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Correlation of Aquatic Parameters to the Cadmium Bioaccumulation Capability onto Microalgae Biomass in an Urban Lake

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ABSTRACT

The distributions of cadmium ions in water, microalgae biomass and sediment from Rawa Kalong Lake-Indonesia, a tropical hypereutrophic urban lake, were studied. Average concentration of cadmium ions in water was above the threshold level for supporting safe aquatic life (ranged from 0.387 to 0.574 μg/L) and microalgae biomass ranged 2.89 to 4.94 μg/g (dry weight). This urban lake was characterized as P-limited hypereutrophic, dominated by *Aphanothece* sp. (Cyanophyte phylum) with total abundance of over 768,200 individuals/L, low alkalinity, and low organic matter. Cyanophyte is capable of accumulating cadmium ions up to 4,150 times higher in its biomass than in water. Our findings demonstrate that the bioaccumulation of cadmium in microalgae show strong correlation to the cadmium content in microalgae biomass and to one of eleven parameters. The most significant parameter influencing the Bio-Accumulation Factor is the total phosphorus. Response Surface Analysis also shows that cadmium content in water is a crucial factor affecting bioaccumulation capability.

Keywords: Cadmium; *Aphanothece* sp.; biosorption; urban lake; aquatic parameters

1. INTRODUCTION

An urban lake has several unique characters. It has at least three important functions, namely ecological, economic and aesthetic. Even so, urban lakes have received little attention in limnological and watershed management literature (Schueler and Simpson, 2001). Its location, frequently found in the urban areas with a dense population of inhabitants, has made it vulnerable to receiving organic and inorganic pollutants. Some lakes are also located in industrial areas, making it more likely that the influx of pollutants will have an impact on its aquatic system (Wetzel, 2001).

Globally, it has been noted that among of many type of pollutants, cadmium (Cd) ions most commonly exist in water bodies receiving wastewater outflows from metal base processing industries. Other sources are anthropogenic activities such as waste disposal/incinerators, stationary fossil fuel combustion, and many other forms of atmospheric depositions. Cadmium is one of the big three metals (together with mercury and lead) posing the greatest hazard to human health (Barwick and Maher, 2003; Caussy et al., 2003; Csuros and Csuros, 2002; Manahan,

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2001). It can lead to a serious deterioration of the aquatic life because it can accumulate through the trophic chain. Furthermore, it can produce toxic effects and teratogenic changes in plants, animals and finally human beings (Barwick and Maher, 2003).

Microalgae are primary producers in the aquatic system. They can naturally bind metals to their life cells (Bellinger and Sigee, 2010; CCME, 2003; Chojnacka, 2010). Therefore, great attention must be given to this issue since once metal enters the aquatic food chain it will affect human health as they are the uppermost consumers (Barwick and Maher, 2003; CCME, 2003; Chen et al., 2016).

In this study, the aquatic parameters (physical-chemical and biological) were examined, which characterize the trophic status of an urban lake, namely Rawa Kalong Lake located in Depok-West Java, Indonesia. Then, the cadmium distribution and accumulation in microalgae was explored, followed by the determination on among which of the observed aquatics parameters gave the strongest effect on the capability of microalgae to bind cadmium in its biomass. This study will give a comprehensive description of cadmium status in microalgae and the water column of Rawa Kalong Lake, and provide a scientific reference to the development of ongoing strategies to utilize urban lakes in the future.

2. MATERIAL AND METHODS

2.1 Study area and field sampling

The lake or "Situ" (local name) of Rawa Kalong lies at the eastern and southern latitudes of 106°53'31.02" and 6°23'45.06". It is in Depok city, a buffer zone city in the southern part of Jakarta - the capital city of Indonesia. This urban shallow lake has a maximum depth (Z_{max}) of around 2 to 4 meters and surface area (A) of about 8 hectares. There are at least five chemical-based manufacturers directly bordering this lake. Dense inhabitants, road ways, a traditional market, and garbage dumps-incinerators also surround it. Local people utilize the water body to cultivate many kinds of freshwater fish and shrimps in many floating fish cages and floating nets.

Water and microalgae biomass samples were taken at three sampling points, namely the inlet, middle part, and outlet (Fig. 1) over ten occasions from March to October 2014. There were a total of 180 water samples and 60 concentrated microalgae biomass samples. They were also supplemented with 360 direct measurements readings of physical-chemical parameters (pH, dissolved oxygen (DO), water turbidity, water temperature, water conductivity, oxidative-reductive potential (ORP) and Secchi disk depth (Z_{SD})) by using the portable water quality checker Horiba U-10, Lutron-Turbidity meter, ORP meter-YSI instrument and Secchi disk. Data was collected over ten sampling occasions every two weeks, which were conducted six times from March to May 2014 and four times from September to October 2014. At every sampling point, water samples were taken at two depths (surface and Secchi disk depth - Z_{SD}) by using Snatch-bottle water samplers.

