Cadmium distribution in water, microalgae biomass, and sediment of River Bonan Dolok, Samosir-North Sumatra, Indonesia

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Abstract. River Bonan Dolok in Samosir is located on the watershed of Lake Toba, an ancient volcanic lake in North Sumatra. Some parts of this river bordered with paddy fields, a common source of cadmium through the leaching process, which then released into the water body. Meanwhile, this river has been proposed as endemic fish (called in the local name as Ihan) conservation area and eco-tourism area. Therefore a scientific reference base management concept is needed. Spatial distribution of cadmium (Cd) must be revealed since this metal is very toxic and can be easily transferred and accumulated in the aquatic food chain. This study aims to inform the distribution of Cd in water, microalgae biomass and sediment. All samples were taken compositely from the upper stream (Station 1), Station 2, Station 3, and lower stream (Station 4) in April 2019. The structure of microalgae community is also identified. The results show that Chlorophyte (mostly consisted of Microspora sp) biomass at Station 2, has the highest Cd concentration (0.57 µgCd/g dry weight). While Cyanophyte (dominated by Microcystis aeruginosa) even observed bloomed at station 4, shows a lower Cd concentration (0.12µgCd/g dry weight). The distribution of Cd in water and sediment (particle size of ≤63 µm) at those sampling stations as well as some water quality also discussed. The range of Cd concentration in water was 0.02 to 0.64 µg Cd/L, while that in sediment was 0.10 to 0.39 µgCd/g dry weight. These data are expected to be used as essential references for developing the management concept of Bonan Dolok ecotourism area in the future.

Keywords: cadmium, microalgae, River Bonan Dolok-Samosir-North Sumatra

1. Introduction
River Bonan Dolok-Samosir lies between the latitude of 2° 30’ - 2° 45’ N and longitude 98° 30’ to 98° 45’E in North Sumatra Province of Indonesia. The river is directly bordered with Lake Toba, which is a gigantic ancient crater lake and the largest lake in Indonesia. This river has an average width and depth of 9 m and 0.4 m, which flows continuously (discharge of 0.7 m³/s) into the lake. A gorgeous waterfall, namely Sitapigagan locates on the upper stream of the river [1, 2]. A natural arboreal zone
covers 66.2% of the river sub-catchment area (mainly at the upper stream), while the grassland and paddy field covers 32% and 1.1%, respectively. This situation exceeds the national regulation No.104/2015 which stated that the minimum arboreal for assigned a conservation area is about 30%.

Moreover, vegetation buffer (10-22 m) in River Bonan Dolok is suitable to maintain the temperature of a stream, which is essential for some fish species, including Ihan, an endemic fish that lives in this river. Therefore, River Bonan Dolok is then proposed to be a conservation area dedicated to Ihan [3]. Recently, the local government (Samosir Regency), also declared Bonan Dolok area as one of the tourism destinations, since its scenic panorama not only of the extensive paddy field, forested area but also the Sitapigagan waterfall [4]. These two contradicting functions must be managed in a sustainable way for warranting the prosperity of the next generation.

In consequence, a proper management concept must be developed based on a set of scientific references[5-7]. Those references reveal some fundamental characters of the ecosystem to comprehend River Bonan Dolok. Among others is a reference which related to Cd distribution in water, microalgae biomass and sediment at the River.

Cadmium naturally occurs in rocks as an impurity of sulfides minerals. It is transported globally by a forest fire, volcanic activity, weathering bedrocks, and atmospheric deposition. Global atmospheric emission of Cd through natural processes is estimated at 1300 tons/year. Anthropogenic activities such as domestic waste, transportation, burning of fossil fuels, and fertilizer use in agriculture also contribute to mobilizing Cd in the environment, including of aquatic ecosystem [8-11]. The exceed level of Cd in aquatic environment poses a severe threat to the aquatic biota for its persistence, high toxicity, and bioaccumulation potentials in the food chain. The microalgae community has roles as primary producers in the aquatic ecosystem. They can easily take up Cd from the water compartment (where they live) into their biomass and then transferred it into the upper level of the food chain [12, 13].

