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Surface Diatoms and Water Quality of Balekambang Lake Dieng, Java, Indonesia

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Abstract

Balekambang Lake is one of the lakes in the Dieng Plateau and has been experiencing a significant problem in shrinking water areas due to high sedimentation. Diatoms are bioindicators that are highly sensitive to environmental changes. This study aims to analyze water quality based on the diatoms communities. Surface sediment from Balekambang Lake was taken from five sampling points, then digestion using 10% HCl and H_2O_2, followed by preparation using 1.73 naphrax and observation using a microscope with 1000x magnification. The results obtained 103 species of diatoms dominated by the genus *Pinnularia* (14 species) and *Nitzschia* (9 species). The relatively abundant relative abundance of *Pseudostaurosiropsis connecticutensis* (17.64%) and *Nitzschia palea* (29.29%) indicates that the lake is run into eutrophication process due to nutrients entering from potato farming, which generally contains agricultural fertilizers containing macronutrients (N, P, K). Based on the Shannon-Wiener diversity index (H'), Evenness index (e), and Dominance index (D), it shows that the condition of Balekambang Lake tends to be stable, which is found to have variations due to adequate nutrition for diatoms.

Keywords: diatom, Balekambang Lake, eutrophication, water quality

1. Introduction

Dieng plateau is the highland in Java, known as *Khayangan*, which means the land of heaven because the land is covered with clouds. Dieng plateau is a volcanic complex, and the remaining small lakes in Dieng have unique characteristics. Dieng's lakes have an important function in ecology, economic, and societal aspects. The soil around Balekambang Lake is comprised of organosol, which is developed from organic substances. Organosol soil comes from swamp forests, has slightly acidic properties, and has a large water capacity with few nutrients [1]. Balekambang Lake is connected to the Arjuna Temple as a water reservoir to prevent flooding in Arjuna Temple. This lake is shaped like an urn; the lake's surface looks narrow, but the bottom is broad.

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The Balekambang Lake is continuously used by the community to irrigate potato farms. As a result, the soil in the lake has lost the ability to withstand erosion rates, causing rapid sedimentation in Balekambang Lake [2]. Recently, the conditions of Balekambang Lake have looked more like a rainwater basin than a lake. This phenomenon affects the lake's water quality, so it is necessary to study water quality using biological aspects.

Water quality assessment plays a vital role in the preservation and management of aquatic ecosystems [3]. The degradation of water quality, often resulting from human activities, poses significant threats to both ecological and human health. Consequently, effective monitoring strategies are imperative for understanding the complexities of water systems and implementing appropriate management actions. Within this context, diatoms, a diverse group of microalgae, have emerged as essential bioindicators for water quality assessment [4].

Bacillariophyta or diatoms are single-celled microalgae with silica cell walls that are unique and have specific ornamentation. The siliceous cell wall of a diatom is resistant to natural processes, so they do not undergo biodegradation well preserved in the sediment in the form of microfossils. Diatom microfossils have been widely used as a tool for environmental analysis because they have sensitivity to changes in environmental conditions; with the help of the distribution and structure of the diatom community, the pattern of changes that occur in the environment can be reconstructed based on the diatom assemblages.

The application of diatoms in water quality assessment primarily revolves around their response to environmental changes. Through the analysis of diatom assemblages, researchers can gain valuable insights into the ecological health and trophic status of aquatic ecosystems, like in Qinhai Lake [5], and Tibetan Plateau [6]. Changes in the composition, abundance, and community structure of diatoms reflect alterations in water quality and can be indicative of pollution sources [7]. The significance of diatoms as bioindicators is not limited to their ability to assess water quality parameters. Diatoms' historical records preserved in sediment cores provide invaluable information. Based on the function of diatoms as bioindicators of water quality, this study aims to analyse water quality based on the diatoms communities.