Microalgae biomass samples for cadmium (Cd) ion determination were taken separately for the identification of microalgae genera as well as microalgae total abundance counting. They were taken by filtrating a 2 L water sample through a Wisconsin plankton net sampler No.25 with a mesh size of 64 μm, while samples for Cd determination were taken by filtrating a 10 L water sample, both followed by adding 1% Lugol solution for preservation. Finally, water and biomass samples for cadmium analysis were stored in acid cleaned polyethylene bottles placed in a cooler at 4°C and transported to the laboratory for further analysis.

Figure 1 Study area and sampling points in Situ Rawa Kalong (Satya et al., 2012)

2.2 Laboratory analysis

Water samples were subjected to chemical analysis in term of aquatic nutrients (Total Nitrogen, (TN) and Total Phosphorus (TP), chlorophyll-a content, Total Organic Matter (TOM) and cadmium ions). The digestion method used in order to convert all forms of nitrogen compounds into nitrate as well as the conversion of all phosphorus compounds into *ortho*-phosphate was done according to Patton and Kryskalla (2003). The resulting nitrate and *ortho*-phosphate were then measured spectrophotometrically with the brucine method and ascorbic acid methods respectively, as described in APHA-AWWA-WEF (1992). TOM in water was measured using the $KMnO_4$ method was also conducted according to APHA-AWWA-WEF (1992). Cadmium digestion was conducted by heating to 120°C and pressurizing in 15 Psig following ASTM (2002) before Cd was measured using Graphite Furnace Atomic Absorption Spectrophotometer Shimadzu A-7000 series (Shimadzu, 2006). The analyses done in duplicate for each water and biomass sample. A standard reference material was also used to verify the accuracy of metal determination in each sample (BCR-414-Plankton, LGC-618-sediment). The recovery rate for Cd was within the standard of 102.6 ± 10% (n = 5).

Identification of the community structure of microalgae biomass was done according to the cited references (Mizuno, 1970; Prescott, 1951, 1970). While the microalgae abundance counting was conducted with an inverted microscope DIAPHOT 300 (magnification up to 400 times) based on the Lackey drop (micro transect) method using a Sedgewick rafter (APHA-AWWA-WEF, 1992). Bio Accumulation or BAF is the ratio of Cd concentration in microalgae biomass to water column, calculated based on the following formula (Eq. 1) according to Chen et al. (2000):

$$BAF = \frac{[Cd]_{microalgae}}{[Cd]_w} \quad (1)$$

Meanwhile, fractionation of Cd ion content in sediment to water was calculated as below Eq. 2 :

$$A_{s-w} = \frac{[Cd]_{sed}}{[Cd]_w} \quad (2)$$

$[Cd]_{microalgae}$ represented the cadmium content of microalgae biomass (µg/g), $[Cd]_{water}$ and $[Cd]_{sed}$ are the cadmium content of water (μg/L) and sediment samples (μg/g).

All the data from the water samples and biomass are presented as average values found at both surface water and Z_{SD} measurements.

2.3 Statistical analysis

Data were calculated by using MS-Excel™, graphed with Sigma Plot 10 for Windows and analysed statistically with Minitab®17.2.1. After examining the normality of the data distribution with Shapiro-Wilkinson method, we then analyzed it for differences in all observed parameter among of three sampling sites (inlet, middle part, and outlet) by using student's t-test with $p < 0.05$. The significance of variations in means of all the parameters were tested by one-way analysis of variance (ANOVA). Regression analysis followed by Response Surface Analysis was done to examine the correlation of some of the aquatic parameters against BAF.

3. RESULT AND DISCUSSION

3.1 Spatial distribution of aquatic physico-chemical parameters

Table 1 and Table 2 present the mean values of aquatic physico-chemical parameters at the inlet, middle and outlet part of the lake. There are no significant differences among the observed values in the three sampling points based on the 2-sample t-test. In general, the results show that turbidity, Z_{SD}, water conductivity, TDS, TOM, ORP and pH values in Rawa Kalong Lake are typical for natural shallow freshwater lakes (Chapman, 1996; Stumm and Morgan, 1966; Weiner, 2008; Wetzel, 2001). Meanwhile DO values, as referred to Weiner (2008), indicate that Rawa Kalong Lake is moderately polluted.

Rawa Kalong is also categorized as soft water due to its low of total hardness value (less than 75 mg $CaCO_3$/L). This condition may increase the toxicity of metal on the aquatic biota (Weiner, 2008). The water temperature of Rawa Kalong Lake is typical of tropical shallow waters (Wetzel, 2001), since it ranges between 29 and 30°C. This parameter is important to be observed, as most aquatic chemical equilibria are temperature dependent, for example the equilibria between ionized and unionized forms of ammonia, hydrogen sulfide, and others (Weiner, 2008). Total alkalinity in Rawa Kalong Lake is less than 20 mg/L therefore this lake is classified as a lake with a minimum level of alkalinity. Alkalinity is a good indicator of the presence of bicarbonate and carbonate ions. It beneficial to the aquatic system since it minimizes pH changes, reduces metal toxicity by forming many complexes with them, and provides nutrient carbon for aquatic plants converted into biomass by photosynthesis (Weiner, 2008; Wetzel, 2001).

