Research article

Improving Water Quality of a University-Managed Biotope

MADOKA KUROTAKI
Graduate School of Agro-Enviromental Science, Tokyo University of Agriculture, Japan
Email:12521002@nodai.ac.jp

MACHITO MIHARA*
Faculty of Regional Enviroment Science, Tokyo University of Agriculture, Japan
Email:m-mihara@nodai.ac.jp

Received 16 January 2022 Accepted 2 May 2022 (*Corresponding Author)

Abstract "Biotope" was coined in Germany by combining the ancient Greek word "Bios", which refers to organisms and life, and "Topos", which refers to a place. In Germany, biotopes have been attracting attention since the 1970s, when environmental problems caused by industrialization became more serious. Since the end of the 20th century, biotopes have been created in various parts of Japan, including tidal flats, wetlands, lakes, rivers, and other water bodies, as well as forests and grasslands. It is still offered as an educational opportunity in Japan. They are prone to water pollution and need to be improved because biotopes are closed environmental water bodies. In Japan, there is no set environmental level for the water quality of biotopes. In this study, we conducted water quality measurement and purification experiments in the biotope in the campus at Tokyo University of Agriculture, Japan. This study aims to evaluate total nitrogen in a biotope. The biotope at Tokyo University of Agriculture had not been managed regularly for a long time. First, the filtration system installed in the biotope was not working, so it was fixed. For measuring water quality, water samples of the biotope at Tokyo University of Agriculture were collected twice a week in a month. And the concentrations of total nitrogen (TN) were measured by a spectrophotometer. In the biotope at Tokyo University of Agriculture, total nitrogen ranged from 1.14 to 3.76 mg/L, which is high compared to the environmental level set by the Ministry of the Environment for lakes and marshes in Japan. Through a set of field observation, this study attempted to improve the water quality the biotope at Tokyo University of Agriculture, which has been unmanaged for more than long years. Water quality measurement and purification experiment revealed that total nitrogen was improved.

Keywords biotope, water quality, filtration system, total nitrogen

INTRODUCTION

Water pollution is one of the most important environmental problems that have a wide range of effects such as the reduction of fishery resources, as well as the formation of ecosystems. Water pollution can be divided into two major categories: first, water pollution caused by toxic substances and pathogens that threaten human health. The first is water pollution caused by toxic substances and pathogens that threaten human health, such as heavy metals, cyanide, and contagious pathogens such as dysentery and cholera. Secondly, water pollution caused by excrement and organic matter discharged by people's daily activities. In addition, eutrophication caused by the runoff of phosphorus and nitrogen contained in pesticides and fossil fuels in closed environmental water bodies such as lakes and marshes result in massive algae blooms that affect many aquatic organisms and cause significant economic losses to fisheries and other human production activities.

Japan has been taking proactive measures to deal with the water quality environment since the period of high economic growth in the 1970s. As a result, the non-achievement rate of environmental standards for substances that affect the human body such as heavy metals, cyanide, organic compounds, and pesticides (health items) in public water bodies is 0.79%, which can be said to be almost achieved.

On the other hand, however, the rate of achievement of environmental standards for living environment items such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD) has not been sufficiently achieved. The percentage of pollution load including domestic wastewater, waste, livestock wastewater, and small-scale business wastewater generated from people's production activities is still high.

Since the late 1960s, organic pollution in rivers has been improving, but the status of achievement of environmental standards for phosphorus and nitrogen in lakes and marshes remains low at around 50%, although there have been signs of improvement in recent years.

As for chemical oxygen demand (COD), one of the representative indicators of organic pollution, the rate of achievement of environmental standards in lakes and marshes in FY2039 was 50.0%, a decrease of 4.3 percentage points from the previous year. Looking at the trends since 1979, COD was almost flat in the upper half of the 3 mg/L range before 2002, but has been in the upper half of the 3 mg/L range since 2003, and was 3.3 mg/L in the first year of 2003.

As for total nitrogen and total phosphorus in lakes, the achievement rate of the environmental standard was 49.2%. This is an increase of 0.4 percentage points from the previous year. The achievement rate for total nitrogen was 21.4%, while the achievement rate for total phosphorus was 50.8%.

