Production of Serious Musty Odor in Clear Upstream River

Behavior of 2-MIB Production by Adherent Cyanobacteria and their Countermeasures

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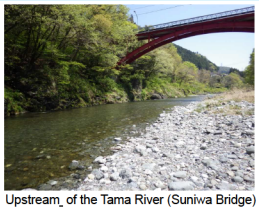
Introduction



Upstream of the Tama River (Suniwa Bridge)

- ✓ The damage from offensive odor affecting the taste of tap water is a major challenge for water suppliers, and 2-methylisoborneol (hereinafter referred to as "2-MIB"), a type of substance which causes musty odors, has a standard value for tap water quality set to 10 ng/L in Japan.
- ✓ Tama River is one of the important water resources in Tokyo, but there has been a problem with 2-MIB, which is caused by adherent cyanobacteria, *Phormidium autumnale* since 2011.
- ✓ Although many cases of the occurrences of musty odor have been reported so far, most of them are due to floating cyanobacteria species or actinomycetes in lakes and the like where eutrophication progressed, and there have been very few cases reporting the occurrences of 2-MIB caused by cyanobacteria adhered to river beds of clear rivers.
- ✓ We conducted this study in order to find the behavior of 2-MIB and adherent cyanobacteria growth in river water, and to find the effect of water temperature on cyanobacterial growth and production of 2-MIB. In addition, this paper also reports measures to eliminate 2-MIB at purification plants.

Methods

Behavior of 2-MIB and Adherent Cyanobacteria Growth

- ✓ In order to grasp the behavior of the concentration of 2-MIB, we selected multiple monitoring points in the range from the Hamura Intake Weir to E point which is located about 20 km upstream of the Weir, and periodically surveyed 2-MIB in the river water. (Figure 1)
- ✓ At places where the concentration of 2-MIB is rising, we periodically investigated the growth state of cyanobacteria by counting the adherent cyanobacteria (Figure 2).

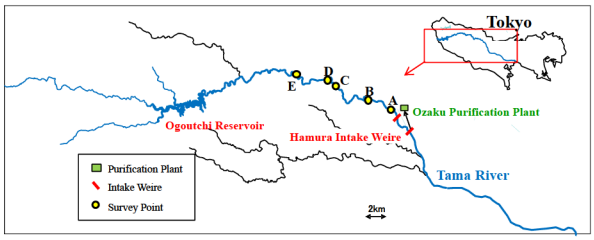


Figure 1. Tama River System and Survey Points

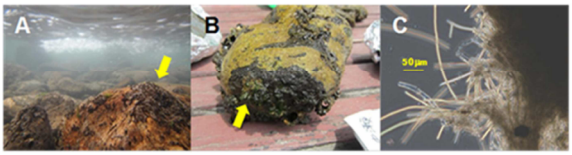


Figure 2. Musty odor producing cyanobacteria (A: Riverbed, B: Collected rock, C: Enlarged cyanobacteria)

Water Temperature Characteristics of Production and Release of 2-MIB

- ✓ In order to clarify the characteristics of production and release of 2-MIB in the high-water temperature period and the low water temperature period, we carried out culturing experiments at 22° C and 6° C respectively.

Measures to Highly Concentrated 2-MIB at Purification Plant

- ✓ At Ozaku Purification Plant, we performed chlorine injection with the prechlorination method. When 2-MIB was detected in raw water for water supply, we responded by injecting powdered activated carbon.
- ✓ For the improvement of 2-MIB removal method using powdered activated carbon, we used a new method of intermediate chlorination that is better than prechlorination, so we verified its effect.

Results and Analysis

Behavior of 2-MIB and Adherent Cyanobacteria Growth

- ✓ In FY2011 and FY2012, 2-MIB concentration in the river in the summer sharply increased around Point A and Point B, which are located about 5 km upstream from Hamura Intake Weir. The number of adherent cyanobacteria at these points was higher in the low water temperature period than in the high-water temperature period in FY2012. (Figure 3)
- ✓ Although it is generally said that cyanobacteria grow in the summer season when the water temperature is high, *P. autumnale* is believed to be able to grow in winter by adapting to low water temperature.