Turbidity according to Weiner (2008); Wetzel (2001) results from the scattering and absorption of incident light by particles in water. Increasing the mineral material or microalgae biomass in water may lead to an increase in turbidity. Turbidity, Z_{SD}, Total Nitrogen, Total Phosphorus and chlorophyll-a content are related to the trophic status of a lake (Chapman, 1996; Wetzel, 2001). Commonly, chlorophyll-a in a hypereutrophic lake according to Chapman (1996) is equal or more than 75 mg/m^3. In Rawa Kalong Lake this parameter about three times that value, therefore the trophic category of this lake is hypereutrophic.

3.2 Spatial distribution of cadmium ions and aquatic nutrient

Results of 2-sample-student t-test show that there are no significant differences based on $p < 0.05$, in term of the mean values among of the observed parameters at the inlet, middle part, and outlet (Table 3). According to CCME (1999), in order to support the life of aquatic biota, the Cd concentration in water must be less than 0.017 μg/L. In this study, there are occurrences of magnification up to 22.76, 24.76, 33.76 times at inlet, middle part, and outlet of the lake. The Cd sources were probably originated from water discharge of manufacturers which directly bordering with Rawa Kalong water body, three garbage dumps incinerators, domestic sewer, etc.

Meanwhile, the Cd content in microalgae biomass (Table 3) are comparable to the values reported by Chen et al. (2000) where average microalgae biomass taken from 20 lakes in Northern America was 2.72 μg/g dry weight. But compared to Taihu lake which was only 0.01 μg/L, as reported by Yu et al. (2012), Cd in Rawa Kalong Lake (between 38.7 to 57.4 times) was greater. Compared to Koleru Lake - India, which contain 0.036 μg Cd/Lon average (Adhikari et al., 2009), Rawa Kalong Lake contains 10.75 to 15.94 times more Cd in water.

According to Weiner (2008), Downing and Mccauley (1992), a hypereutrophic water contains more than 1.5 mg TN/L and 0.100 mg TP/L. Based on this criterion, Rawa Kalong Lake is also categorized as hypereutrophic. Furthermore, Downing and Mccauley (1992) reported that algal biomass in lakes is significant influenced by the TN/TP ratio when TP is higher than 0.005 mg/L. TP becomes limiting factor in lakes when the TN/TP ratio is greater than 21. Levels of TN and TP in lakes, is generally influenced by a complex set of biogeochemical processes such like sedimentation, nitrification, denitrification, fixation etc. (Wetzel, 2001). From these findings, Rawa Kalong Lake can be classified as a P-limited lake.

Table 1 Spatial variation of the average values of physico-chemical parameters (represented as mean ± standard deviation) in Rawa Kalong Lake over the ten samples taken from March 2014 to October 2014

Location	**pH**	**Conductivity (mS/cm)**	**DO (mg/L)**	**Hardness (mg $CaCO_3$/L)**	**Water Temperature (°C)**	**Alkalinity (mg $CaCO_3$/L)**
Inlet	7.69±0.58	0.138±0.045	8.18±3.25	31.99±3.02	29.17±0.74	18.85±13.07
Middle part	7.95±0.70	0.144±0.053	7.69±2.39	30.71±2.86	29.56±0.82	18.60±13.29
Outlet	7.55±0.57	0.139±0.041	6.15±3.44	31.9±0.46	28.94±0.82	18.58±12.91

Table 2 Spatial variation of the average values of physico-chemical parameters (represented as mean ± standard deviation) in Rawa Kalong Lake over the ten samples taken from March 2014 to October 2014

Location	**TDS (mg/L)**	**Turbidity (NTU)**	**Chlorophyll-a (mg/m^3)**	**Z_{SD} (cm)**	**TOM (mg/L)**	**ORP (mV)**
Inlet	87.24±25.95	77.3±33.9	263.2±78.7	24.19±2.51	104.9±54.50	71.3±45.1
Middle part	91.33±29.70	76.0±34.1	255.5±43.7	26.15±3.67	81.21±30.58	81.0±48.3
Outlet	87.95±25.19	78.9±33.3	244.0±47.1	25.60±3.02	93.80±53.00	120.6±28.4

Table 3 Spatial variation of the average cadmium content and aquatics nutrient (represented as mean ± standard deviation) in Rawa Kalong Lake over the ten samples taken from March 2014 to October 2014

Location	Total Cd in water (μg/L)	Total Cd in microalgae (μg/g dry weight)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	TN/TP
Inlet	0.387±0.05	2.89±0.14	11.18±2.62	0.39±0.04	28.51±6.95
Middle part	0.421±0.05	4.94±0.24	10.79±2.59	0.37±0.05	29.29±7.67
Outlet	0.574±0.08	3.38±0.03	11.43±2.75	0.39±0.05	30.22±9.81

3.3 Bio-Accumulation of Cd in microalgae community

The microalgae community in Rawa Kalong Lake in 2010 was dominated by *Oscillatoria* sp. from Cyanophyte with a total abundance 1,468,035 (Sulawesty et al., 2012). At that time, four phyla were found, namely Cyanophyte, Chlorophyte, Cryophyte and Euglenophyte. As the dominant phyla, Cyanophyte consisted of seven species, namely *Oscillatoria* sp., *Anabaena* sp., *Chroococcus minutus*, *Merismopedia punctata*, *Microcyctis aeruginosa* and *Spirullina* sp.

