Surface Sediment Diatom as A Water Quality Indicator: Case Study: Cilalay and Cibuntu Ponds, Cibinong

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Abstract

Diatom is classified as algae within the Division of *Bacillariophyta*. They are unicellular eukaryotic organisms characterized by siliceous cell walls that can be long preserved in sediments. Therefore, diatom analysis in sediment records is a potential water quality indicator for present or paleo studies. The current knowledge on the distribution and diversity of diatoms in the sediment in the urban pond is poorly known. This study aimed to identify the distribution and diversity of diatoms from the sediments of the pond. We expect to obtain a primary database of a variety of diatoms. The sediment samples were taken from Cibuntu and Cilalay Ponds in Cibinong Botanical Garden. Sediments were digested using HCL and H_2O_2. The resulting diatom solution was dried and transferred onto glass coverslip, which subsequently mounted onto microscope slides using Naphrax (Refraction index 1.7). Diatom identification was examined using a light microscope at 1,000x magnification. Diatom communities in Cibuntu Pond were dominated by species *Aulacoseria ambigua*, *Eunotia bilunaris*, *Cymbopleura sp*, *Discostella stelligera*, and *Rossithidium sp* with diversity index of 2.4 and species evenness of 0.8. Whereas, species *Fragilaria sp*, *Eunotia monodon*, *Navicymbula pusilla*, *Eunotia bilunaris*, and *Pinnularia viridis* were predominant in Cilalay Pond with diversity index of 1.6 and species evenness of 0.5. Based on the diatom community, Cibuntu Pond is eutrophic indicated by the occurrence of *Aulacoseria ambigua*, whereas Cilalay Pond is meso-eutrophic indicated by the dominance of *Fragillaria*. This exploratory survey provides the first inventory of diatom assemblage in Cibuntu and Cilalay Ponds for roughly inferring the environmental changes in a shallow lake ecosystem.

Keywords: Diatom, water quality, urban ponds, Cibuntu, Cilalay

INTRODUCTION

Cibinong is one of the urban areas in Indonesia that has many ponds. There are 17 ponds in the downtown area and 95 ponds around the border area. Ponds in cities are often classified as “green-space areas”, because they are usually located within parks or other urban green zones and constitute important components of these areas (Harisson *et al*., 1995). Cibuntu Pond and Cilalay Pond are located in Central Cibinong within the Cibinong Botanical Garden. Those ponds serve as a source of agricultural irrigation water and a recreational site. Cilalay Pond is a closed pond, its water source is only from a spring around the pond. Cibuntu Pond has

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one inlet from Kalibaru River. The river flows along with industry, housing, and plantation area before coming into the pond (Nugroho, 2002).

Urban Ponds are often polluted by industrial and household wastes, as the impact of development city ignores environmental aspects. Moreover, sedimentation dynamics in many urban ponds are very high. The shrinkage of the number and area of lakes in Jakarta, Bogor, Tangerang, and Bekasi (Jabotabek) occurred due to silting, as a result of sedimentation and eutrophication, which eventually became land and used as cropland or settlement development.

Previous research by Nugroho (2002) examined the vertical water quality of Cibuntu Pond showed good quality to support aquatic organisms. Further research by Sadi (2013) shown that significant changes had occurred in the pond, where nitrogen and organic matter concentrations in Cibuntu Pond were very high. The high value of chlorophyll-a concentration of 25.55 to 87.61 mg/l is also an indication of pollution originated from anthropogenic activities around ponds and industrial waste carried through Kalibaru River.

The changes in water quality that occurred in both ponds are very interesting. Cilalay Pond has a natural shoreline (Henny & Meutia, 2014), while Cibuntu is an artificial pond built to support agricultural activities and has experienced dredging since five years before this study was conducted.

