MACRO-ZOOPLANKTON ABUNDANCE IN RELATION TO METAL ACCUMULATION AND WATER QUALITY IN TRUC BACH LAKE

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Abstract. Urban lake pollution is one of the serious issues due to suffering of waste discharged from householders. However, there is a gap of knowledge about the diversity of zooplankton species and how metals accumulate in zooplankton in urban ecosystems. We addressed this by determining the rule of blooming macro-zooplankton in the Truc Bach lake and levels of two essential metals: copper (Cu), and zinc (Zn) and of three non-essential metals: arsenic (As), and lead (Pb) in water samples were determined. The results showed that cladocerans and copepods are macro-zooplankton dominant species in the Truc Bach lake. Water temperature significantly affects the variety of copepod blooming. Arsenic concentration in water collected from the lake exceeded the safety level of current Vietnamese technical regulation (QCVN 08-MT:2015/BTNMT). Arsenic concentration in macro-zooplankton positively correlated with metal concentrations in the water (p < 0.05) while the concentration of Cu, Zn, and Pb in water has no significant correlation with the metal in zooplankton’s body. The relative abundance of adult copepods in the Truc Bach lake had a negative correlation with As concentration in water (p = 0.01). The higher As concentration in water, the lower relative abundance of copepods was found in the sample.

Keywords: metal bioaccumulation, macro-zooplankton abundance, urban lakes.

Classification numbers: 3.1.2, 3.4.2, 3.6.1.

1. INTRODUCTION

Zooplankton plays an important role in transferring energy from primary producers to the higher trophic levels in the aquatic ecosystem. Zooplankton and phytoplankton form the base of...
the food chain in the aquatic environment. The structure of the zooplankton community and its abundance can be affected by physical, chemical and biological factors. In general, factors such as temperature, eutrophication, nutrient concentrations and electrical conductivity can change the species composition and abundance of zooplankton species [1]. Thus, zooplankton has been used as an indicator of lake trophic state [2]. Metals are the common contaminants in the urban lakes in Hanoi resulting from discharging effluents from households and public services, industrial and construction activities. It is well-known that zooplankton is sensitive to the dissolved metals in the aquatic environment and have the ability to accumulate metals from the environment, they have been identified as a good bio-indicator of water quality to assess metal contamination [3]. In recent years, as a consequence of an increasing the crisis in the environment due to climate change and pollution from urbanization, lake ecosystems in Hanoi are becoming less diversity and pollution. Understanding the relationship between species composition of zooplankton and water characteristics of urban lakes is crucial to develop the solutions to control the pollution in lakes. Previous studies have focused mainly on eutrophication in urban lakes in Hanoi [4]. There is a lack of knowledge on metal pollution and its influence on the zooplankton composition of urban lakes in Hanoi. This study was carried out in the Truc Bach lake, a typical small urban and eutrophicated lake in Ha Noi from September 2017 to January 2019. The objective of this study was to determine the current pollution status of the Truc Bach lake concerning understand factors affecting the variation of zooplankton species composition and metal accumulation in those species.

2. MATERIALS AND METHODS

2.1. Water sampling and analysis

Twenty-four surface water samples for nutrient and phytoplankton analyses was collected from September 2017 to January 2019. Weather conditions including temperature, raining status, sunny etc., was exposed differently during the sapling period. The temperature was recorded in the Table 1. The sampling procedure and analysis followed the ISO 17025 standard. The sampling procedure followed the TCVN 5994:1995 (ISO 5667-4:1987) – Water quality – Sampling: Guidance on sampling in natural and artificial lakes. Field measurements included the depth (m, ultrasonic device), water temperature (°C), pH (pH Meter DREL/2010), dissolved oxygen (mg/l, the percentage of saturated oxygen %) (WTW Oxy 330), conductivity (WTW 249 electrode). Chemical analysis was performed for COD (SMWW 5220C/D, ISO 6060:1989), BOD₅ (SMWW 5210B, ISO 10707:1994), Kjeldahl nitrogen (4500-Norg C, ISO 5663:1984), total P (4500-P E), Chl-a (SMWW 10200 H) and metal (As, Pb, Cu and Zn) (ICP-MS, ELEMENT, Finnigan MAT, EPA 2008)

