Analysis of disinfection by-products of water treatment plants in Daegu and Gyeongsangbuk-do

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***Abstract*— In this study, the correlation between the occurrence of disinfection byproducts (DBPs) and temperature of source waters to water treatment plants in Daegu and Gyeongbuk for over 13 years from 2011 to 2023 was examined. The occurrence of DBPs at water treatment plants with advanced processes against conventional ones was also compared. In all of the THMs, HAAs, and HANs, water treatment plants with lake water and river water were higher than those with groundwater. Concentrations of THMs correlated with temperature, while those of HAAs and HANs did not exhibit a distinct correlation with temperature. The advanced processes produced less THMs, HAAs, and HANs than the conventional process. Therefore, it is essential to ensure the safety of tap water to maintain an appropriate residual chlorine concentration in all water supply systems. As a decrease in residual chlorine concentration or the generation of DBPs is closely related to temperature, care should be taken.**

Keywords—Disinfection by-products, THMs, HAAs, HANs, Chlorine

I. INTRODUCTION

A water treatment facility is built to sterilize pathogens, and to supply safe and clean tap water effectively. After the completion of the first water treatment facility, Ttukdo Water Treatment Plant, in 1908 in Korea, regulations on water treatment standards were established due to the detection of pathogenic viruses in tap water in the late 1990s, and virus treatment standards were revised and applied due to continuous development. With the establishment of these standards and continuous investment, the average water treatment rate in Korea reached 99.4% at the end of 2020. According to the Ministry of Environment's water supply statistics, the total annual water supply has been increasing every year, with 6,651 million m^3 in 2011, 6,279 million m^3 in 2015, and 6,651 million m^3 in 2020 [1]. To meet this increasing water demand, water treatment facilities disinfect water with ozone and UV by introducing advanced treatment processes for effective sterilization, but the disinfection process using chlorine is still the most widely used in Korea. This is because chlorine-based disinfectants are cheaper than other disinfectants and have residual properties, which are the advantages of chlorine disinfection, to prevent contamination during the process of water supply.

On the other hand, when disinfection is performed using chlorine, various types of disinfection byproducts (DBPs) harmful to the human body are generated by reacting with natural organic materials (NOM) in water. Physical and chemical factors affecting the production of DBPs are known to include pH, contact time, temperature, chlorine dose, and characteristics of NOM [2]. The types of chlorine DBPs generated are largely divided into THMs, HAAs, and HANs. THMs contain a variety of substances, but chloroform accounts for the largest portion of them. The effects of chloroform on the human body are known to cause cancer or cause liver, kidney, and central nervous system disorders [3].

Since the Four Major River Projects in Korea, the concentration of T-P in the Nakdong River basin has decreased, the concentration of BOD, COD, and TOC has increased, and the concentration of THMs has the highest in the Nakdong River basin among the four major rivers in Korea. Because there are many industrial cities distributed in the Nakdong River basin, the concentration of DBPs is judged to be higher because chlorine disinfection is stronger than in other regions to remove many pollutants contained in the water source [2][4].

In addition, according to future climate changes, surface outflows will increase significantly and water pollution discharge loads will also increase, negatively affecting surface water quality [5]. As the water quality of raw water deteriorates and there are more pollutants, chlorine disinfection is strengthened, which inevitably increases the generation of DBPs. Therefore, this study aimed to investigate the occurrence of DBPs at water treatment plants in the Nakdong River basin over 13 years from 2011 to 2023, and assessed the correlation between DBPs levels and other parameters.

II. MATERIALS AND METHODS

A. Target Sites

This study collected the concentrations of DBPs by classifying a total of 90 water treatment plants in Daegu and Gyeongsangbuk-do into four water sources, including underground water, river water, river-bed water, and lake water. There were 59 plants corresponding to river-bed water, including Gaeun Water Treatment Plant, Gaheung Water Treatment Plant, Gamcheon Water Treatment Plant,

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Goryeong Water Treatment Plant, Yecheon Water Treatment Plant, etc. The three plants corresponding to groundwater were Gacheon Water Treatment Plant, Chojeon Water Treatment Plant, and Geunnam Water Treatment Plant. There were seven plants corresponding to river water, including Gyeongsan Water Treatment Plant, Gumi Water Treatment Plant, Munsan Water Treatment Plant, Goryeong Water Treatment Plant, and Gumi Water Treatment Plant. There were 21 points corresponding to the lake water, including the Gachang Water Treatment Plant, Galpyeong Water Treatment Plant, Bomun Water Treatment Plant, Bulguk Water Treatment Plant, Industrial Complex Water Treatment Plant, and Yeongcheon Integrated Water Treatment Plant.