Meanwhile, river sediment is not only being the main sink of Cd but also as secondary sources of Cd when river condition changes [14, 15]. Accordingly, a recent record on Cd concentration in water, sediment, and microalgae biomass at every observed sampling station of River Bonan Dolok is needed. This record will be used as an information package to develop scientific references related to River Bonan Dolok.

A report dealing with the influence of domestic waste (originated from inhabitants houses and hotels) to Lake Toba water quality mentioned that the household wastewater is mainly dominated by zinc (Zn), free chlorine and Fluor [16], while Cd concentration in water was 0.00009 mg/L or 0.09µg/L. Meanwhile, in this study, we determined Cd concentration not only in water but also in microalgae biomass and sediment compartments of River Bonan Dolok, including the community structure of microalgae. We explored the distribution of Cd in those three sample matrices at four sampling stations and aimed to provide necessary data for developing sustainable management concept of River Bonan Dolok.

2. Materials and Methods
2.1. Sampling
River Bonan Dolok was observed at four sampling stations (figure 1) on 9-13 April 2019. Station 1 (St 1) or upper stream is located on the upper stream, which is approximately 950 m from the edge of Lake Toba and nearby to waterfall. The riverbed mainly consists of Andesite boulders. It surrounded by the pristine forest, and some part of the riverbank is dominated by densely tall shrubs. A heavy current of water flows among the big scattered boulders. Station 2 (St 2) represented a stream of moderate turbulent flows and distances of 661 m from the edge of Lake Toba. It surrounded by paddy field which only about 4.0 to 5.5 m from both river banks, and few parts also seen a shrubbery cover. Station 3 (St 3) is about 362 m from the edge of Lake Toba. Its watercolor is tea-like dark reddish-brown with calmer stream flows among of gravel and smaller boulders. Its perimeter is about 4 m from a road of 1m wide, paddy field and inhabitant’s houses. It is seen that riverbanks are hardened
with the river stone walls and more open riparian areas. Meanwhile, Station 4 (St 4) or lower stream station is directly bordered with Lake Toba water body. The estuarine width of ±157 m which seen at the bottom consists of sandy gravel (64 – 256 mm). On the eastern part of the riverbank is bordered with an asphalt road, while on the western part is covered by dense bushes of *Mimosa pigra* (a giant sensitive plant). Its watercolor is greenish with a few water hyacinth plants was found [17].

![Sampling Sites](image)

**Figure 1.** Four sampling sites (St 1 to St 4) of River Bonan Dolok [18].

In situ measurement of conductivity, pH, water temperature, and Oxidative Reductive Potential (ORP) were conducted using portable water quality checker Horiba U-10, Japan. Meanwhile, water samples (250 mL) were taken from every site then preserved with nitric acid. A 63µm plankton net size was used to sample microalgae biomass from 10 L of water and concentrated in 25 mL of sample bottle then preserved with two dropwise of Lugol solution. A sediment grab was used to take the sediment sample. All samples were then transported to the laboratory for treatment and analysis.