The environmental standard attainment rate of 50.0% for lakes is still low compared to rivers and seas. It is said that the achievement rate of closed environmental water bodies is lower than that of other water bodies due to the fact that closed environmental water bodies have a large pollution load that flows in and accumulates easily. It can be said that measures to deal with nitrogen and phosphorus in domestic wastewater, which contribute to this, are a major issue. In particular, lakes and dammed lakes are often the source of water for water supply, and this causes problems such as moldy odor, filtration problems caused by blue-green algae, and bad odor.

The main source of pollution in Japan is domestic wastewater from cooking, washing, bathing, and urination. About 60% of the pollution load flowing into closed environmental water bodies comes from domestic wastewater, and the load from domestic miscellaneous wastewater (excluding urine) is particularly large. Domestic wastewater from households, such as cooking, washing, bathing, and urination, is an important source of water pollution in public water bodies.

However, if we look at the sources of pollution in terms of nitrogen and phosphorus rather than BOD, manure accounts for a high percentage of 80% and 60%, respectively. This raises the question of the importance of countermeasures.

On the other hand, measures to deal with the pollution load discharged from a wide range of sources such as farmland and forests are also considered important. It is said that 20% of the total pollution load flowing into lakes and marshes comes from this wide area, but the priority of measures remains low due to the current high pollution load from domestic wastewater.

When we took water samples from the biotope on the university campus and measured them in a class, they did not meet the total nitrogen and total phosphorus standards of the “Environmental Standards for the Conservation of the Living Environment for Lakes and Marshes” (Ministry of the Environment). We were also interested in the water quality of closed environmental water bodies such as lakes and marshes, so we chose a biotope, which can be considered a closed environmental water body, as my target site.

The term "biotope" was coined in Germany by combining the ancient Greek words “Bios” meaning organism or life and "Topos" meaning place. In Germany, biotopes have been attracting attention since the 1970s, when environmental problems caused by industrialization became more serious. In Japan, too, biotopes have been created in various places since the end of the 20th century, including water bodies such as tidal flats, wetlands, lakes, and rivers, as well as forests and grasslands. Since biotopes are closed environmental water bodies, they are prone to water pollution and need to be improved.

OBJECTIVE

Our biotope itself was artificially created. However, because it had been neglected for many years, the surrounding vegetation had become overgrown and desolate. The filtration system itself had deteriorated and was not functioning as it should, with pumps and other equipment failing. In addition, with the construction of the surrounding facilities, the biotope itself was reduced in size, and the flow of water that should have been there was lost, resulting in the current situation

This study aims to evaluate total nitrogen of this biotope, compare it to the environmental standard and examine the filtration capacity of the filter.

METHODOLOGY

The biotope in the campus of Tokyo University of Agriculture is divided into two main areas: the Chitose Gate side is called the back and the Ichigokan side is called the front in this study.

The back of the biotope and the front of the biotope are connected by a siphon to keep the water level constant. The water supply at the back of the biotope brings in new water. In addition, a fully automatic upward-flow rapid filtration machine is installed near the back of the biotope. It operates from 8:00 a.m. to 8:00 p.m. and absorbs sludge from the back of the biotope and drains the filtered water to the back of the biotope.

Since the biotope itself had been neglected for many years and we could not even recognize its original shape, we decided to clean and repair it. We collected fallen leaves floating on the surface of the biotope and cut down the surrounding trees.

It was repaired the deteriorated fully automatic upward-flow rapid filtration system. It was repaired the malfunctioning pump, cleaned the siphon, cleaned the water intake and drainage pipes, loaded filter media, replaced the filter, and installed a filter on the water intake pipe. The work was carried out over October 16, October 26, October 30, and November 9. The normal operation of the pump was confirmed on November 9.

Water samples were taken periodically for about a month at the biotope on the campus of Tokyo University of Agriculture, the target site. Starting on October 27, water samples were taken in the morning of October 30, November 3, November 6, November 10, November 13, November 17, November 20, and November 24, and measurements were taken in the afternoon.