In 2014, that community structure had changed. Although Cyanophyte still dominated 99.8 to 99.9% of the microalgae community (Fig. 2), there were also observations of Bacillariophyte. Cryophyte decreased to only 23 individuals/L. Dominating genera in Cyanophyte changed from *Oscillatoria* sp. into *Aphanothece* sp., accounting for up to 99.9% of Cyanophyte (Fig. 3).

The following Fig. 4 to Fig. 7 describes the total abundance of each phylum during the observations in 2014. Chrysophyta was not depicted in the figures as the abundance was too low.

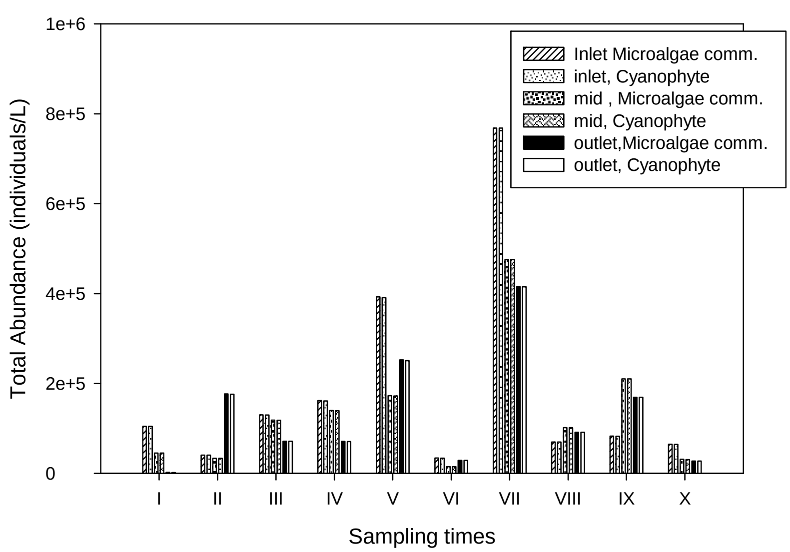

Figure 2 Comparison of the total abundance the microalgae community and Cyanophyte during the ten sampling occasions at the three sampling points in Rawa Kalong Lake in 2014

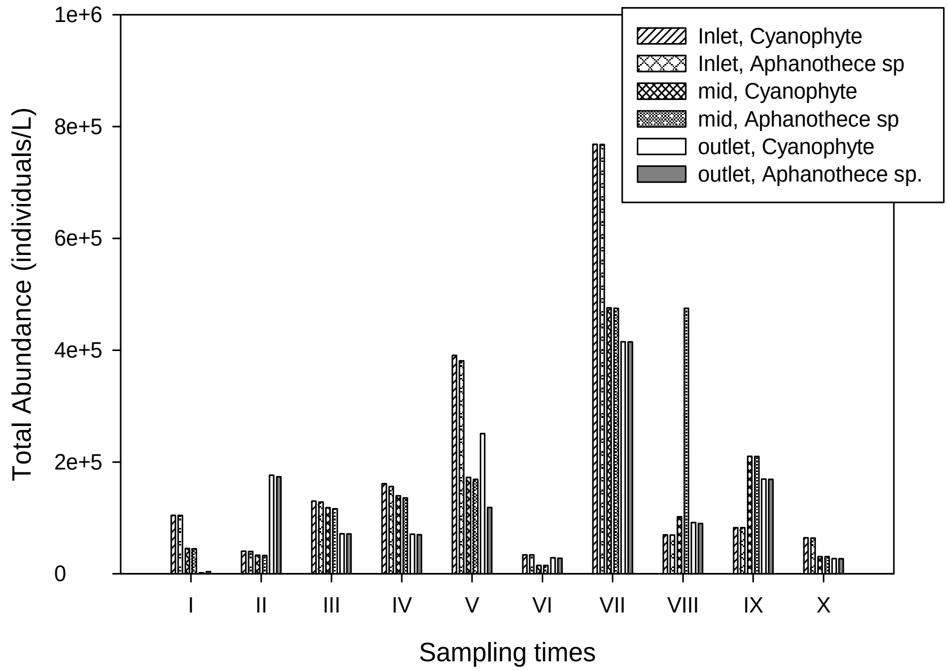

Figure 3 Comparison of the total abundance of Cyanophyte and *Aphanothece* sp. during the ten sampling occasions at the three sampling points in Rawa Kalong Lake in 2014

