Evaluating Primary Productivity Based on Chlorophyll-a in Ciburuy Lake, West Java Indonesia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Ciburuy Lake is the one of many natural lakes in Padalarang, West Java. Padalarang is industries area and pruduce huge waste water to contamination Ciburuy Lake. Ciburuy Lake area has many functions such as tourism, settlement, agriculture and industry. This study aim to evaluate velue of primary productivity based on chlrophyill-a. Chlorophyll-a is one of the indicator to creat management plan of water resources in Ciburuy Lake. This research was conducted from January to March 2021. Sampling carried out in 4 station with deferent water situation. This research used chlorophyll-a concentration measurment method to determine primary productivity. Result obtained in terms of water quality are: temperature range of 24 - 28 ^{o}C; depth water range of 151,83 – 190,83 cm; Transparation range of 22,83 – 27,67 cm; pH range of 5,94 – 8,00; CO_2 range of 6,98 – 33,52 mg/L; BOD range of 7,84 – 12,14 mg/L; nitrate range of 0,235 – 0,312 mg/L; fosfate range of 0,142 --0,156 mg/L, and chlorophyll-a concentration range of 0.024 - 0.065 mg/L . This research showed that Ciburuy Lake has water condition eutrophic to hypertrophic because primary productivity in Ciburuy Lake has middle to high condition based on chlorophyll-a concentration.

Keywords: Primary productivity; Chlorophyll-a; Ciburuy Lake; Water quality; Indonesia.

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1. INTRODUCTION

Ciburuy Lake is the one of many natural lakes in West Java, Indonesia. The location is specificated in Padalarang West Bandung Regency. Ciburuy Lake area has many functions such as tourism, settlement, agriculture and industry [1]. The Geographic of Ciburuy Lake is around the hill full of limestone. Padalarang is industries area with a lot of limestone mining activities from small industrial scale to big industrial scale. Limestone mining activities has a negative impact as damaging the environmental around the mine [2]. Human and industry activities produce weste water and give high consectration of organic matter to Ciburuy Lake.

There are a lot of problems in Ciburuy Lake that polluted by tourism activity waste, agricultural waste, domestic waste and industrial waste. Their activities produce organic substance and deliver to Ciburuy Lake. Amount polluted to take organic metter with huge concentration in the water potentially raise blooming phytoplankton [3]. Blooming of phytoplankton will only occur if it is supported by other factor such as availability of under water light and physical condition of water [4]. Ussualy blooming phytoplankton can make ecological disorder such as the mass death of water biota and aestethic disorder [5].So preventive action to keep water quality still good is to know about water management and specialy primary productivity

Primary productivity is the rate of production of organic carbon (carbohydrates) in time and volume through photosynthesis carried out by green plant organisms [6]. Primary productivity level can used for give an overview of fertility of the waters [7]. There are several ways that can be used in determining primary productivity including method of : enumerasi, chlorophyll-a concentration, organic carbon, the concentration O_2 and CO_2 , and biovolume calculation [6].

Chlorophyll-a is one of the pigments owned by phytoplankton and functions in the photosynthesis process [8]. This pigmen is an indicator in determining water fertility because it can be used as parameter in determining primary productivity [9]. This study aim to evaluating the velue of primary productivity based on chlrophyill-a.

2. MATERIALS AND METHODS

2.1 Research Time and Place

This research was carried out on the Ciburuy Lake, Ciburuy Village, Padalarang District, West Bandung Regency, West Java, Indonesia with coordinate 6°49'50" S - 107°28'8" E. the method use in this research is the survey method and the sampling technique is purposive sampling. Determination of the station is done in January to March 2021. Sample water ware taken on the surface from 4 stasion with 6 repitation of sample. Distribution of location is distinguished based on human and water activities. Location detail :

- Stasion 1 is an Inlet of Ciburuy Lake Located with coordinate 6°49'44" S - 107°27'45" E. This stasion near from resedential area and a place for receiving waste water that enters to Ciburuy Lake.
- Station 2 is a midle of Lake with coordinate 6°49'53" S - 107°28'7" E. There is the effect of waste water from restaurants in the middle of the island. Station 2 – Station 4 area used as a tourist area and crowded by boat for the transportation.
- Station 3 is the middle part of the Ciburuy Lake that forms the bay with coordinate 6°49'36" S - 107°28'7" E. This area is often used by the atlite to practice various water sports.
- Station 4 is an outlet of Ciburuy Lake located with coordinate 6°50'1" S - 107°28'11" E. This area is a tourism center in Ciburuy Lake and there is a lot of garbage.