2.2. Macro zooplankton collection

54 zooplankton samples and water sample were carried out in the Truc Bach lake from January 2018 to January 2019. The macro-zooplankton samples were collected randomly two times per month. At each location, the sample was collected at the surface layer, about 0.5 m below the water surface. The sample was preservative by HNO₃ and transferred to the laboratory. Samples were filtered through the macrozooplankton sieve (200 µm) to obtain the macrozooplankton. At the same time, zooplankton was also collected through cone net (200 µm) for analyzing metal accumulation in macro zooplankton biomass. The macro zooplankton samples were then preserved in 4 % formalin and transfer to the laboratory in about one hour. In
the laboratory, 50 ml of each sample was brought in a 100 ml flat bottom glass flask. The sample was stirred in a zigzag motion, a 1 ml sub-sample was then transferred into a 1-ml Sedgwick Rafter Counting Chamber to determine the species composition and density of macrozooplankton. All the zooplankton in the counting chamber was observed and identified using standard keys [5] and counted using an inverted microscope (Nikon, Japan, model: TMS-F) with high power (×40). The densities of cladocerans and copepods and the relative abundance between study groups were then computed to identify average zooplankton density in three sub-samples.

2.3. Metal accumulation analysis

Zooplankton used for study metal accumulation were sorted and placed in a nylon sieve thoroughly with distilled water to prevent metal contamination in samples. After cleaning macrozooplankton was treated by acid HNO₃ 5 %, then was dried in at 80 °C and was weighted. The samples were digested for analyzed with HNO₃ (65 %, Merck) heated at 100 °C for 4-8 hours. These digestes were measured by ICP MS (ICP-MS, ELEMENT, Finnigan MAT, EPA 2008.). Bioaccumulation factors (BAF) were calculated for each metal to evaluate the degree of enrichment and bioaccumulation in biomass of zooplankton (mean metal concentrations for each sample (fresh biomass µg/g)/ (mean metal concentration in water in µg/l). In this research, dried biomass samples were converted into fresh biomass samples by multiple with 0.70 following the suggestion of Chen, C. Y. [6].

3. RESULTS AND DISCUSSIONS

3.1. Water quality in Truc Bach lake

Water temperature strongly influences the chemical processes and biological reaction in the body of aquatic organisms such as growth, reproduction, and even mortality under temperature extremes. Since the temperature can affect the toxicity of chemicals, including metals, to aquatic organisms, the wide variation of ambient temperature would affect the reproductive rate, population size and metabolism of many species, for example, cladocerans and copepods [7]. Table 1 showed wide range of temperature during in sampling period in the Truc Bach lake. This temperature variation would effect to aquatic life in the Truc Bach lake. pH in the Truc Bach lake was deviated from neutral to base, from 7.7 - 8.5. Aquatic organizations would get troubles when living in permanently alkaline environments [8]. Many factors would affect the change in pH of the Truc Bach lake water and the most important factor was likely the broken H⁺ balance in water due to the up taking bicarbonate during the development of the algae. This speculation was corroborated by blooming algae in lake. Anthropogenic activities including discharging untreated domestic wastewater would also affect the pH of the lake. The data on nutrients and chlorophyll-a revealed the Truc Bach lake as the eutrophic lake that is in agreement with a previous study of Hong et al. [9]. The blooming of algae would significantly change water characteristics e.g. high pH and aquatic life. Dissolved oxygen (DO) is an essential element for aquatic life. DO in the Truc Bach lake varied widely from 4.06 to 11.24 (mg/l). Low oxygen (DO < 4 mg/l) normally caused by the high level of organic substances together with the respiration of organisms during the night while there was no photosynthesis. High DO during the day was probably the result of the eutrophication. Phosphorus is the key factor for changes in the biodiversity and trophic structure of the lake. Species richness was related to the concentration of phosphorus in water [10].

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Table 1. Variation of water quality on the Truc Bach lake.

| Parameter                | Min  | Max  | Mean  | QCVN 38:2011 BTNMT |
|--------------------------|------|------|-------|-------------------|
| Temperature (°C)         | 16   | 30.8 | 25.5  | -                 |
| pH                      | 7.4  | 8.5  | 7.95  | 6.5 - 8.5         |
| DO (mg/l)                | 4.06 | 11.24| 7.47  | > 4               |
| P total (mg/l)           | 0.44 | 1.56 | 0.65  | -                 |
| N total (mg/l)           | 24   | 37.35| 23.52 | -                 |
| Chlorophyll-a (mg/m³)   | 121  | 1701 | 538.65| -                 |
| Hardness (mg CaCO₃/l)   | 200  | 260  | 206   | -                 |
| As (µg/l)                | 3    | 27.74| 15.39 | 20               |
| Pb (µg/l)                | N/D  | 8.67 | 3.06  | 20               |
| Cu (µg/l)                | 0.5  | 610  | 124.18| 200              |
| Zn (µg/l)                | 20.56| 310  | 87.18 | -                |