The water samples were placed in containers marked with the date of collection and stored in a refrigerator. The total nitrogen concentration was measured by absorption spectrophotometry using the HC-1000 eutrophotometer. The dilution ratio for total nitrogen concentration measurement was 5 times. In the alkaline potassium peroxodisulfate decomposition and UV absorption method used here, sodium hydroxide and potassium peroxodisulfate are added to the sample water, and the water is autoclaved (132℃, 30 min) to oxidize and decompose all nitrogen compounds and replace them with nitrate ions. Then, the absorbance at the wavelength targeted for nitrate ions is measured and determined as the total nitrogen concentration. For the total nitrogen concentration, the following Equation (1) was used to correct the reading value.

$$\text{Total nitrogen concentration (mg/L)} = \text{reading} \times \text{dilution factor} \times 1.2 \tag{1}$$

RESULTS AND DISCUSSION

After repairing the biotope by collecting fallen leaves on the surface of the water and cutting down the surrounding trees, the water area of the biotope became clearly wider than before. Since the biotope had been neglected for many years, it was confirmed that sludge had accumulated in the biotope itself and metals had been dissolved.

In addition, shellfish and goldfish were found living in the water of the biotope. Since the biotope was artificially created, it is unlikely that shellfish and goldfish came from nature to live there. Therefore, we think it is more likely that they were introduced artificially to improve water quality. We also saw other aquatic plants that had been planted on the tires. The plastic covers that covered the pipes were also observed in the water.

Total nitrogen showed a decreasing trend after the collection of fallen leaves on the 30th of October. This is thought to be because the fallen leaves that were floating on the water surface were collected and did not accumulate on the bottom of the water without decomposing in the water. As was confirmed during the cleanup, the bottom of the biotope was filled with a sludge-like substance where fallen leaves had sunk and decomposed. We believe that these had a lot to do with the water quality of the biotope and also affected the total nitrogen value. The values were on the increase after the collection of fallen leaves once on October 30. Since it is impossible to completely remove trees and leaves, we think that fallen leaves accumulated on the water surface again, sinking and turning into sludge, which affected the values.

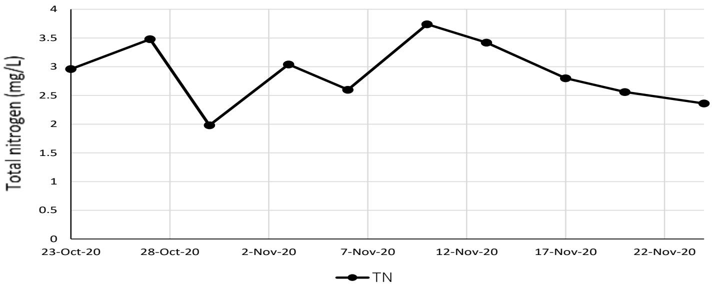

Fig. 1 Changes in total nitrogen concentration at Biotope back (Chitose Gate side)

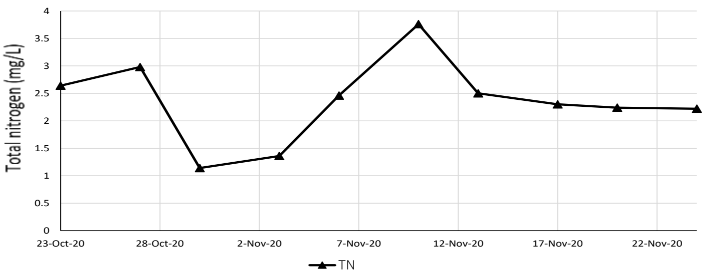

Fig. 2 Changes in total nitrogen concentration at Biotope front (Ichigokan side)

On the other hand, the values have been on a downward trend since November 9, when the pump was confirmed to be in operation. This is thought to be due to the fact that the fully-automatic upward-flow rapid filtration system works by filtering out mud and pollutants from the water, which lowers the value of total nitrogen.

The total nitrogen obtained in this study was compared with the "Environmental Standard for the Conservation of Living Environment (Lakes and Marshes)" of the Ministry of the Environment. The total nitrogen was less than 1 mg/L, which means that the item type is classified as V. In other words, it can be said that the adaptability of the purpose of use lies in industrial and agricultural water use.