2. Materials and Method

2.1 Study area

Balekambang Lake, located at coordinates 7º 12' 44' - 7º 12' 53' SL and 109º 54'47' - 109º 54' 56' EL. This lake is located south of the Arjuna Temple complex and has a sacred cultural value for the community. The name Balekambang means 'bal kumambang,' which means floating land. The area of the lake ranges from nearly 3 hectares and is filled with water hyacinth plants (Figure 1). The hydrological condition of Balekambang Lake has decreased a lot because residents use it for irrigation. The shrinkage of water that occurs causes Balekambang Lake to turn into peatland. In 1983, this lake was still a large area flooded with water, but from time to time, it turned into agricultural land due to considerable sedimentation. Physically, the condition of Balekambang Lake is very concerning because the water body's volume continues to decrease progressively, so the lake almost disappears

Figure 1: The current condition of Balekambang Lake is filled with water hyacinth.

2.2 Data Collection

Sampling was done in 2021 by taking sediment samples for diatom analysis and in situ water quality measurements. Surface sediment samples for diatoms were taken from 5 sites: B1 is near inlets representing the impact of agriculture, B2 around gardens, B3 inlets, B4 from floating soil, and B5 catchment areas (Figure 2). Surface sediment samples were taken using a small trowel. Water quality measurements include pH, temperature, conductivity, turbidity, and dissolved oxygen (DO) using Horiba water checker U50 with three repetitions.

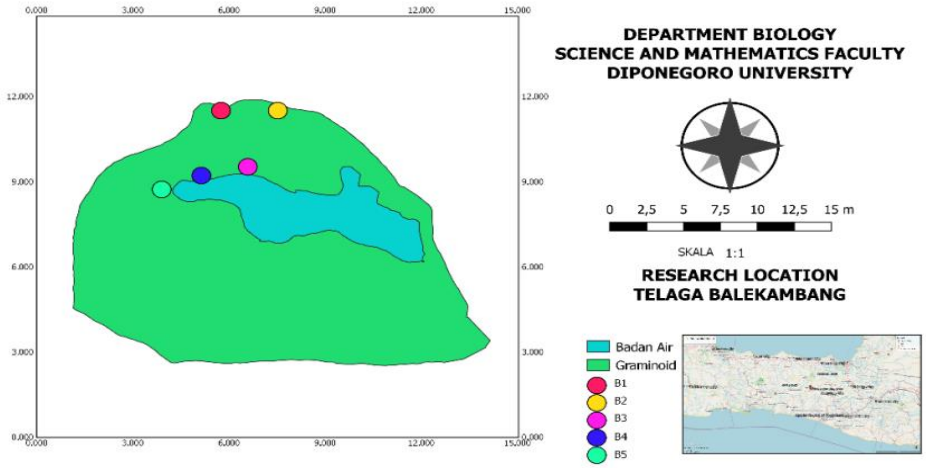

Figure 2: Research site at Balekambang Lake. B1: inlets representing the impact of agriculture, B2: around gardens, B3: lake inlets, B4: floating soil, B5: lake catchment areas

2.3 Data Analysis

Diatom analysis was carried out according to Battarbee [8]; firstly, the sediment was weighed 1 gram and then digested to separate the diatoms from the sediment by adding 50ml of 10% HCl and 10% H_2O_2. Preparation of sediment samples permanently using Naphrax with a refractive index of 1.73. Identification of diatoms under a 1,000x magnification, using Olympus microscopy with optical camera, and then the results of photograph compared using the identification books [9,10] and AlgaBase.org [11]. Calculation of the Shannon-Wienner diversity index (H'), Evenness index (E), and dominance index (D) using PAST version 4.1. Shannon-Wiener diversity index (H') can be calculated using the following equation [12]:

$$H' = -\sum_{T=1}^{S} Pi \ln Pi. \quad (1)$$

Description:
H' = Diversity index
S = Total genus
P_i = N_i/N
N_i = Proportion of individuals of i species in a whole community
N = Total number of individuals in a community

Evenness index (E) can be calculated using the equation [13]:

$$E = \frac{H'}{\ln S}. \quad (2)$$

Description:
E = Evenness index
H' = Diversity index
S = Total genus

Dominance index (D) can be calculated using the equation [13]:

$$D = \sum(\frac{Ni}{N})^2. \quad (3)$$

Description:
N = Total number of individuals in a community
N_i = Proportion of individuals of i species in a whole community
D = Dominance index