Diatom is a common proxy used to monitor water quality and infer past environmental conditions (Smol & Stoermer, 2010). Diatom is classified as algae within the Division of Bacillariophyta. They are unicellular eukaryotic organisms characterized by a siliceous cell wall that can be long preserved in sediments (Battarbee *et al*., 2001). Currently, thousands of species of diatom have been identified. Taxonomy is based on the size, shape, and sculpturing of the silica cell walls called frustule (Smol, 2008). In Indonesia, research on the reconstruction of environmental conditions and water quality with diatom proxies has been done in Lake Rawa Pening to find out the history of eutrophication (Soeprobowati *et al*., 2012). At Telaga Warna Dieng, diatom assemblages are associated with human activities (Soeprobowati *et al*., 2018). Diatoms are very sensitive to many environmental variables including pH, oxygen, salinity, current velocity, temperature, moisture condition, light, inorganic nutrients (carbon, phosphorus, nitrogen, silica), organic carbon, and organic nitrogen. Consequently, they are considered a powerful indicator of environmental changes, including eutrophication, climate change, and acidification both in the present and paleo studies (Van Dam, 1993).

There have been many studies on surface sediments diatom to determine environmental conditions and water quality in water bodies (lake or pond), such as research conducted by Thayer *et al*. (1983) using diatom sediments at near surface sediments to correlate it with several physical parameters such as sedimentation rate, distance from shore, and water depth at Lake Superior, USA. Besides, diatom concentrations in surface sediments are positively correlated with limnetic chlorophyll-a concentrations in Florida (USA) lakes (Whitmore, 1991). The surface sediment diatom was also carried out to determine any species that present in many eutrophic urban ponds in St. Petersburg, Russia (Ludikova, 2016).

The purpose of this study was to identify diatom distribution and diversity in surface sediments of Cibuntu and Cilalay Ponds and how they represent current water quality. Initial knowledge of the diatoms in the sediment surface in both ponds is needed before any further research to reconstruct the water quality dynamics in the past particularly in natural ponds.

METHODS

Study Site

Cibuntu and Cilalay Ponds are located in Cibinong Botanical Garden, Cibinong, West Java, Indonesia (Figure 1). Cibuntu and Cilalay are close with 366 m distance. The surface area of

Cibuntu Pond is 15.834 m² (Zulti *et al*., 2012), and Cilalay Pond has a surface area of 12,910 m² (Sadi, 2013). The depth of Cibuntu Pond is around 1.8 m, whereas Cilalay Pond is 0.5-1 m (Sadi, 2013). Regionally bedrock compositions of Cilalay and Cibuntu Ponds are tuff, sandy tuff, and conglomerate tuff (Turkandi *et al*., 1992). Sediments inside ponds are dominated by soils, rocks debris, and sediments from inlets river, where the materials are likely grayish-black clays.