2.2 Sampling and Water Quality Measurment

Sampling of water and chlorophyll a was carried out six times with an interval of once every seven days at 4 stations. Samples were taken from 9 am to 12 pm. The water and chlorophyll a was carried out on the surface section of the Ciburuy Lake by inserting 2 liters of water into a sample bottle, and than analyzing the water quality parameters in-situ and ex-situ. The equipment used in measuring water quality are : seccidisk, pH meter, DO meter, sentrifuge and spectofotometer. In-situ water quality measurements include temperature, transparency, depth, pH, CO_2, and DO. Ex-situ analysis in the form of analysis of BOD, nitrate,
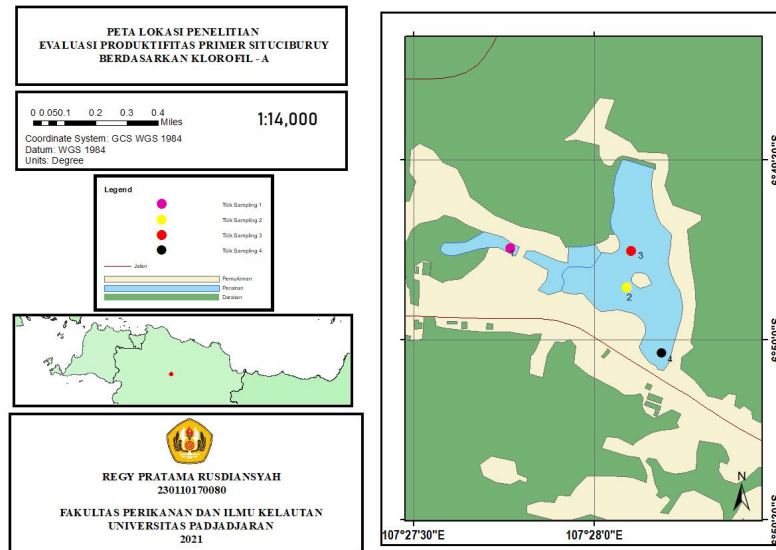
Fig. 1. Map Research of Ciburuy Lake

phosphate and chlorophyll-a conducted at the Water Resources Management Laboratory Faculty of Fisheries and Marine Science Padjadjaran University.

2.3 Primary Productivity Measurment

The calculation of primary productivity was conducted by calculating the concentration of chlorophyll-a pigment using the trichromatic method. Based on [8], the value of chlorophyll-a concentration can be calculated using the following formula:

Chlorophyll-a (mg/L) = Ca . (v/V.L)

Ca : (11.6 x D665) – (1.31 x D645) – (0.14 x D30)

Description :

v = Acetone volume used (mL)
V = Filtered water volume to be extracted (L)
L = Cuvet length (cm)
D665 = Optical density at wavelengths 665 nm
D645 = Optical density at wavelengths 645 nm
D630 = Optical density at wavelengths 630 nm

3. RESULTS AND DISCUSSION

3.1 Water Quality Parameters

Temperature in Ciburuy Lake have range betwen 24°C – 28°C with an average of 26.17±1.17°C at

station 2,3,4 and 25.67±1.21°C at station 1 (Table 1). The optimum temperature for phytoplankton growth in tropical waters ranges from 20-30°C [10]. if a water has a temperature lower or higher than the optimum temperature according to [11] this will have a negative impact on the quality of chlorophyll-a phytoplankton and will cause a decrease in the primary productivity of the waters. Thus, Ciburuy Lake is included in the category good waters for phytoplankton growth.

The depth of Ciburuy Lake ranges from 132 cm – 220 cm with the deepest depth at station 1 with an average of 215±7.8 cm and the shallowest at station 3 with an average of 152±5.1 cm (Table 1). This not too big difference in depth illustrates that the waters of Ciburuy Lake have a sloping bottom. The slightly different depth at each station indicates that the bottom contour of Ciburuy Lake is uneven. According to [12] The difference in depth in a water can be caused because each bottom of the water has a different topography. In addition, dredging activities at the inlet carried out in 2012 made station 1 Ciburuy Lake have the deepest depth compared to other stations.

The transparency of sunlight on the surface Ciburuy Lake has a value with a range between 19 cm – 33 cm (Table 1). Station 1 has an average transparency of 27.67±3.33 cm, this value is higher than the other 3 stations, while station 2 is the station with the lowest

transparency with a value of 22.83±2.14 cm. Light intensity optimum for phytoplankton is between 30 – 50 cm [13]. Waters that have high transparency do not necessarily have a high concentration of chlorophyll-a, this is because photoinhibition can occur. According [6] photoinhibition is the process of inhibition caused by the intensity of light in waters that are too high. Based on Table 2 , the waters of Ciburuy Lake are included in the category hypertrophic.

pH value of Ciburuy Lake with a range between 5.31–8.37. The highest average pH value was at station 3 of 8.00±0.27 and the lowest was at station 1 with a pH value of 6.25±0.65 (Table 1). Station 1 has the lowest pH value among other observation stations. This is due to the fact that this area is directly adjacent to residential areas and limestone factories. According [14] a good and ideal pH value for the life of aquatic organisms, especially plankton, is in the range lower or slightly higher than the pH value of 7. When viewed as a whole, the condition of Ciburuy Lake is still quite good. The reason is, based on the Presidential Regulation of the Republic of Indonesia Number 22 of 2021, the threshold for the pH value of the waters ranges from 6-9.