Metal concentration in the Truc Bach lake water originated from many sources such as rock bed, anthropogenic activities (craft works and domestic wastewater), and sediments. Arsenic may result from the use of gallium arsenide and arsine gas in semiconductor devices from transportation activities or manufacturing [11]. Table 1 showed arsenic concentration in the Truc Bach lake was from 3 to 27.74 µg/l. The concentration of arsenic from January to May 2019 was higher than at the end of the year. In some period of the year, the arsenic concentration in the water exceeded the safety level of current Vietnamese technical regulation QCVN 08-MT:2015 BTNMT column A for surface water bodies (20 ppb). Toxicity of As depends largely on the valence state, solubility, and rate of absorption and elimination. An organic form of arsenic such as arsenobetaine and arsenocholine occurring with seafood is less harmful more than inorganic form [11]. The concentration of Pb in water from undetected concentration (LOD < 0.1 µ/l) to 8.67 ppb which is lower than the allowable concentration of the QCVN 08-MT:2015 BTNMT column A (20 ppb). Lead in the lake normally comes from the use of leaded gasoline and lead-based paint has resulted in the airborne lead, contaminated wastewater leaded dust. Although lead concentration in the Truc Bach lake was low, it is considered as the high metal risk to the aquatic ecosystem due to its highly accumulated in aquatic organizations. Zinc (Zn) and copper (Cu) were present in the Truc Bach lake quite low. Degree of variation of Zn and Cu varied greatly 20.56 - 310 µg/l and from 0.5 - 610 mg/l, respectively, depending on water quality characteristics as well as species being considered [12].

3.2. Zooplankton abundance

Table 2 illustrated the dry zooplankton biomass varied greatly during the studying period from 2.7 to 24.9 mg/g which was much less than the variability of this biomass collected from natural lake Bajo de Giuliani, (3.37 - 8.37 g/g) and in Don Tomás lake, Argentina (3.75 - 4.61 mg/g) [13]. The dry zooplankton biomass collected in Truc Bach lake was also less than the dry mass values collected at the coastal station in Corrientes, Argentina, 11.8 - 54.5 mg m⁻³ [14].
Macro-zooplankton abundance in relation to metal accumulation and water quality in Truc Bach lake

Table 2. Zooplankton abundance and biomass collected in the Truc Bach lake.

| Parameter                        | Min  | Max  | Mean |
|----------------------------------|------|------|------|
| Biomass (mg·dry/l)               | 3.7  | 26.0 | 12.27|
| Zooplankton density (individuals/l) | 40   | 284  | 120  |
| Density of Copepoda (individuals/l) | 40   | 270  | 67   |
| Density of Cladocera (individuals/l) | 20   | 130  | 53   |
| Density of Rotifera (individuals/l)  | 4    | 20   | 8    |

During the study period, great variability in zooplankton abundance was recorded in Figure 1. The range varied between 45 individual/L and 278 individual/L. Zooplankton density collected in the Truc Bach lake was lower than the density of macrozooplankton in the West lake (average 788 individual/l) where shares the same effluent with Truc Bach lake [15]. The West Lake, which is ten times larger than the Truc Bach lake, would have better stable environmental condition. A large area with a diversity of aquatic ecosystem helps protect West Lake from untreated wastewater effluents better than the Truc Bach lake. The Truc Bach lake had the highest abundance of zooplankton species in the spring, especially when the water temperature was 20 – 22 °C (January). The density of zooplankton during this period reached 278 individual/m³. Many factors would affect the change in abundance of macro zooplankton and species composition of macrozooplankton in samples. One of the important factors is water temperature. Our finding showed that when the water temperature was lower than 20 °C, the Copepoda was the dominant group. Cladocera preferred to live in warmer water (22 – 28 °C). The result indicated that temperature remarkably correlates with the biomass collected from the field (p = 0.001. According to El-Bassat, R. A. (2008), chlorophyll-a in water would be very important factor effect on the copepod abundance in water [15]. However, our finding could not find the relationship between chlorophyll-a and copepod density. Possibly, the density of chlorophyll-a is always higher than the maximal grazing of copepods, therefore no effect of food limitation could be observed for copepod species in the lake.