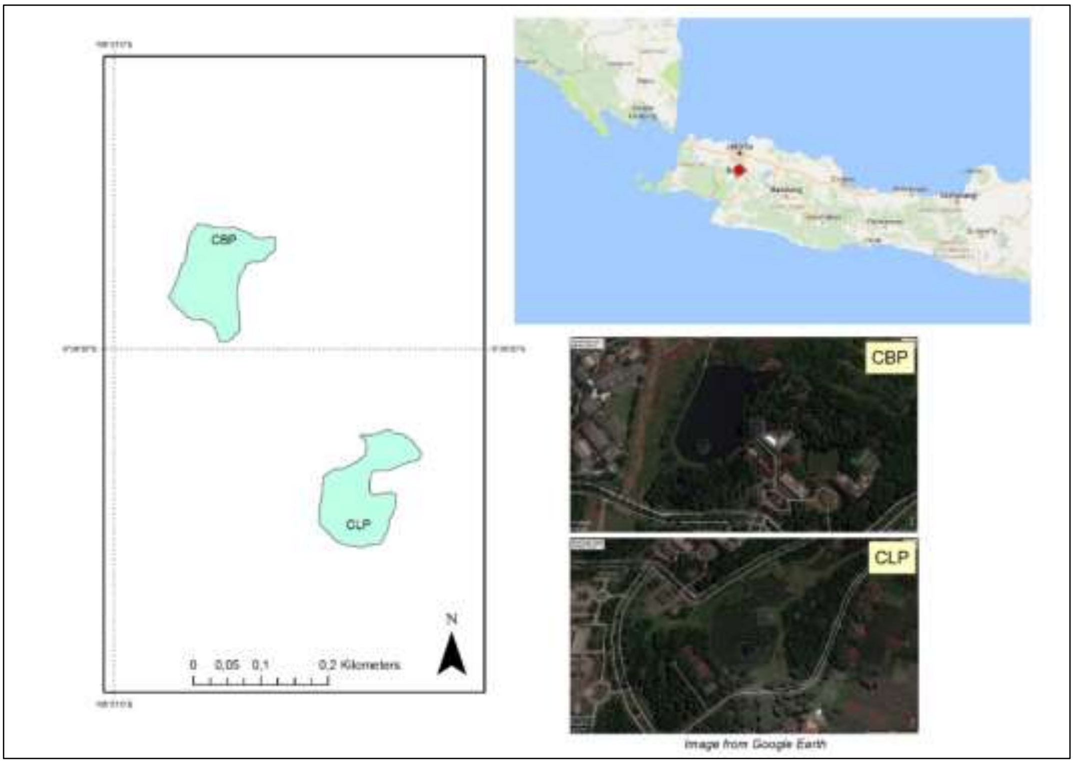

Figure 1. Study area showing Cibuntu (CBP) and Cilalay (CLP) Ponds located in Cibinong Botanical Garden, Bogor, West Java.

Surface Sediment Sampling

Along 10 cm surface sediment samples were taken from Cibuntu Pond (CBP) and Cilalay Pond (CLP) in September 2016 using a pipe tube (5 cm internal diameter). Samples were taken at one point of each pond. Afterward, sediment samples were removed from the pipe tube and mixed, then stored in the laboratory for the preparation process. Water quality measurements were conducted during sediment sampling. Water quality measurements involved Temperature, Dissolved Oxygen (DO), pH, Conductivity, Total Dissolved Solids (TDS), Turbidity, and Oxidation Reduction Potential (ORP).

Preparation, identification, and enumeration of diatom valves

Sediments preparation was conducted in the chemistry laboratory of Research Center for Limnology followed step from Soeprobowati *et al*. (2009, 2016). 5 grams of sediment sample was taken and put into a beaker glass, 50 ml of 10% HCl was added to remove carbonates. Afterward, 50 ml of 10% H_2O_2 was added to remove organic matters, then around 30ml of diatom residue resulted. The further process was making a permanent slide by putting 200 microliters of the residue onto coverslip glass until dry then put onto microscope slide with Naphrax mountant (synthetic resin with 1.7 refraction index). Microscope with 1,000X magnifications was used for identification, individual calculation of diatom species encountered made up of at least 300 valves (Soeprobowati *et al*., 2016). Taxonomy identification followed Lange-Bertalot 2001 volume 2; Kramer & Lange-Bertalot 2003 volume 4; Gell *et al*. (1999), database of the University of Colorado (http://westerndiatoms. colorado.edu), and AlgaeBase (http://www. algaebase.org).

Data Analysis

The species distribution is expressed in percent of relative abundance in the whole assemblage. The number of relative abundances, Shannon diversity and Shannon's equitability by Pielou's Evenness index are calculated using PRIMER-E. Taxonomic richness using C2 software version 1.7.6 (Juggins, 2003).

Shannon diversity index (H') and Pielou's evenness index (J') were calculated for all ponds to evaluate diatom biodiversity in surficial sediments, as follows:

$$H' = -\sum(p_i \; ln\, p_i) \qquad (1)$$

Where p_i is the number of individuals of a given diatom taxon (i) divided by total number of individuals.

$$J' = \frac{H'}{Log\,(S)} \qquad (2)$$

S is the number of total species counted in each lake. Shannon's equitability has a range value between 0 and 1. For each diatom community H' and J' were calculated to reveal if individuals are distributed evenly among the different species.