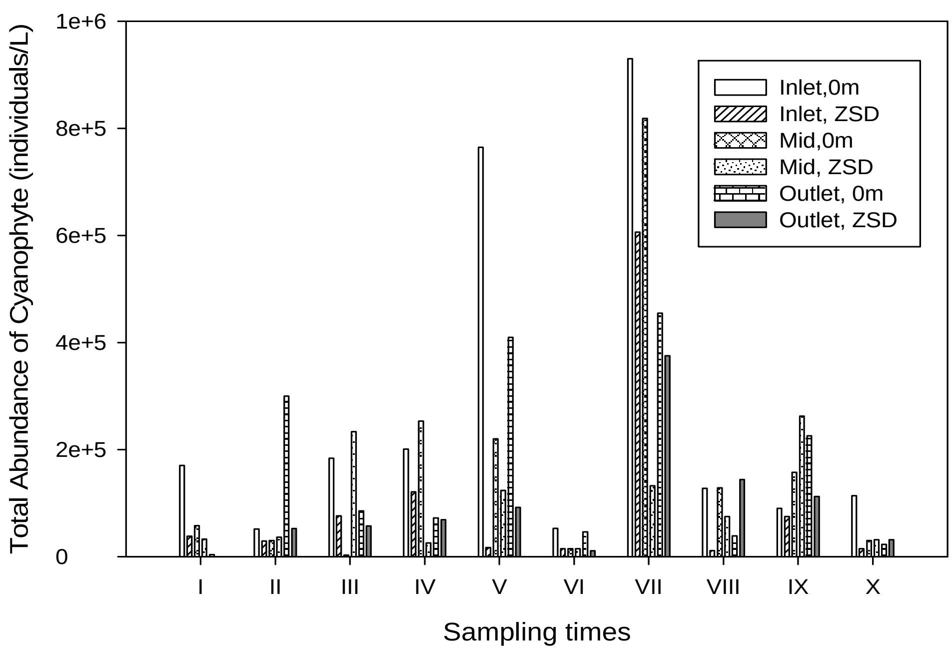

Figure 4 Total abundance of Cyanophyte which consisted of six genera in Rawa Kalong Lake in 2014; The microalgae composition consisted of: 1) *Anabaena* sp.; 2) *Aphanothece* sp.; 3) *Merismopedia punctate*; 4) *Microcystis aeruginosa*; 5) *Spirulina* sp.; 6) *Oscillatoria* sp.

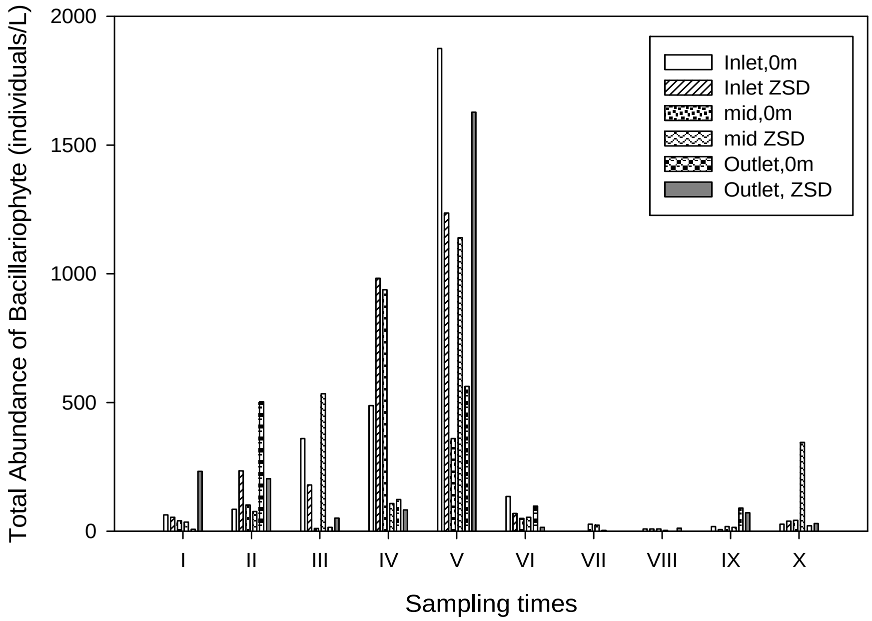

Figure 5 Total abundance of Bacillariophyte which consisted of three species in Rawa Kalong Lake in 2014; The microalgae composition consisted of: 1) *Navicula viridis*; 2) *Synedra ulna* ; 3) *Frusturia rhomboides*