3. Results and Discussions

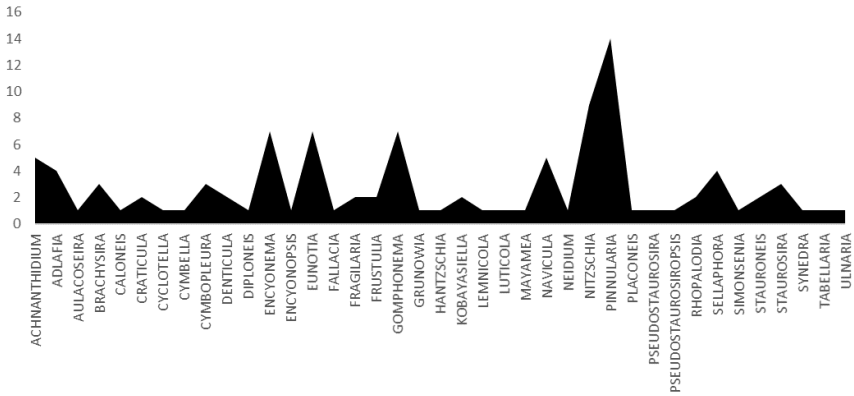

Figure. 3 Genera preserved in the surface sediment of Balekambang Lake, Dieng.

The diatoms recognized in Balekambang Lake consisted of 103 species of diatoms, which included 39 genera and just 10 species that had an abundance of more than 2% (Table 1). The genera with the highest number of species were *Nitzschia* (9) and *Pinnularia* (13), as shown in Figure 3. The abundance of the *Pinnularia* was also found in Poland [14], Luxembourg [15], and Malaysia [16]. The dominance of *Pinnularia* indicates the excess of nitrate, nitrite, and phosphate, which come from agriculture and enter the lake [7].

The *Nitzschia* genus is a diverse group of one of the largest diatoms, comprising numerous species found in marine, freshwater, and terrestrial habitats worldwide. *Nitzschia* are significant primary producers in aquatic ecosystems. They play a vital role in the carbon and nutrient cycles by converting inorganic nutrients into organic matter through photosynthesis [17]. Research by Duong *et al.,* [18] provide scientific evidence for the relationship between *Nitzschia* and environmental conditions such as nutrient availability, temperature, and

light. The abundance of this genus indicates that the condition of the waters is in eurofic status and moderate pollution.

Table 1: Diatoms abundance (%) preserved in the surface sediment of Balekambang Lake

Species	% Abundance				
	B1	B2	B3	B4	B5
Pantocsekiella delicatula (Hustedt) K.T.Kiss & E.Ács	7.89	0.00	0.71	11.96	3.74
Denticula elegans Kützing	11.84	3.55	0.00	0.46	0.00
Denticula tenuis Kützing	0.00	11.55	0.00	0.77	0.00
Diploneis subovalis Cleve	6.58	4.62	0.71	2.30	2.25
Gomphonema lagenula Kützing	9.21	0.00	0.00	3.22	2.99
Gomphonema parvulum (Kützing) Kützing	6.58	2.66	16.43	4.75	1.65
Nitzschia palacea (Grunow) Grunow	10.53	0.00	0.00	0.00	3.74
Nitzschia palea (Kützing) W.Smith	0.00	0.00	29.29	7.21	9.58
Pseudostaurosiropsis connecticutensis E.A.Morales	0.00	8.53	15.00	17.64	9.73
Staurosira construens Ehrenberg	0.00	0.00	0.00	0.31	0.45

The Shannon-wiener diversity index (H') shows that sites B2, B4, and B5 have a high diversity condition indicating a stable ecosystem. The Evenness index (E) showed that only site B4 showed a trend towards unevenness (<0.05). The dominance index showed the absence of dominant species in all sites (Figure 4). The ecosystem conditions in Balekambang Lake are almost similar to those in Cebong Lake [19]. Both are springs located in the Dieng mountain region and are experiencing a decrease in size due to changes in land use to agriculture and the increasingly rapid sedimentation rate on the lakeside. Different influences cause the difference in the value of each site.