### 2.2. Sample treatment and measurement

After 5 mL of the concentrated phytoplankton biomass was subsampled for species identification, the remaining biomass sample was then oven-dried at 60°C in a pre-weighed petri-dish for 3 x 24 hours. The dried biomass was then weighed to find the dry weight of the biomass (by subtracted it with empty petri dish weight) followed by dissolved it with 10 mL of demineralized water. Further, this solution was digested using autoclave at 120°C for 45 minutes after adding 5 mL of concentrated nitric acid and 2 mL of 30 % H₂O₂ in a Pyrex digester vessel capped with Teflon liner. After the digestion solution cooled down to room temperature, it was transferred to a 25 mL volumetric flask and diluted to the mark with demineralized water[19]. The total concentration of Cd was tested using a Graphite Furnace Atomic Absorption Spectrophotometer (Hitachi AA-2700, Japan) following to analytical condition as designed by the manufacturer. Digestion of Cd in water and sediment samples (previously, oven-dried sediment samples (60°C for three days) were homogenized through sieving with 63 µm screen) also conducted using a similar method except the adding of 5 mL acid mixtures
solution (HNO\textsubscript{3}-HCl of 3:1). All processed samples were divided into two subsamples for replicate testing before digestion, so it resulted in two tested valued with two replicate samples as the basis for calculations and statistical analysis. The results are presented in the pictorial graphics. The determination of chloride and sulfate was conducted following the standard method of APHA\textsuperscript{[20]}. Identification of the community structure of microalgae biomass was made according to the cited references (\textsuperscript{[21]}; \textsuperscript{[22]}; \textsuperscript{[23]}). While the microalgae abundance counting was conducted by an inverted microscope DIAPHOT 300 (magnification up to 400 times) based on the Lackey drop (micro transect) method using a Sedgewick rafter \textsuperscript{[20]}

2.3. Analytical quality control
For ensuring the accuracy, parallel, and replicate analysis was conducted. Blank samples were used. Laboratory fortified unused solution with known cadmium concentration was used as part of the quality control step. The Relative Standard Deviation (RSD) of replicated samples was less than ten percent, and recovery of a reference sample solution was 97-102 percent.

2.4. Data calculation and statistic
Bio-Accumulation Factor (BAF) was used to calculate partitioning of chemical between water and aquatic organism. It refers to uptake chemicals from surrounding water by an organism, which includes the food \textsuperscript{[24]}. It is formulated in equation (1)

\[ BAF = \frac{Cd_{org}}{Cd_{w}} \quad (1) \]

Meanwhile, fractionation of Cd ion content in sediment to water (\(A_{s-w}\)) was calculated as equation (2)

\[ A_{s-w} = \frac{Cd_{sed}}{Cd_{w}} \quad (2) \]

Where \(Cd_{org}\) and \(Cd_{sed}\) are the concentration of Cd in dried microalgae biomass; \(Cd_{w}\) is the level of Cd in the water environment.

The abundance of microalgae species is calculated using Sedgewick-Rafter Counting (SRC) method which is formulated in equation (3)

\[ N = n \times \frac{V_{c}}{V_{d}} \times \frac{V_{cg}}{V_{t}} \times \frac{O_{t}}{O_{p}} \quad (3) \]

Where \(N\), \(n\), \(V_{d}\), \(V_{c}\), \(V_{cg}\), \(V_{t}\), \(O_{t}\), \(O_{p}\) are abundance (\#/L), counted cell, volume of filtered water sample, volume of Sedgewick-Rafter chamber (mL), volume of filtered water sample (mL), surface area of the SRC cover glass (mm\(^2\)), and observation area (mm\(^2\)).

3. Results and Discussion
3.1. Concentration of Cd in water, sediment, and microalgae biomass in River Bonan Dolok
Figure 2 (a) presents the Cadmium concentration in the water of the River Bonan Dolok. The highest (0.64 µg/L) was found at Station 3 (which was seven times higher from average Cd concentration in Lake Toba water as reported by Indirawati et al. \textsuperscript{[16]}). The lowest level (0.02 µg/L) was found at Station 1 (Upper stream). Cadmium concentration in sediment was gradually increased from the smallest at St 2 (0.10 µg/g dry weight) to the highest at Lower stream (0.39 µg/g dry weight). While in microalgae biomass, Cd concentration found to be highest (0.57 µg/g dry weight) at Station 2 and the lowest at the upper stream (0.01 µg/g dry weight). Meanwhile, at Station 4 Cd concentration in microalgae biomass was 0.12 µg/g dry weight) or only a quarter of Cd concentration observed on the Station 2.