However, the total nitrogen obtained in this study was very high, ranging from 2.0 to 3.0 mg/L, compared to the standard of 1 mg/L or less. We think that humus and decomposing matter are the possible causes of the high total nitrogen value in the biotope. The fact that the collection of fallen leaves on the surface of the water and the cutting down of trees had a great effect on the decrease of the total nitrogen value, and the fact that rotten fallen leaves were accumulated on the bottom of the biotope, led us to the above conclusion.

We heard that many people had dealt with the water quality improvement of biotopes as a theme for their graduation thesis or research in the past. Because of this, there were many shellfish, plants, and other things left in the biotope that would have been used for research in the past. In addition, the biotope has been reduced in size due to the construction of neighboring facilities, and the water flow that should have been there has been lost, which may have affected the water quality. In fact, by cleaning the biotope and adding new water, the water area has become much wider than before the repair.

CONCLUSION

Seeing the state of the biotope, which had been neglected to the point of changing its shape, we strongly considered the importance of maintenance and management. In this study, the fully automatic upward-flow rapid filtration machine, which had been repaired and was now working properly, can be said to have fully fulfilled its purification function and contributed to the improvement of water quality. The filter media, which is considered a consumable item, had not been replaced, and the filtration was not working because it had not been inspected or repaired. wen the future, it will be important to check and replace the filter media on a regular basis.

In this study, we thought that the total nitrogen value decreased by collecting fallen leaves. In order to prevent leaves from falling in the future, it would be a good idea to install a net. However, it is necessary to manualize and periodically repair the system, since it could be left for a long time and deteriorate, causing water pollution.

Also, it was considered that such measures for the maintenance and management of the biotope should have already been incorporated into the plan when it was artificially created. If the quality of water and the environment of the biotope is the first priority, it is necessary to clean and repair the biotope on a regular basis as we did in this study. If it is difficult to do so, we have to consider the possibility of removing them.

ACKNOWLEDGEMENTS

We would like to express my sincere gratitude to Associate Professor Toru NAKAJIMA for his guidance from the conception of the research to the experimental methods and writing of the paper, despite their busy schedules.

We would also like to express my deepest gratitude to Professor Atsushi TAJIMA and his team of the Biorobotics Laboratory for their cooperation in repairing the biotope and filter.

REFERENCES

Chiba Prefecture 2020. Results of public water testing. Chiba Prefecture, Japan, Retrieved from http://www.pref.chiba.lg.jp/suiho/kasentou/koukyouyousui/data/documents/r1_07_lake.pdf

Ministry of Land, Infrastructure, Transport and Tourism 2008. Measures to conserve and improve lake water quality. Ministry of Land, Infrastructure, Transport and Tourism, Japan, Retrieved from https://www.mlit.go.jp/river/shishin_guideline/kankyo/kankyou/kosyo/tec/pdf/5.pdf

Ministry of the Environment 2009. Current status of the water environment. Ministry of the Environment, Japan, Retrieved from https://www.env.go.jp/water/confs/fpwq/01/mat03_1.pdf

Ministry of the Environment 2010. Administrative response to eutrophication control. Ministry of the Environment, Japan, Retrieved from https://www.env.go.jp/earth/coop/coop/document/mle2_j/009.pdf

Ministry of the Environment 2011. Environmental standards for water pollution. Ministry of the Environment, Japan, Retrieved from https://www.env.go.jp/hourei/add/e018.pdf

Ministry of the Environment 2019. Public water quality measurement results for 2019. Ministry of the Environment, Japan, Retrieved from https://www.env.go.jp/water/suiiki/r1/r1-3.pdf

Ministry of the Environment 2020. Public water quality measurement results for 2019. Ministry of the Environment, Japan, Retrieved from https://www.env.go.jp/water/suiiki/r1/r1-1_r.pdf

Ministry of the Environment 2020. Environmental standards, items requiring monitoring, and guideline values for water pollution. Ministry of the Environment, Japan, Retrieved from https://www.env.go.jp/water/suiiki/r1/r1-2.pdf, received date 2021-01

Ministry of the Environment 2022. Environmental standards for water pollution. Ministry of the Environment, Japan, Retrieved from https://www.env.go.jp/kijun/wt2-1-2.html

Ministry of the Environment 2022. Appendix of environmental standards for water pollution. Ministry of the Environment, Japan, Retrieved from https://www.env.go.jp/kijun/mizu.html