The results of CO_2 measurements in the Ciburuy Lake ranged from 4.19 mg/L – 37.71 mg/L with the highest average value at station 1 with a value of 33.52±5.30 mg/L and the lowest at station 4 with a value of 6.98±2.16 mg/L (Table 1). CO_2 concentration in the station 1 Ciburuy Lake has the highest value. This is influenced by the area that is directly adjacent to community settlements so that the household waste produced every day affects water quality and makes the concentration of chlorophyll-a low. High and excessive concentrations of dissolved CO_2 in waters have the potential to interfere with the survival of aquatic organisms because they are toxic [15].

BOD measurements in Ciburuy Lake waters are quite diverse with a range between 3.24 mg/L – 14.59 mg/L. The highest average BOD was at station 2 with a value of 12.16±2.24 mg/L and the lowest was at station 4 with a value of 7.84±1.90 mg/L (Table 1). The Waters with a BOD value category of less than 3 mg/L are classified as good waters and if they have a BOD value of more than 10 mg/L these waters are polluted with organic matter [16]. The high value of BOD in the waters of Ciburuy lake is due to the high organic matter contained in the waters of Ciburuy Lake. Concentration of BOD and organic matter

have a directly proportional relationship. high concentration of bod will be followed by high concentration of organic matter [17].

DO measurement results have values in the range between 6.1 mg/L – 7.3 mg/L. The highest DO average was at station 3 with a value of 7.1±0.4 mg/L and the lowest was at station 1 with a value of 6.3±0.3 mg/L (Table 1). Station 3 has the highest dissolved oxygen content because its area has a large enough open area so that it is possible for the diffusion of oxygen from the air into the waters. Air diffusion and photosynthesis are the main resources of oxygen in the waters [18].

Nitrate concentration in Ciburuy Lake have range of 0.200 mg/L – 0.360 mg/L. The highest average nitrate concentration at station 4 with a value of 0.312±0.038 mg/L and the lowest was at station 1 with a value of 0.236±0.020 mg/L (Table 1). Station 4 as an active outlet is used as a tourism area so that more garbage is found than other stations. According [18] garbage in the waters undergoes a process of decomposition, weathering and becomes the main source of organic matter in the waters such as nitrate and phosphate. There are 3 criteria in determining water productivity including: nitrate concentration below 0.1 mg/L classified as oligotrophic waters, nitrate content between 0.1 – 0.2 mg/L can be classified as mesotrophic waters and nitrate content more than 0.2 mg/L included in the eutrophic waters [19]. Situ Ciburuy has an average nitrate concentration ranging from 0.236 to 0.312 mg/L so that it can be categorized in Eutrophic waters.

Measurement of phosphate concentration in Ciburuy Lake shows a value that is not too significant for each station. Each station has a value in the range of 0.130 mg/L – 0.160 mg/L with the highest average being at station 1 with a value of 0.154 ± 0.005 mg/L and the lowest at station 2 with a value of 0.142 ± 0.008 mg/L. High phosphate concentrations accompanied by uncontrolled increases can result in an explosion of phytoplankton or what is often called blooming algae [10]. There are 3 classifications of water productivity based on phosphate, namely: a phosphate value of 0.003 – 0.010 mg/L classified as oligotrophic, phosphate with a concentration of 0.011 – 0.030 mg/L including mesotrophic and a phosphate value of 0.031 – 0.1 mg/L it can be said that the waters are eutrophic [20]. Based on this classification, Ciburuy Lake is included in the category of eutrophic.