RESULTS AND DISCUSSION

Cibuntu Pond

Total 19 species were identified in surface sediment samples (epipelic diatom) of Cibuntu and Cilalay Ponds. The relative abundance of taxa is shown in Figure 2. Diatoms assemblages among ponds were significantly different especially for several dominant diatoms. Cibuntu Pond was dominated by *Aulacoseria ambigua*, *Eunotia bilunaris*, *cymbopleura sp*, *Discostella stelligera*, and *Rossithidium sp*.

Aulacoseria ambigua was relatively easy to identify because only these species have a hollow ringleist (Figure 3) (Buczkó *et al*., 2010). In addition, *Aulacoseria ambigua* has cylindrical frustules and form colonies. *Aulacoseria* is one of diatom genus that is very widely distributed, the species is most commonly found in mesotrophic and eutrophic waters (Gell *et al*., 1999). The abundance of this species made Cibuntu more eutrophic than Cilalay (Figure 2). In line with past studies (Table 1), it can be shown that the nutrient levels tend to increase over the last two decades. The increase in nutrient levels was due to the anthropogenic activity along with the stream inflow.

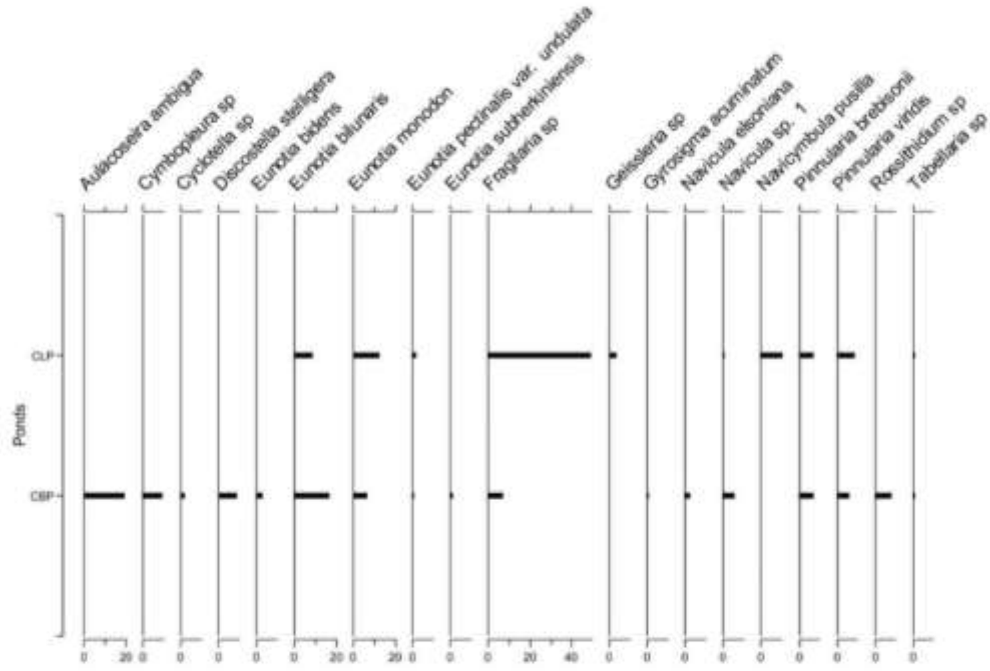

Figure 2. Relative abundance of diatom taxa in surficial sediments from Cibuntu and Cilalay Ponds.

Table 1. Water quality of Cibuntu Pond over the last two decades.

Years	DO (mg/L)	pH	TN (mg/L)	TP (mg/L)	Chlorophyll-a (mg/L)	DOC (mg/L)	References
1999	4.46-9.97	5.97-7.46					(Sulawesty, 2005) (Sulastri & Nomosatriyo, 2005)
2002			2.30	0.33			(Tarigan, 2002)
2007	5.52	7.15	1,95	0.39			(Tarigan, 2008)
2012-2013			2.74				(Sadi, 2013)
2014	7.6	6.53	0.763	0.026	5.472	35.484	(Henny & Meutia, 2014)
2015			4.06-5.21	0.041-0.054			(Chrismadha, *et al*., 2016)

Moderate nutrient concentrations in this pond also potential to an abundance of *Discostella stelligera* (Saros *et al*., 2012). Another dominant diatom in Cibuntu Pond indicating oligotrophic to mesotrophic water condition was *Rossithidium sp* (Gell *et al*., 1999) and *Cymbopleura* (Taylor *et al*., 2007).