The related three aquatic physio-chemistry parameters were also observed (figure 2b), in which temperature and pH were gradually increased (about 9 °C and 1.5 points) as approached to lower stream. Highest ORP was at Station 3 (+60.90 mV) while the lowest (+45.70 mV) was at the upper stream. The highest Cd concentration in water at Station 3 was consistent with that of ORP value. This indicated that Station 3 received most Cd from various sources not only from natural (e.g., from
weathering rocks) but also from domestic and agricultural wastes. The implementation of phosphate fertilizer usually became a source of cadmium as which is reported by Tao et al. a similar pattern was also observed in Lake Taihu-China [24]. However, the highest Cd concentration in water and sediment at Station 3 was far below Cd concentration in Lake Kolleru-India which about 36 µg/L and 6.3 µg/g dry weight as reported by Adhikari et al.[25]. The highest Cd concentration in microalgal biomass at Station 2 also ten magnitudes lower than of Cd in phytoplankton biomass sampled at River Caoqiao-China (1.34 µg/g dry weight) as reported by Tao et al. [24]. Meanwhile, compared to an urban lake Situ Rawa Kalong-West Java, the highest concentration of Cd in water and microalgae was ten magnitudes lower, as reported by Satya et al. respectively were 0.574 µg/L and 4.79 µg/g dry weight [26]. Therefore, it can be said, overall Cd concentration found in water, sediment, and microalgal biomass of River Bonan Dolok were still below those reported by Tao et al., Satya et al. as well as Adhikari et al. [24-26].

3.2. Community structure of microalgae in River Bonan Dolok

In figure 3, it was seen that the microalgal community in River Bonan Dolok has consisted of three phyla namely Chlorophyte (Green), Bacillariophyte (Diatom) and Cyanophyte (Blue-green). It was found that species counts of Chlorophyte, Bacillariophyte, and Cyanophyte were 19, 13 and 5 species. Chlorophyte was more abundant and more distributed at Upper stream, Station 2 and Station 3 than of two other phyla. Cyanophyte was mostly found abundant at the lower flow up to 96.98 % that consisted of Microcystis aeruginosa (27,638 ind./L) and Spirulina sp. (12 ind./L), while Bacillariophyte tends to be more distributed in Upper stream, Station 2 and Station 3. The highest abundance of Microcystis aeruginosa on that quantity indicated that the Lower stream of River Bonan Dolok has belonged to eutrophic status.

Table 1 presents that the upper stream shows the highest in diversity, while Station 2 and Station 3 were modest. On the contrary, the lower stream station shows the lowest diversity. This fact was confirmed by the species abundance as well as the dominance index, evenness index, and species count. It shows that the highest cell abundance was dominated by Microcystis aeruginosa occurred at the lower stream station. Hence, it can be concluded that the lower stream station was facing eutrophication symptoms (table 1). Even so, the abundant Cyanophyte at Station 4 did not inevitably contain the highest cadmium concentration in the microalgal biomass. This is consistent with the...
previous discussion, which mentioned that the highest cadmium concentration in microalgae was found at Station 2, which was mainly consisted of Microspora sp. of 41.88 % of the total individual/L.

**Figure 3.** Species composition of microalgae community in River Bonan Dolok-North Sumatra.

**Table 1.** Community structure of microalgae in River Bonan Dolok-North Sumatra.

| Nama                      | Location | Upper stream | St 2 | St 3 | Lower stream |
|---------------------------|----------|--------------|------|------|--------------|
| Abundance (Ind./L)        |          | 158          | 88   | 229  | 28,528       |
| Species count             |          | 22           | 19   | 19   | 15           |
| Diversity Index (H')      |          | 3.013        | 2.827| 2.841| 0.277        |
| Evenness Index (E)        |          | 0.412        | 0.438| 0.362| 0.019        |
| Dominance Index (D)       |          | 0.210        | 0.241| 0.230| 0.939        |