In research at Cebong Lake [19], 60 species were found with *Achnanthidium minutissimum* found to be abundant and dominant at all sampling points. These species have a fairly wide tolerance range, from oligotrophic to hypereutrophic [20]. Conditions in Cebong Lake are also favorable for *A. minutissimum* to live, namely that it is filled with hyacinths, where this species is epiphytic (attached to plant substrates). Different things were found in the conditions of Balekambang Lake, where the floating soil characteristic was beneficial for *N. palea* to live. *Nitzschia* is one of the largest (about 900 species) and is distributed worldwide in marine and freshwater habitats, soil, on rocks, in caves, etc. [20]. However, based on the diatom composition found, Cebong Lake is still in an oligo-mesotrophic condition, cleaner than Balekambang Lake, which is experiencing eutrophication due to the supply of macronutrients from potato farming, as is the condition experienced by Rawapening Lake is experiencing eutrophication due to the supply of nutrients from the agricultural, which reaches up to N (769,025 ton) and P (105,432 ton) [21].

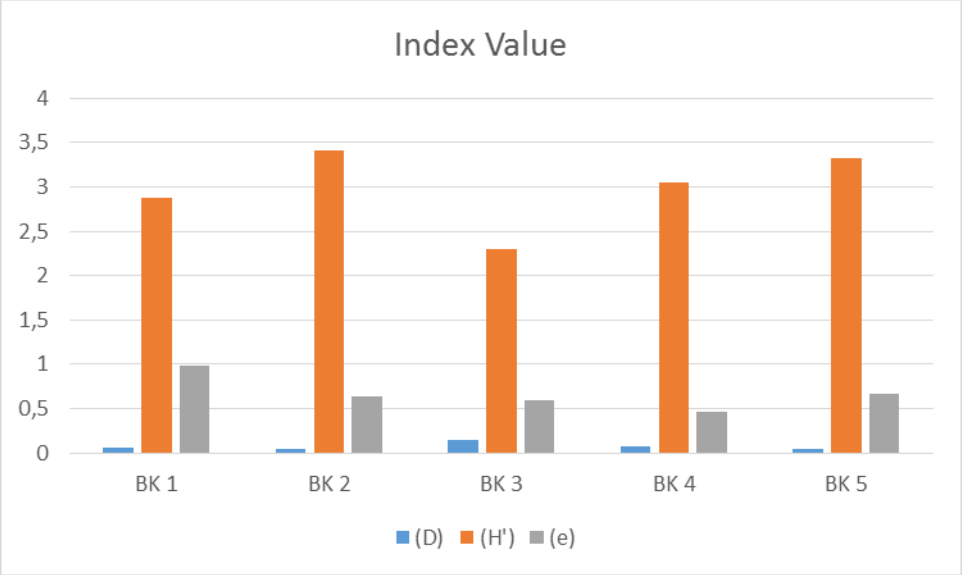

Figure 4 The diversity index (H'), the dominance index (D), and the evenness index (E) show relatively stable ecosystem results in Balekambang Lake.

Calculations using the Shannon-Wierner diversity index (H') indicate the stability of the ecosystem, the evenness index (E) shows the distribution of individuals, and the dominance index (D) determines the emergence of species dominance. The more diatom species discovered can indicate that ecosystem productivity is also increasing. This is because the problems faced by Balekambang Lake problem is sedimentation due to potato farming. Potato farming drains fertilizer particles that contain nutrients for diatoms, such as N, P, and K content [22], characterized by an abundance *of N. palea*. Diatoms in paleolimnological studies are often used to reconstruct environmental conditions from the past to the present. Within a lake, diatom communities change between substrates and depth locations because of the associated variation in resources and physical conditions [23].