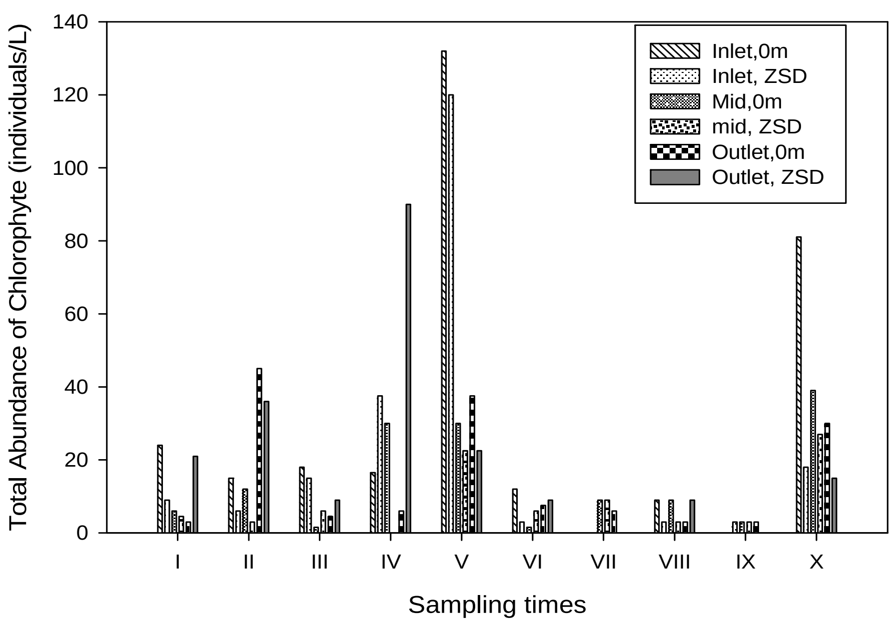

Figure 6 Total abundance of Chlorophyte in Rawa Kalong Lake. There were 12 species found in 2014; The microalgae composition consisted of: 1) *Pediastrum duplex*; 2) *Scedesmus arcuatus*; 3) *Scenedesmus incrassatulus*; 4) *Scenedesmus quadricauda*; 5) *Scnedesmus bernardii*; 6) *Scenedesmus dimorphus*; 7) *Pediastrum dimorphus*; 8) *Pediastrum simplex*; 9) *Pediastrum duplex*; 10) *Staurastrumplayfairi*; 11) *Selenastrum*; 12) *Staurastrumformosum*

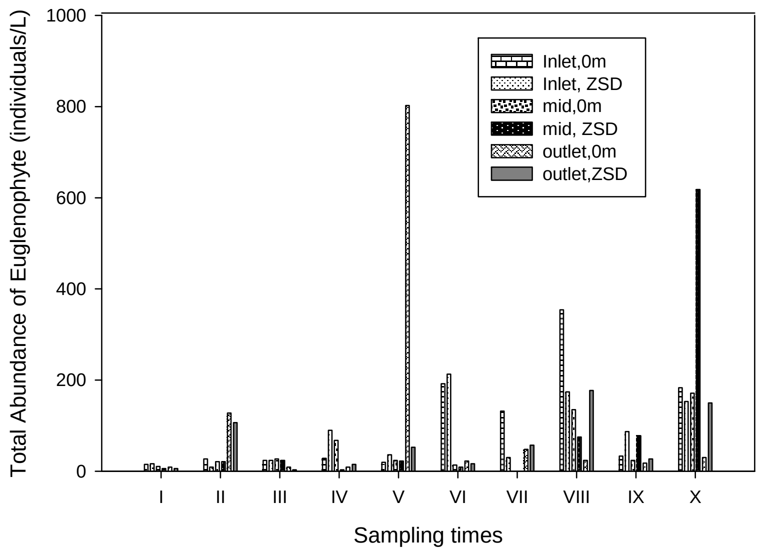

Figure 7 Total abundance of Euglenophyte in Rawa Kalong Lake in 2014, consisting of four species; The microalgae composition consisted of: 1) *Euglena viridis*; 2) *Phacus helikoides*; 3) *Phacus longicauda*; 4) *Phacus orbicularis*

Higher total abundance of microalgae was observed in May (sampling period V) and in September (sampling period of VII) as describe in Fig. 2 to Fig. 4. In those periods, the Cyanophyte became as predominant phylum. Even sampling report only provided the air temperature (28.5°C on May and 28.7°C on September 2014) and obviously sunny weather observed both in those periods, those months are noted as the driest months for Depok City area. It can be deducted like that since according to report on Depok Municipal Official Portal (2015), in general, dry season occurred between the months of April-September and rainy season between the months of October to March. Furthermore, those report also mentioned that averagely in the whole of the year the temperature, humidity and solar radiation are 24 to 33°C, 25% and 49.8%. Those peaks of microalgae abundance were observed since higher solar radiation was available which boosted the photosynthesis process resulting to produce the higher microalgae biomass. In the same time there was no raining dilution effect in the dry season period.

The capability of microalgae to accumulate metal in its biomass was evaluated by calculating the Bio-accumulation Factor (BAF). BAF Microalgae must be considered to be potentially significant to accumulate metal if the calculation result equal to or more than 100 (Usepa, 1991). Table 3 presents the calculation results in this study. Over the ten sampling occasions, only the middle part and outlet gave significant results. This occurred two times in the fifth and sixth sampling period. The highest BAF (4,150) was found at outlet followed by BAF at middle part (1,684). It is higher than previous study in 2010 as reported by Satya et al. (2012), which BAF was only 1,352. This finding suggests that *Aphanothece* sp. has a greater cadmium bioaccumulation capability than *Oscillatoria* sp. However, BAF in this report is comparable to BAF reported by Yu et al. (2012) which the in total microalgae community in Taihu Lake-China (in which 90% of the microalgae community was dominated by three phyla: Chlorophyte, Bacillariophyte and Cyanophyte) was 5240. Compare to Chen et al. (2000), this result is far above the BAF in the 20 Northern Eastern Lakes of United States which was only 41.85.