Furthermore, *Eunotia bilunaris* was also abundant in Cibuntu. *Eunotia bilunaris* has arcuate valves, with convex dorsal and ventral margins concave, rounded to acutely rounded apices (Figure 3). This species is widely distributed in waters with a low mineral content, commonly found in acid waters conditions (Kulikovskiy *et al*., 2010). The pH value at the time of direct measurement was 6.82 (Table 2), while monitoring carried out by Research Center for Limnology in Cibuntu Pond showed that pH values ranged between 5.97-7.46 (Table 1). The genus has a worldwide distribution. Numerous species are restricted to tropical areas, due to these environmental conditions convenient for their habitat (low to neutral in pH, low conductivity, low transparency, and high temperature) (Sala *et al*., 2002).

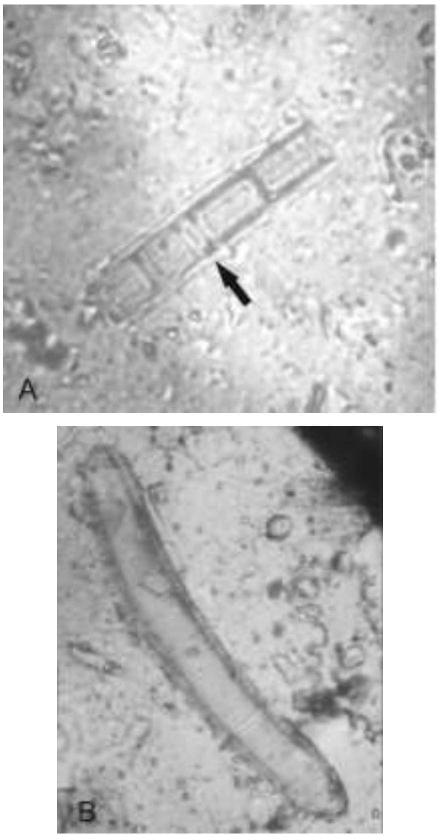

Figure 3. Microscope photograph of diatom species *Aulacoseria ambigua* (A) with hollow ringleist and *Eunotia bilunaris* (B).

Cilalay Pond

Cilalay Pond is much less affected by anthropogenic activities, in contrast to Cibuntu that is affected by anthropogenic activities. Cilalay surface water quality measurements during sampling are shown in Table 2. 10 diatoms species were identified, namely *Eunotia bilunaris*, *Eunotia monodon*, *Eunotia pectinalis var. undulata*, *Fragilaria sp*, *Gissleira sp*, *Navicula sp* 1, *Navicymbula pusilla*, *Pinnularia brebisonii*, *Pinnularia viridis*, and *Tabellaria sp*. The most dominant species were *Fragilaria sp*, *Eunotia monodon*, *Navicymbula pusilla*, *Eunotia bilunaris*, and *Pinnularia viridis*.

Fragilaria was the most dominant species in Cilalay. Evenness index of 0.5 indicates the predominance of a species (Table 3). *Fragilaria* has lanceolate valves with capitate ends (Figure. 4). *Fragilaria* tends to associate with circumneutral to slightly alkaline environment (Gell *et al*., 1999). The species is also commonly found in temperate waters mesotrophic lake. This condition is in line with the previous study from Henny & Meutia (2014) that the Trophic Status Index (TSI) of Cilalay Pond was 40 – 61, which categorized as mesotrophic-eutrophic.

