at the Ozaku Water Treatment Plant”, Proceedings of the 2018 JWWA National Waterworks Conference, pp. 388-389, 2018 (in Japanise) ○Suetsugu. R et al., “Development of a simple detection method for cyanobacteria-derived fungal odor synthetase Genes and Utilization of

	Detection Results in Fact-Finding Surveys", Proceedings of the 2018 JWWA National Waterworks Conference, pp. 618-619, 2022 (in Japanise)