Figure 4 describes that Synedra ulna (Bacillariophyta), Staurastrum sexangulare (Chlorophyta), and Spirulina sp. (Cyanophyta) frequently appeared on all observed stations. While Gomphonema sp, Navicula radiosa, Synedra ulna, Microspora sp., Staurastrum sexangulare, Stigeoclonium sp., Oscillatoria tenuis, and Spirulina sp., were always appeared on the upper stream. However, three species of microalgae that found at Station 4 namely Cosmarium contractum, Staurastrum prionotum, and Microcystis aeruginosa. This different pattern may indicate microalgae preferences to particular physicochemical condition, such as pH, nitrogenous-phosphorous compounds, water temperature, etc. as ever reported by Haande et al. [27]
3.3. Bioaccumulation of Cd in microalgae biomass in River Bonan Dolok

The highest Bio-Accumulation Factor (BAF = 2.89) of Cd was found in the microalgae community biomass of River Bonan Dolok. It was observed at Station 2 (figure 5a), where microalgae community mainly consisted of Chlorophyte (81.20 % of abundance) (figure 5b). It was far below BAF Cd observed in Lake Taihu-China and Lake Situ Rawa Kalong which were up to 5,240 and 4,150 [24, 26]. However, BAF value depends on other factors such as Cd concentration in water, absorption properties of microalgae as well as Cd concentration in sediment [12]. BAF is evaluated for knowing the ability of microalgae to accumulate Cd from water. If BAF value is more than 1, it means that microalgae have the potential to accumulate Cd, and it will be considered significant if more than 100 [24, 28]. Therefore, even though Microspora sp (42.6 % of Chlorophyte) at Station 2 has the potential to accumulate Cd, but it has not signed yet as the Cd bioaccumulation. Meanwhile, Cyanophyte has dominated the microalgae community (96.92 % of total abundance) at the lower stream but it did not confirm that its BAF also highest since it was only found about half of the BAF of Chlorophyte.
3.4. Sedimentary fraction of Cd in River Bonan Dolok

The value of Cadmium fraction between sediment and water ($A_{s-w} = 8.63$) was highest at the upper stream, which almost doubled compared to that of the lower flow (3.82) (figure 6a). It suggests that the weathering rock process at Station 1 has become one of a possible source of Cd. It is confirmed with field report that indeed the bed of River Bonan Dolok mainly consists of the Andesite boulders [17]. Andesite is a fine-grained rock that formed when the magma erupted onto the surface and crystallized quickly. This rock is commonly found in a volcanic area and is one source of Cd since it belongs to a chalcophile (sulfur-loving) stones [29]. In River Bonan Dolok, the $A_{s-w}$ was gradually decreased up to Station 3. Probably it occurred due to the influence of water flow and slope of the land. Oppositely, at Station 4, where water flows relatively slower, the $A_{s-w}$ elevated. Figure 6b shows that water conductivity increased remarkably when reach on the lower stream. It probably caused by more input from anthropogenic activities flowing into this location compared to other sampling locations. Meanwhile, the highest chloride and sulfate concentrations (54.9 mg/L and 11.4 mg/L) were observed on Station 3. It may have related to the mixed inflows from anthropogenic activities (Station 2 and station 3). In case of data obtained at the upper stream, it may appropriate used as a background level for conductivity, chloride, and sulfate for River Bonan Dolok area, since it can be implied from reports of Allison et al and Henley and Berger those levels are characteristic for weathering chalcophile rock derived soil [9, 29].

**Figure 5.** Bio-Accumulation Factor (BAF) of Cd in microalgaes community (a) and the percentage of phylum abundance (b) in every sampling stations of River Bonan Dolok-North Sumatra.
Figure 6. Cadmium fraction between sediment and water (A_s-w) (a) as well as the conductivity value, chloride, and sulfate ions (b) in every sampling station of River Bonan Dolok - North Sumatra. The pictures of every sampling location were taken by Larashati et al. [6].