B. Data Collection and Analysis

For data analysis, data from 90 water treatment plants in Daegu and Gyeongsangbuk-do were collected from the National Water Supply Information System (www.waternow.go.kr/) operated by the Korea Water Resources Corporation. The collected parameters were water treatment processes, types of water source, concentrations of THMs, concentrations of HAAs, and concentrations of HANs. In this study, the concentration of HANs was calculated as the sum of Dibromoacetonitrile (DBAN), Dichloroacetonitrile (DCAN), and Trichloroacetonitrile (TCAN). Types of water sources included spring water, river-bed water, groundwater, river water, and lake water; in the case of spring water there has been data since 2014, and the number of data is significantly small, so the data was excluded.

The collected data were classified into four water sources: river-bed water, groundwater, river water, and lake water, and then the concentrations of THMs, HAAs, and HANs were analyzed by year and month to analyze the occurrence of DBPs in Daegu and Gyeongsangbuk-do. To compare the occurrence of DBPs between water treatment plants with advanced treatment processes and water treatment plants with conventional water treatment processes, the average amount of DBPs was calculated by separating them based on the presence or absence of the advanced treatment.

III. RESULTS AND DISCUSSIONS

A. THMs

From 2011 to 2023, the monthly THMs generation amount at the water treatment plants in Daegu and Gyeongsangbuk-do was classified by the water sources and summarized in Figure 1. The overall THMs were relatively higher in the water treatment plants using river water and lake water as raw water than in the water treatment plants using river-bed water and groundwater. This is considered that the concentration of THMs was relatively low in reflux and groundwater because the precursors of THMs were filtered once by soil and gravel. In addition, in the case of river-bed water, groundwater, and river water, it was high in August and September, and in the case of lake water, the concentration of THMs increased relatively late, showing high in September and October. In conclusion, the concentration was higher in summer than in winter and since the temperature affects the production of THMs, it was judged that the concentration of THMs was higher in summer when the temperature was high.

To examine the correlation between temperature and THMs as a numerical value, the concentration of THMs in the temperature range was summarized in Figure 2. Since the water temperature was not measured separately at the water treatment plant, the atmospheric temperature was used. Since THMs are affected by various factors such as water quality, water treatment processes, and chlorine injection amount, it was difficult to know the correlation accurately by simply comparing the temperature and THMs concentration, but overall, the concentration of THMs tended to increase as the temperature increased. In addition, when analyzed by the head of water, river water, and reflux water showed a trend of increasing THMs according to temperature, while groundwater and lake water showed a constant trend regardless of temperature. It can be determined that temperature acts as an important factor in the generation of THMs at water treatment plants.

The concentrations of THMs in finished water by a conventional water treatment process and an advanced water treatment process were compared. Since most water treatment plants that use advanced water treatment processes in Daegu