3.4 Correlation of aquatics parameters to BAF

To understand the correlation of the observed aquatic parameters described in Table 1 to Table 3 to the Bio Accumulation Factor (BAF) of cadmium (as presented on Table 4), we conducted a regression analysis. The result is summarized in Table 5. There are eleven regression equations models with a high coefficient of determination (R-square) ranging from 90.94 to 96.84%.

Fig. 8 shows that the Cd content in biomass is a fixed predictor that significantly affects BAF. ATP 0.35 mg/L and 15 μg Cd/g dry weights in microalgae biomass resulted in the highest BAF. The strongest correlated predictors were Cd content in biomass combined with Total Phosphorus, which can be inferred the form the R-squared and p-values (Eq. 9 in Table 5). TP had greater influence on BAF than TN. It is probably caused by the fact that of TP is a limiting factor for microalgae growth in Rawa Kalong Lake. Cadmium content in microalgae biomass and total abundance of cyanophyte were significantly affected on BAF (Eq. 1 of Table 5). It correlated with the fact that cyanophyte was being dominate in the micro-algae community structure (Fig. 4).

Table 4 Bio-Accumulation Factor (BAF) of cadmium ion during the ten samplings in 2014 at Rawa Kalong Lake

Location	**Sampling times*)**									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Inlet	10.2	5.0	16.0	76.4	69.7	13.3	11.1	< 0.01	< 0.01	< 0.01
Middle part	1.6	4.8	18.6	55.1	1,684	133	< 0.01	< 0.01	< 0.01	0.13
Outlet	3.4	63.6	37.7	44.1	549.8	4,150	< 0.01	< 0.01	0.42	0.08

*) I = 11 March 2014; II = 25 March 2014; III = 8 April 2014; IV = 22 April 2014; V = 7 May 2014; VI = 20 May 2014; VII = 3 Sept 2014; VIII = 17 Sept 2014; IX = 1 October 2014 and X = 15 October 2014

Table 5 Linear Regression Model for aquatic parameters that were significantly correlated ($p < 0.05$) to BAF of Cd ion for Rawa Kalong Lake

No	**Regression Equation Models**	**R-square (%)**	**P-value**
1	BAF = –111 + 106.5* Cd biomass – 0.00183* TA Cyanophyte	92.02	0.006
2	BAF = –818 + 96.9* Cd biomass + 4822* water Conductivity	93.71	0.004
3	BAF = 991 + 94.3* Cd biomass – 40* water Temperature	90.94	0.008
4	BAF = –801 + 96.8* Cd biomass + 762* Total Dissolved Solid	93.08	0.005
5	BAF = 609 + 89.5* Cd biomass – 28.1* Secchi disk depth	92.40	0.006
6	BAF = –361 + 97.7* Cd biomass + 1.53* water turbidity	92.65	0.020
7	BAF = –533 + 94.3* Cd biomass + 1.34* Chlorophyll-a	91.75	0.007
8	BAF = –242 + 94.2* Cd biomass + 1.50* Total Hardness	91.20	0.008
9	BAF = –1589 + 104.53* Cd biomass + 3722* Total Phosphor	96.84	0.001
10	BAF = 224 + 89.8* Cd biomass – 37.7* Total Nitrogen	91.40	0.007
11	BAF = –349 + 104.3* Cd biomass + 348* Cd in water	93.63	0.004

Meanwhile TDS and water conductivity have almost equal effects on BAF (Eq. 2 and Eq. 4 in Table 5). This seems related to the fact that both water conductivity and TDS may be included in dissolved minerals and salts. These two parameters have similar characters, since in natural waters, major contributors to TDS and conductivity are carbonate, bicarbonate, chloride, sulfate, phosphate and nitrate salts (Weiner, 2008). Fig. 9 shows how conductivity together with Cd in microalgae biomass affects BAF. The Water conductivity of about 0.13 mS/cm and 15 μg Cd/g dry weights gives the highest BAF.

Water temperature, Secchi disk depth and Total Nitrogen combined with Cd in microalgae biomass (Eq. 3, 5 and 10 in Table 5) are significantly correlated to BAF. These three parameters are reduction predictors. It means that when these three parameter increase, BAF will decrease. Water turbidity, Chlorophyll-a, Total hardness and Cd concentration in water combined with Cd in microalgae biomass (Eq. 6, 7, and 8 in Table 5) tend significantly decrease BAF.

Special attention must be addressed to Cd content in water coupled with Cd content in biomass (Eq. 11 in Table 5), since Cd content in water of even about 0.1 μg Cd/L has the capacity to maximize of BAF (Fig. 10). It is also connected to the fact that Rawa Kalong Lake is relatively rich in microalgae biomass which shows high capability to absorb Cd ion in its biomass. There are several functional groups such as carboxylic, ethylate, amide, amine, hydroxyl on surface of microalgae cell which poses high affinity to divalent metal cations (Chojnacka, 2010). When the cations further enter the intra cellular part, binding cations also occur between the absorbed metal cation with some enzymes that have sulfhydryl groups. Some proteins which are rich in thiols groups can effectively bind and deactivate cations in the microalgae cell without causing toxic effects. Therefore, using these adapted microalgae as metal bio-sorbent is more efficient than non-adapted one.