P. connecticutensis dominates in Balekambang Lake, which indicates that the pH conditions in Balekambang Lake are neutral and are at the eutrophic trophic level, which is similar to the research of Radhakrishnan *et al*., [24] in India. The abundance of this species indicates increased erosion in the catchment area, leading to runoff into the water, resulting in cation input, which is closely related to foredune instability and vegetation clearance due to agro-pastoral or crop and livestock practices. This species also indicates a shallow water environment. *Pseudostaurosiropsis connecticutensis* has a limited autecology, and its presence can also be considered an indication of freshwater dominance in waters with slight saline variation [25]. This can also be shown through the results of calculating water parameters (Table 2), which indicates that Balekambang Lake is a freshwater ecosystem.
N. palea was found in sediments having a reasonably high dominance; this indicates that Balekambang Lake is eutrophic and polluted with heavy metals. *N. palea* is primarily found in the B3 site; this is because the inlet at the B3 comes from an agricultural area; based on research, human activities in the catchment area affect the water quality of the lake, the use of fertilizers for agricultural activities causes a eutrophic condition of lake waters. *N. palea* was the most commonly found species, and the chemical characteristics of water mostly determined its distribution. It was predominantly found in extremely polluted locations [26]. *N. palea*, a species with a high nutrient tolerance, has been found in heavily cultivated agricultural areas and urban contexts. The diatom *N. palea* removes ammonia, nitrate, phosphate, and chemical oxygen demand (COD) from wastewater [27].

G. parvulum has been widely acknowledged as cosmopolitan, widespread, and morphologically diverse, with numerous reported variants. Furthermore, cells belonging to the *G. parvulum* group exhibit a high degree of sensitivity towards alterations in water quality [28]. That was classified as a species that can tolerate organic pollutants, as indicated by previous research . It has a relatively low pollution tolerance rating [29]. Prior studies have demonstrated that *G. parvulum* is frequently observed in water bodies that have undergone significant disturbance and are rich in organic matter. Additionally, it can serve as an indicator species for river eutrophication [30]. Furthermore, *Gomphonema angustatum, Cymbella naviculiformis, Cymbella sinuata*, and *Melosira varians* can also be markers of mild or moderate pollution [29]. It means lake conditions were in poor health and might have organic pollution or other human disturbances.

A nutrient increase also occurred in Warna Lake [31], where this lake is still one area with Balekambang Lake in Dieng. The high level of nutrients entering Warna Lake is characterized by the appearance of the *Sellaphora*, which indicates that the water conditions contain high total phosphorus [32]. This genus was found in Rawapening Lake with conditions containing total phosphorus. In a study by López-Sandoval [33], it was shown that *P. viridis* is a thermophilic species and was found at 30.4ºC and 47ºC. This finding is consistent with the temperatures measured at all sampling sites in this study (Table 2).

P. divergentissima is an aerophilic taxon, similar to *Hantzschia. amphioxys*, which has tolerance to harsh and stressful environments, such as humidity, temperature, and sedimentation [33]. The dominance of aerophilic taxa is generally abundant in open waters due to land clearing around the waters for community needs. This causes low productivity of diatoms, so aerophilic taxa appear because they adapt well to metal pollution and sediment deposition [34]. As Balekambang Lake continues to experience sedimentation yearly, *P. divergentissima* species are still abundant.

Table 2: Water quality of Balekambang Lake

NO.	PARAMETERS	Site				
		B1	B2	B3	B4	B5
1.	pH	7.60	7.64	7.78	7.59	7.64
2.	DO (ppm)	6.13	8.82	9.32	10.35	10.97
3.	Conductivity (Ms/cm)	0.485	0.557	0.555	0.447	0.548
4.	Temperature (C)	31.82	31.83	16.84	31.78	32.41
5.	Turbidity (NTU)	108	81.4	-	94.5	82.7

The condition of the waters in Balekambang Lake based on the physical factors of water (Table 2) shows that based on the Government Regulation of the Republic of Indonesia Number 22 of 2021 [35], no parameters exceed the standard quality threshold for lake waters. The novelty of this research is that the lake's condition is still quite good based on these physical factors. However, based on the diatom species Balekambang Lake is in a eutrophic condition due to the influx of nutrients from potato farming and settles at the lake's edge periodically, causing sedimentation.

4. Conclusion

Surface sediment collection in Balekambang Lake with five sampling locations showed that *P. connecticutensis* had the highest abundance among the 103 diatom species found. The appearance of this species and *G. parvulum* indicates that the water conditions are in eutrophic conditions, although based on water physics measurements, the lake shows good conditions. Ecosystem conditions also show relatively stable conditions based on the calculation of the diversity index (H'), evenness index (E), and dominance index (D). As environmental

bioindicators, the results shown by diatoms prove the influence of agriculture and human activities on the ecosystem and water quality in Balekambang Lake.

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6. Conflict Of Interest

The authors declare no competing interests.

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