The data showed there was no relationship between the metal concentration of Cu, Zn, and Pb in water and the blooming of macrozooplankton in the Truc Bach lake. This was possible since the fact that the concentration of metal in the water was low and might not be strong enough effect on the development of macrozooplankton. This speculation was supported by the fact that the Cu (124.18 ug/l), Zn (20.56 µg/l) and Pb (3.06 µg/l) were 4, 10, 10 times lower than the LC50 for copepods, cladocerans and rotifers, respectively. However, metals can be uptaken and accumulated in zooplankton’s body not only from water but also from food and suspended solid maters. Our data showed that although the concentration of As in water is higher than the limitation level of the QCVN 38:2011/BTNMT (Viet Nam technical regulation for aquatic life protection), it did not significantly affect the density of cladocerans (p = 0.19). However, the As concentration in water strongly positively correlated with density of mature copepods (p = 0.01). This result indicated that the growth of copepods was negatively affected by As in water. Previous studies found that the concentration of phosphorus and nitrogen in water would affect significantly to the blooming of the cladocerans [16]. However, due to the limitation of data, we could not find the correlation between phosphorus concentration in water and the density of cladocerans in this study.
Figure 1. Zooplankton abundance and biomass collected in the Truc Bach lake.

3.3. Metal accumulation in macro zooplankton

The concentrations of As, Pb, Cu, and Zn in the zooplankton greatly changed along the sampling period. Probably, the accumulation of these elements in the zooplankton of the Truc Bach lake depended on the biogeochemical environmental conditions and the species composition of the community. Among metal, Zn had the highest accumulation factor in macrozooplankton (BAF = 258.57) shown in Table 3. The reason for this is because Zn is an essential element for aquatic organisms. Zn plays an important role in metabolism activities and enzyme.

Table 3. Metal accumulation in macro zooplankton in the Truc Bach lake.

| Elements | Minimum concentration (ug/g) | Maximum concentration (ug/g) | BAF (mg/g dried biomass) (Minimum) | BAF (mg/g dried biomass) (Maximum) |
|----------|-----------------------------|-----------------------------|-------------------------------------|-------------------------------------|
| As (ug/g)| 5.14                        | 65.80                       | 0.71                                | 4.09                                |
| Pb (ug/g)| 9.41                        | 95.00                       | 4.06                                | 81.84                               |
| Cu (ug/g)| 0.88                        | 270.00                      | 2.59                                | 34.12                               |
| Zn (ug/g)| 8.06                        | 720.00                      | 5.67                                | 258.57                              |

Noticeably, the BAF of non-essential metal like Pb was higher than the BAF of Cu which is essential metal for the zooplankton development. Although the concentration of Pb in the water was low, this metal still was up taken highly in the body of macrozooplankton. This result indicated that Pb was taken from their food more than from the water. The data also indicated that there was a significant positive correlation between temperature and the concentration in Pb
accumulated in macrozooplankton (p = 0.005). The higher the water temperature increased, the more Pb was up taken into the body of macrozooplankton. This finding is in agreement with the conclusion of Rainbow [17] that metals may strongly affect their uptake and toxicity in aquatic organisms. Another reason is that environmental temperature can affect the bioavailability of metals due to the higher solubility, and thus higher concentrations of free metal ions can be up taken in the zooplankton body. However, our research could not find a correlation between temperature and concentration of Cu, Zn and As accumulated in zooplankton (p = 0.182, 0.6, 0.28, respectively). The data showed the As concentration in water strongly correlated to the As concentration accumulated in the body of macrozooplankton. This result indicated that the source of As in the body of macrozooplankton might come mostly from the water. For other metals like Pb, Cu, and Zn, there were no significant correlations between metal concentration in water and in the body of zooplankton. Zooplankton groups mostly feed on phytoplankton which may contribute to the transfer of Pb, Cu, and Zn from phytoplankton to higher trophic levels like zooplankton.

4. CONCLUSIONS

The study analyzed the abundance of macrozooplankton and measured the metals in water samples and the metal concentration in zooplankton living in the Truc Bac lake in Viet Nam. As expected, the abundance and density of macrozooplankton in the Truc Bach lake were affected by multiple factors including temperature, metal concentration in water, characteristics. There was a significant correlation between temperature (p < 0.0001) and As concentration (p = 0.01) in water and the density of zooplankton. Regarding the metal accumulation in macrozooplankton, the Pb and Zn were highly accumulated in the body of macrozooplankton while the accumulation of As was low. The As accumulation in zooplankton mostly came from water since there was a strong correlation between As in water and As in macrozooplankton. Understanding about the relationship between biodiversity, environmental variability, and anthropogenic contamination, would help to predict the change of ecosystem structure and function under the changing environment. Therefore, it is necessary to have more comprehensive and long-term studies investigating in abundance and metal accumulation in aquatic species in urban lakes to have better lake management.

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