Rawa Kalong Lake in this study has been proven to be a good potential source of cadmium bio-sorbent based on microalgae biomass. There are eleven parameters (TP, total abundance of Cyanophyte, water conductivity, water temperature, TDS, Secchi disk depth, water turbidity, chlorophyll-a, total hardness, and TN) which have a significantly strong effect on the capability of microalgae biomass to bind with cadmium ions.

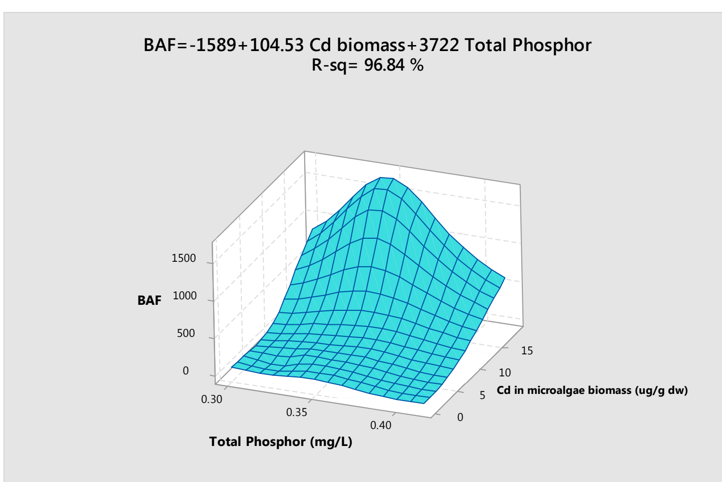

Figure 8 Surface response of BAF with Total P and Cd content in microalgae biomass as significant predictors

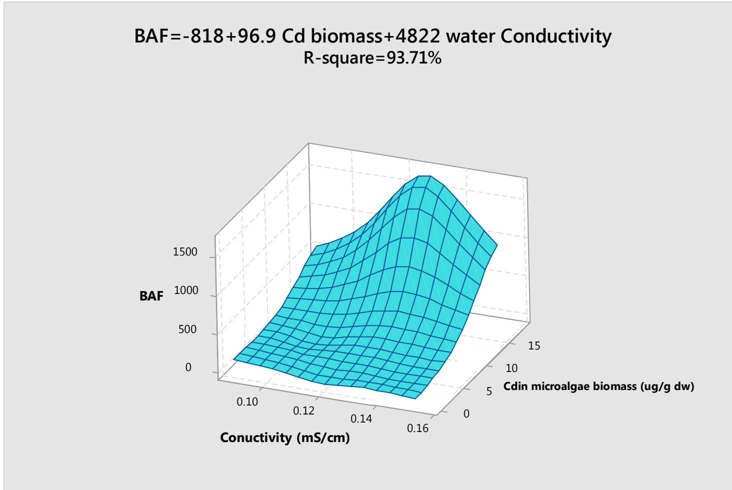

Figure 9 Surface response of BAF with water conductivity and Cd content in microalgae biomass as significant predictors

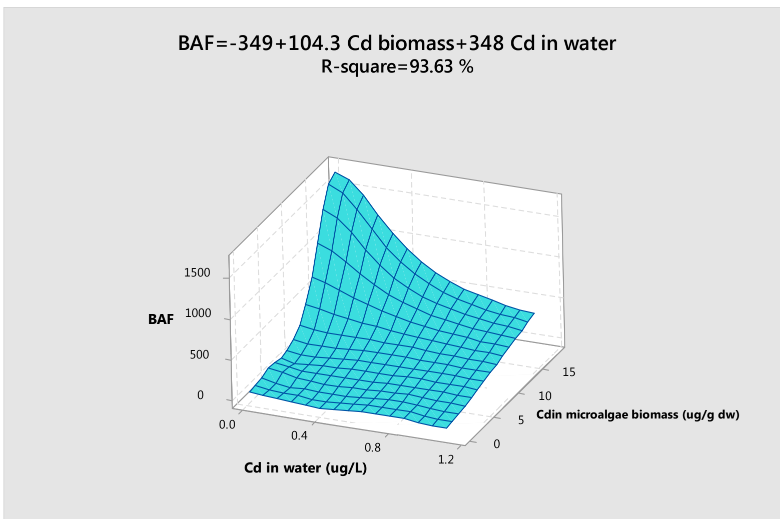

Figure 10 Surface response of BAF with Cd in water and Cd content in microalgae biomass as significant predictors

CONCLUSIONS

This study demonstrated that Rawa Kalong Lake is classified as a soft waters type, hyper-eutrophic tropical shallow lake whose productivity is limited by phosphorus. Occasionally the cadmium content in both the water column and microalgae biomass are above the safety level needed to support aquatic life. The fluctuation of cadmium content seemed to be affected by other physico-chemistry characteristics. *Aphanothece* sp. (belong of Cyanophyte phylum) dominated with approximately 99% of the total abundance microalgae community. This microalga is proven to have a high capability to bind with cadmium ions in its biomass. However, there were eleven aquatic physico-chemical parameters, which had strong significant correlations to cadmium bioaccumulation in this microalga.

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