Moreover, *Eunotia monodon* was the second large abundant species in Cilalay. This genus is a large genus of predominantly freshwater diatoms that are especially successful in acid habitats, and genus *Pinnularia* that is commonly found in acidic waters (Gell *et al*., 1999). *Eunotia monodon* valves are arcuate and the ventral margin of the valve is concave. *Eunotia* is a diatom genus that has limited ecological tolerance. Their occurrence is limited to oligotrophic and oligosaprobic waters. In consequence, *eunotia* taxa are considered important ecological indicators (Kwandrans, 2007). Water pH measurements at the time of sampling showed a neutral pH value (Table 2). However, measurements in 2014 by Henny & Meutia (2014) found that Cilalay water pH had a value of 5.9. Although this pH is not acid, it can be used to indicate that the pH condition before 2014 was considered lower.

Furthermore, *Navicymbula pusilla* was also dominant in Cilalay. This species has a moderately *dorsiventral*, *semilanceolate* valve with moderately arched and slightly convex dorsal or ventral margin approximately straight, end variably rounded (Fig. 4). This species is a very cosmopolitan species from temperate to tropical zones and often found in the oligotrophic until eutrophic waters with middle to upper-middle electrolyte contents, *Navicymbula* is also found in alkali water (krenophilic) and in the waters that have high contents of Ca and Cl salinity (Krammer *et al*., 2003).

Table 2. Water quality of Cibuntu and Cilalay Ponds during sampling.

Site	DO (mg/L)	pH	Conductivity (µS/cm)	TDS (g/L)	ORP (mV)	Turbidity (NTU)
Cibuntu	10.3	6.82	0.076	0.05	156	28.6
Cilalay	10.83	6.07	0.069	0.095	229	31.8

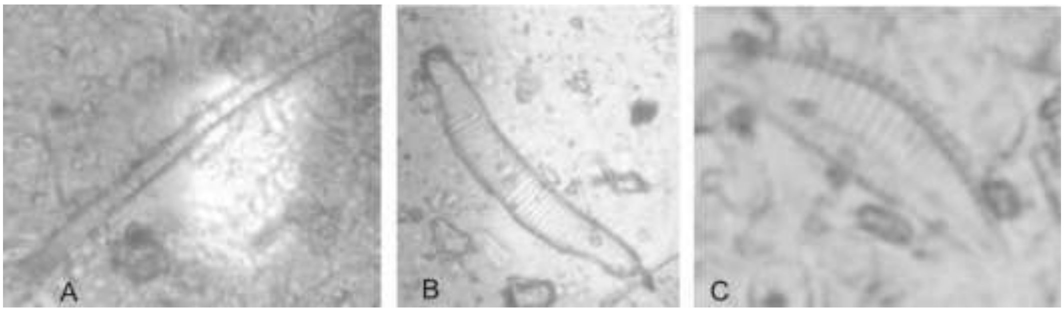

Figure 4. Microscope photograph of diatom species Fragilaria sp (A), Eunotia monodon (B), and Navicymbula viridis.

Table 3. Ecological indices of diatom

Ponds	Individuals (N)	Species (S)	Shannon Index (H')	Pileou's evenness (J')
Cibuntu	300	17	2.4	0.8
Cilalay	300	10	1.6	0.5

Diversity index (H') and Evenness Index (J') of Cibuntu and Cilalay Ponds

The diversity index of Cibuntu is higher than Cilalay, but in terms of water quality Cilalay is better which is characterized by the dominance of *Fragilaria* and supported by existing water quality measurement. In line with Pileou's evenness index, Cibuntu has a value of 0.8, which is a high evenness value (close to 1), the distribution of species spread evenly.

Different levels of disturbance of limnological properties of each lake have a different effect on diatom diversity. Diatom community analysis showed that Cilalay and Cibuntu Ponds have different limnological conditions and trophic states.

CONCLUSION

Our study provides an inventory of diatom diversity and distribution in Cibuntu and Cilalay surficial sediments. We identified a significant difference between the diatom community composition of Cibuntu and Cilalay Ponds. The difference in diatom community composition is consistent with the prevailing limnological conditions between the ponds.

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