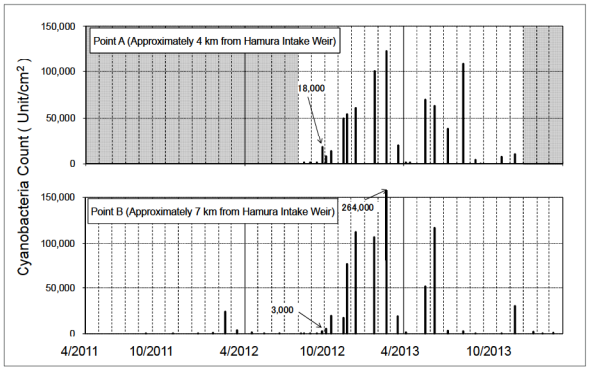


Figure 3. Growth of musty odor producing cyanobacteria

Water Temperature Characteristics of Production and Release of 2-MIB

- ✓ Depending on the cultivating experiment, although the growth rate at the low temperature of 6°C was lower than that at 22°C, it was suggested that it can grow to the same cell density at the low temperature as at the high-water temperature period. (Figure 4, A)
- ✓ It was found that production and release of 2-MIB were promoted at high water temperature, whereas they were considerably suppressed at low temperature.(Figure 4, B,C)

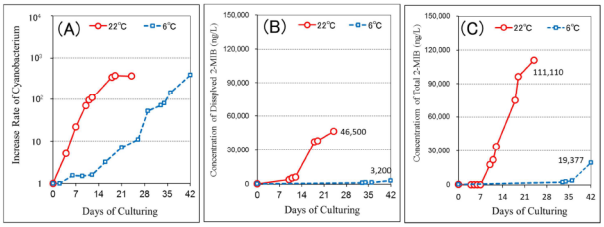


Figure 4. Change in Increase Rate of Cyanobacteria, Concentration of 2-MIB in a Dissolved Form and Concentration of Total 2-MIB at High Water Temperature and Low Water Temperature

Measures to Highly Concentrated 2-MIB at Purification Plant

- ✓ The problem with introducing the intermediate chlorination method to the existing facilities was that there was no space to install the intermediate chlorine mixing pond. For this reason, in experiments at a 1/5 scale plant that we carried out in FY 2014, partition walls were installed in the sedimentation water channel to promote mixing of the chemicals.
- ✓ We started of the intermediate chlorination system in July 2016. When there was 50 ng/L of 2-MIB in raw water, the removal amount of 2-MIB was approximately 0.7 ng per 1 mg of powdered activated carbon using the prechlorination method, while it improved by roughly twice up to 1.4 ng using the intermediate chlorination method. (Figure 5)

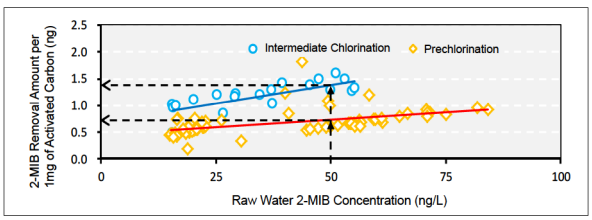


Figure 5. Difference of Removal Effect of 2-MIB by Chlorination Method

Conclusion

- ✓ Based on the results of the survey to find the growth status of adherent cyanobacteria and the culturing experiments to find the effect of water temperature, it was confirmed that an adherent cyanobacterium *P. autumnale* can grow even at low water temperature, while the amount of production and release of 2-MIB depends on water temperature and it increases at high water temperature.
- ✓ As a response to the high concentration of 2-MIB, the existing facilities and equipment of Ozaku Purification Plant were remodeled from the prechlorination method to the intermediate chlorination method, and the removal effect by powdered activated carbon was investigated. As a result, it was found that the removal amount was roughly doubled.

[1] Oikawa T, Tsunoda T, Nakahigashi H, Shimoriku M, Kanami T and Kimura S., Musty odor producing benthic cyanobacteria in the Tama River (Japan) and identification of species by genetic analysis, Journal of Water Supply: Research and Technology – Aqua, Volume64, Issue7, pp 839-846, 2015

[2] Tsunoda T, Nakahigashi H, Kanami T, Oikawa T, Genetic analysis of 2-methylisoborneol-producing cyanobacterium sampled from the upper research of the Tama, Journal of Japan Society on Water Environment, Vol.37, No.1, pp 9-13, 2014