4. Conclusion
The average Cd concentration in water, sediment, and microalgae biomass were taken from the upper stream to the lower flow of River Bonan Dolok were ranged between 0.02-0.64 µg/L, 0.10-0.39 µg/g dry weight, and 0.01-0.57 µg/g dry weight. The highest Cd in the water was found at Station 3 since this location received more Cd sources (not only from weathering rocks process and domestic waste but also from paddy fields which implement phosphate fertilizers) than other sampling locations. Meanwhile, the highest Cd concentration in sediment was found at the downstream of the river. Station 2 which is nearest to paddy field (only ± 4 to 5.5 m from both riverbanks) compared to other sampling locations, shows highest concentration of Cd in microalgae biomass. The most abundant Cyanophyte (96.98 % which consisted of Microcystis aeruginosa) at the downstream did not contain the highest cadmium concentration. The highest Cd concentration in microalgae community biomass was observed on the Chlorophyte (which consisted of Microspora sp. 41.88 % of the total individual/L). But, since the Bio Accumulation Factor of Chlorophyte was only 2.89. Therefore, a term of bioaccumulation cannot be attributed to this microalga. In summary, this work provides a comprehensive status of cadmium in water, sediment, and microalgae biomass of River Bonan Dolok. It also delivers a comparison with other studies from China, India as well as Indonesia. Therefore, it would be useful for stakeholders to refer and develop a sustainable management concept for River Bonan Dolok in the future.

5. References
[1] B.P.S 2018 BPS-Samosir Regency: Sianjur Mulamula Subdistrict in Figures 2018 No.ISBN: 978-602-6860-43-9.
[2] Mucek A E, Danišík M, de Silva S L, Schmitt A K, Pratomo I and Coble M A 2017 Post-supereruption recovery at Toba Caldera Nature Communications 8 15248
[3] Larashati S and Ridwansyah I 2017 Habitats characterization for Ihan (Neolissocichilus sp.) Conservation planning around Lake Toba, North Sumatra, Indonesia Lake Ecosystem Health and Its Resilience: Diversity and Risks of Extinction PROCEEDINGS of the 16th World Lake Conference, ed A D Miratul Maghfiroh, Taofik Jasalesmana, Irma Melati, Octavianto Samir, Riky Kurniawan, Alfin (Discovery Kartika Plaza-Bali-Indonesia: Copyright © 2017 by Research Center for Limnology, Indonesian Institute of Sciences) p 20

[4] pariwisataSUMUT.Net 2019 Bonan Dolok dan Air Terjun Sitapigagan, Wisata Alam Samosir yang Instagenik https://www.pariwisatasumut.net/2019/04/bonan-dolok-dan-air-terjun-sitapigagan.html. Accessed on 7 Oct 2019.

[5] Catherine A, Mouillot D, Maloufi S, Troussellier M and Bernard C 2013 Projecting the Impact of Regional Land-Use Change and Water Management Policies on Lake Water Quality: An Application to Periurban Lakes and Reservoirs 8

[6] Leite Lima M A, Rosa Carvalho A, Alexandre Nunes M, Angelini R and Rodrigues da Costa Doria C 2020 Declining fisheries and increasing prices: The economic cost of tropical rivers impoundment Fisheries Research 221 105399

[7] Hannah L, Costello C, Elliot V, Owashi B, Nam S, Oyanedel R, Chea R, Vibol O, Phen C, and McDonald G 2019 Designing freshwater protected areas (FPAs) for indiscriminate fisheries Ecol. Model. 393 127-34

[8] CCME 2014 Canadian water quality guidelines for the protection of aquatic life: Cadmium. In Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, (Winnipeg).