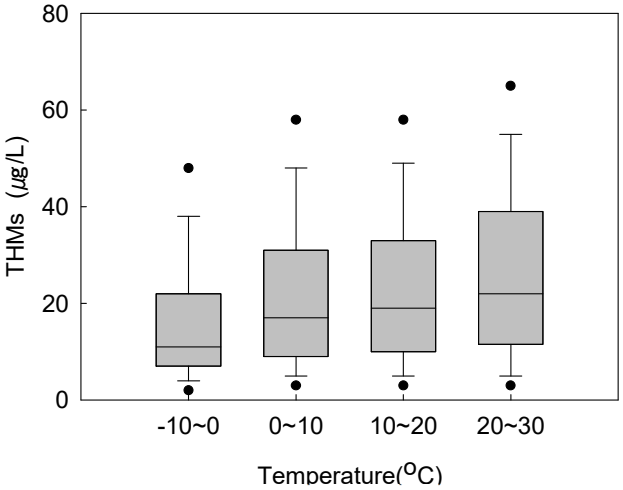


Figure 1. THMs based on temperature range

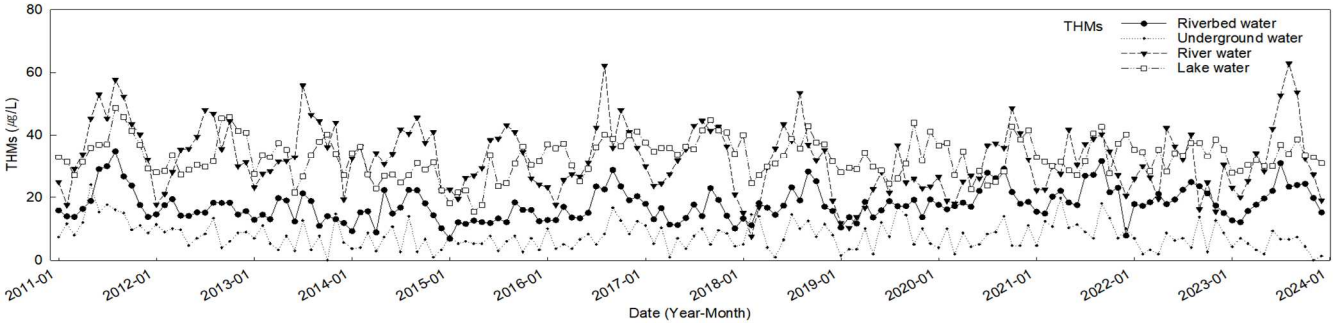


Figure 2. The average monthly concentration of THMs

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and Gyeongsangbuk-do used river water as a source water, water treatment plants that use conventional water treatment processes were also selected and organized only to use river water. The concentration of THMs was lower than that of the water treatment plant using conventional water treatment.

B. HAAs and HANs

Figure 3. shows the average concentration of HAAs generated monthly at the water treatment plants in Daegu and Gyeongsangbuk-do for 13 years during the data survey period. Similar to THMs, the concentration of HAAs in the water treatment plants using lake water and river water as raw water was higher than the plants using groundwater. In the case of river-bed water, the amount of occurrence was small before 2016, but it gradually increased since 2016, showing a similar number to that of river water. Because groundwater has better water quality than other water sources, it seems that the amount of chlorine injected during disinfection is relatively small and the precursor, which is the cause of disinfection by-products, is contained less. In addition, unlike THMs, there was no change in HAAs concentration according to seasonal changes, which showed that the effect of temperature on the generation of HAAs was not significant. In addition, the water quality standard of HAAs is 100μg/L, and the maximum value among the 13 years of data is 43.33μg/L, which is well followed. However, the concentration of HAAs has increased since 2020.

The average HAAs concentration tended to increase slightly depending on the temperature, but the difference in value was not large, and most of them showed a constant value regardless of the temperature. The results showed that the amount of HAAs generated increases when the temperature increases, but it is judged that the results were not properly produced due to changes in various occurrence factors in the domestic water treatment plant[6].

Figure 4. shows the HAAs concentration in both advanced and conventional water treatment plants. The HAAs concentration was much lower in the advanced water treatment plants. This seems to be due to the high removal rate of precursors in advanced water treatment plants.

Figure 5. shows the average concentration of HANs generated monthly at water treatment plants in Daegu and Gyeongsangbuk-do from 2011 to 2023. The HANs concentration of the water treatment plant using the lake water and river water as raw water was high, yet the ones with groundwater did not generate them. Because groundwater has better water quality than other water sources, it seems that the amount of chlorine injected during disinfection was relatively small and the precursor, which is the cause of disinfection by-products, was contained less. In the case of river-bed water, the water quality is cleaner than that of river water and lake water, but because it is directly affected by the water quality of river water, the water quality deteriorates due to floods, and the concentration of HANs is high. Since June 2020, the frequency of high concentrations of HANs has increased in

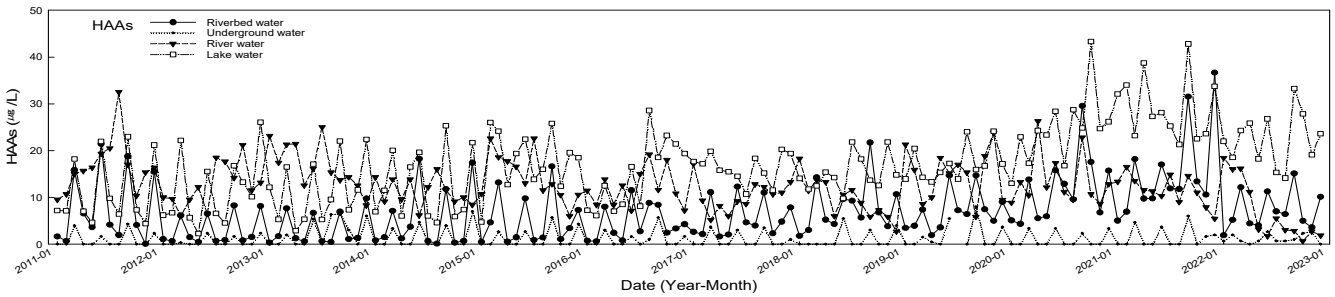


Figure 3. Average monthly concentration of HAAs

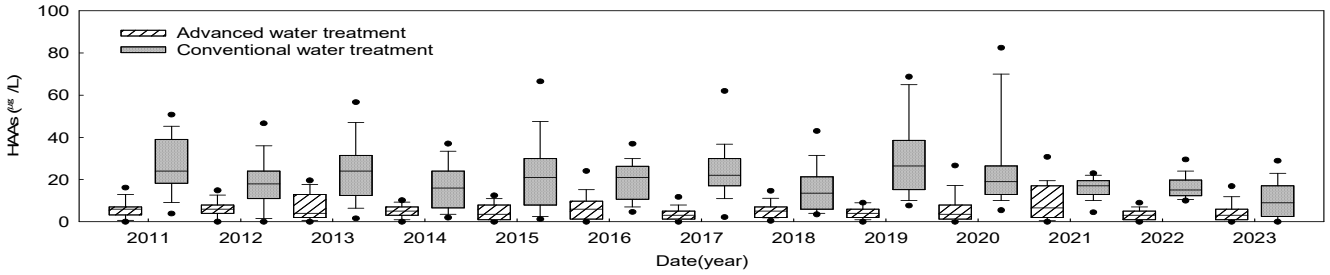


Figure 3. Concentration of HAAs in advanced and conventional water treatment

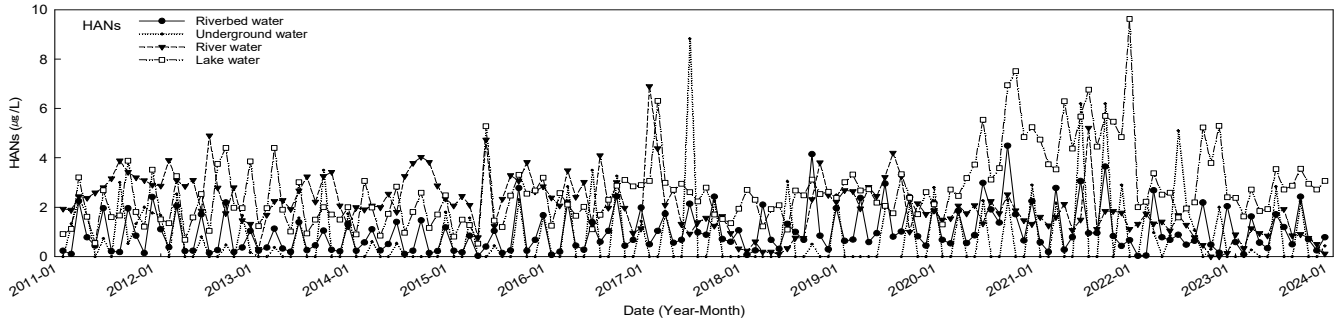


Figure 5. Average monthly concentration of HANs

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the water treatment plant using appealing water, and it has been steadily high in 2022. Both HAAs and HANs began to show high concentrations around the same time, and more thorough monitoring and water treatment are expected to be required. Additionally, It does not look likely to see a correlation between temperature and concentration of HANs.

IV. CONCLUSIONS

The following results were obtained by analyzing the status of the occurrence of DBPs at the water treatment plants in Daegu and Gyeongsangbuk-do for 13 years from 2011 to 2023.

As a result of comparing the monthly average data for 11 years by head of water, THMs, HAAs, and HANs surveyed all showed higher in lake and river water than groundwater and double stream water, and higher water was found than groundwater. In addition, THMs showed relatively high concentrations in summer, and HAAs and HANs showed no seasonal variation.

In the case of THMs, the coefficient of correlation with temperature was 0.67, and there was a positive correlation between the occurrence of THMs and temperature, but in the case of HAAs and HANs, there was no correlation with temperature.

All kinds of disinfection by-products occurred at lower concentrations in water treatment plants that introduced using treatment processes than conventional water treatment plants. It was confirmed that THMs differed by 1.15 times on average, and HAAs and HANs differed by 3.5 to 4.0 times on average.

For effective and stable water treatment and DBP management, the introduction of advanced water processes at the water treatment plants needs to be considered. In addition, maintaining residual chlorine concentration considering seasonal effects can prevent DBPs caused by excessive chlorine and tap water contamination due to lack of chlorine concentration.

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