[9] Henley R W and Berger B R 2013 Nature’s refineries — Metals and metalloids in arc volcanoes Earth-Sci. Rev. 125 146-70

[10] Mar S S and Okazaki M 2012 Investigation of Cd contents in several phosphate rocks used for the production of fertilizer Microchem. J. 104

[11] Roberts T L 2014 Cadmium and Phosphorous Fertilizers: The Issues and the Science Procedia Engineering 83 52-9

[12] Karlsson S, Meili M and Bergström U 2002 Bioaccumulation factors in aquatic ecosystems A critical review R-02-36, (Stockholm Sweden: Svensk Kärnbränslehantering AB Swedish Nuclear Fuel and Waste Management Co) p 72

[13] Li S and Zhang Q 2010 Risk assessment and seasonal variations of dissolved trace elements and heavy metals in the Upper Han River, China J. Hazard. Mater. 181 1051-8

[14] Rżetała M A 2016 Cadmium contamination of sediments in the water reservoirs in Silesian Upland (southern Poland) J. Soils Sed. 16 2458-70

[15] Zhao X-M, Yao L-A, Ma Q-L, Zhou G-J, Wang L, Fang Q-L, and Xu Z-C 2018 Distribution and ecological risk assessment of cadmium in water and sediment in Longjiang River, China: Implication on water quality management after pollution accident Chemosphere 194 107-16

[16] Indirawati S and Muntaha A 2018 Analysis of chemical parameters sourced from domestic waste in Lake Toba Region IOP Conference Series: Earth and Environmental Science 205 012027

[17] Larashati S, Yustiawati, Paramitha I G A A P and Ridwansyah I 2019 Field trip on R. Bonan Dolok-North Sumatra 9-13 April 2019 (unpublished work). RC for Limnology-LIPI. 9

[18] Ridwansyah I 2019 Sampling sites on River Bonan Dolok-Samosir -North of Sumatra. Database of Research Center for Limnology-The Indonesian Institute of Sciences (unpublished work)
[19] ASTM 2002 *Designation: D 1971-02: Standard Practises for digestion of water samples for determination of metals by flame atomic absorption, graphite furnace atomic absorption, plasma emission spectroscopy, or plasma mass spectrometry* (The American Society for Testing and Materials)

[20] APHA-AWWA 1992 *Water Environment Federation (1998) Standard methods for the examination of water and wastewater* (Washington, DC)

[21] Mizuno T 1970 *Illustration of the freshwater plankton of Japan* 313

[22] Prescott G W 1951 Algae of the western Great Lakes area *Cranbrook Institute of Science Bulletin* 31 p 946

[23] Prescott G W 1970 *How to know the freshwater algae* (Iowa: W.M.C. Brown Company Publisher) p 348

[24] Tao Y, Yuan Z, Xiaona H, and Wei M 2012 Distribution and bioaccumulation of heavy metals in aquatic organisms of different trophic levels and potential health risk assessment from Taihu lake, China *Ecotoxicol. Environ. Saf.* 81 pp 55-64

[25] Adhikari S, Ghosh L, Giri B S, and Ayyappan S 2009 Distributions of metals in the food web of fishponds of Kolleru Lake, India *Ecotoxicol. Environ. Saf.* 72 pp 1242-8

[26] Satya A, Sulawesty F, Harimawan A, and Setiadi T 2018 Correlation of Aquatic Parameters to the Cadmium Bioaccumulation Capability onto Microalgae Biomass in an Urban Lake *Journal of Water Sustainability. University of Technology Sydney & Xi’an University of Architecture and Technology* 8 pp 59-72

[27] Haande S, Rohrlack T, Semyalo R P, Brettum P, Edvardsen B, Lyche-Solheim A, Sørensen K, and Larsson P 2011 Phytoplankton dynamics and cyanobacterial dominance in Murchison Bay of Lake Victoria (Uganda) in relation to environmental conditions *Limnologica - Ecology and Management of Inland Waters* 41 pp 20-9

[28] Chen C, Stemberger R S, Klaue B, Blum J, Pickhardt P and Folt C 2000 Accumulation of heavy metals in food web components across a gradient of lakes *Limnol. Oceanogr.* 45 pp 1525-36

[29] Greaney A T, Rudnick R L, Helz R T, Gaschnig R M, Piccoli P M, and Ash R D 2017 The behavior of chalcophile elements during magmatic differentiation as observed in Kilauea Iki lava lake, Hawaii *Geochim. Cosmochim. Acta* 210 pp 71-96

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