Table 1. Water Quality Parameters Ciburuy Lake

Water Parameters		Station			
		1	2	3	4
Temperature (°C)	Range	24-27	25-28	25-28	25-28
	Average	25.67±1,21	26.17±1.17	26.17±1.17	26.17±1.17
Depth (cm)	Range	200-220	132-168	144-157	175-196
	Average	215±7.8	158±13.8	152±5.1	191±8.0
Transparancy (cm)	Range	23-33	20-25	19-28	17-30
	Average	27.67±3.33	22.83±2.14	24.33±3.20	25.17±4.49
pH	Range	5.31-7.15	7.65-8.63	7.71-8.37	6.63-8.31
	Average	6.25±0,65	7.94±0,21	8.00±0.27	7.36±0.61
CO_2 (mg/L)	Range	25.14-37.71	4.19-8.38	4.19-12.57	4.19-8.38
	Average	33.52±5.30	7.68±1.71	7.68±3.15	6.98±2.16
DO (mg/L)	Range	8.11-12.97	8.11-14.59	3.24-19.27	4.84-9.73
	Average	9.73 ±2.05	12.16 ±2.24	8.65 ±4.06	7.84 ±1.90
BOD (mg/L)	Range	8.11-12.97	8.11-14.59	3.24-12.97	4.84-9.73
	Average	9.73 ±2.05	12.16 ±2.24	8.65 ±4.06	7.84 ±1.90
Nitrate (mg/L)	Range	6.1-6.8	6.2-7.1	6.4-7.3	6.2-6.6
	Average	6.3±0,3	6.6±0.3	7.1±0.4	6.5±0.2
Phosphate (mg/L)	Range	0.213-0.270	0.200-0.280	0.213-0.320	0.260-0.360
	Average	0.236±0.020	0.235±0.034	0.269 ±0.045	0.312 ±0.038
Chlorophyll-a (mg/L)	Range	0.149-0.160	0.130-0.150	0.140-0.158	0.142-0.151
	Average	0.154±0.005	0.142 ±0.008	0.148 ±0.006	0.147 ±0.003

3.2 Consentration of Chlorophyll-a

The concentration of chlorophyll-a in the Ciburuy Lake during observations fluctuated values ranging from 0.024 -0.065 mg/L. Overall, the highest concentration of chlorophyll-a was at station 3 and the lowest was at station 1. Station 3 had the highest average concentration of chlorophyll-a, which was 0.058 ± 0.004 mg/L. This is because the station area 3 is an open water area that forms a bay. The bay area in Situ Ciburuy has calm waters and a longer water retention period than the other station. Station 1 has the lowest average chlorophyll-a concentration of 0.034 ± 0.008 mg/L this is because the waters of station 1 are the first inlet affected by the discharge of household and industrial limestone waste in the Ciburuy Lake area. The concentration of chlorophyll-a can be affected by the abundance of phytoplankton because every phytoplankton must have chlorophyll-a [6]. The classification is based on the trophic status of the water is chlorophyll at the range of <0,002 mg/L classified as oligotrophic, <0,005 mg/L in mesotrophic, <0,015 mg/L classified as eutrophic and ≥ 0,200 classified as hypertrophic [21]

Relationship between chlorophyll-a and phytoplankton abundance can viewed in Figure 2. The concentration of chlorophyll-a at station 1 has a value of 0.034 mg/L with an abundance of phytoplankton as much as 339.67 ind/L. Furthermore, the increase in the abundance of phytoplankton at station 2 with a value of 8867.67 ind/L was followed by an increase in n concentration of chlorophyll-a by 0.056 mg/L. This is because the correlation between the abundance of phytoplankton and the concentration of chlorophyll-a has a strong relationship [22]. However, not always a high abundance of phytoplankton is followed by a high concentration of chlorophyll-a. The opposite relationship occurred at station 4, an increase in the abundance of phytoplankton to 8913.33 ind/L followed by a decrease in the concentration of chlorophyll-a to 0.045 mg/L. According to [23], fluctuations in the concentration of chlorophyll-a do not show the same as the amount of abundance, which means that although high abundance of phytoplankton does not mean high concentrations of chlorophyll-a. One of the causes is that the phytoplankton filtered by the planktonnet and quantified are phytoplankton that have died and become carrion so that they do not have chlorophyll-a. When viewed from the size of the phytoplankton, waters that have a high abundance of phytoplankton and low concentrations of chlorophyll-a may have a lot of small phytoplankton so that the chlorophyll-a contained is not too much [24].

Nutrients such as nitrate and phosphate are factors that affect the concentration of

chlorophyll-a in water. According to [19] nitrate and phosphate can affect the concentration of chlorophyll-a, this has been tested by multiple regression analysis which results show a pattern of relationship that is directly proportional to the coefficient of determination (R^2) describing 97% of chlorophyll-a influenced by nitrate and phosphate. Increased nitrate and phosphate occurred at stations 2 and 3 Ciburuy Lake. In Figure 3 the increase in nitrate from 0.235 – 0.269 mg/L and phosphate from 0.142 to 0.148 mg/L was followed by an increase in chlorophyll-

a concentration from 0.056 – 0.058 mg/L. However, at station 4 there was an increase in nitrate to 0.312 mg/L and a decrease in phosphate to 0.147 mg/L. This event was followed by a decrease in the concentration of chlorophyll-a. This is because phosphate is a form of phosphorus that functions as an essential element for plants and phytoplankton, so that phosphate in waters becomes a limiting factor for phytoplankton growth and affects the productivity level of waters Davis and Cornwell in [10].
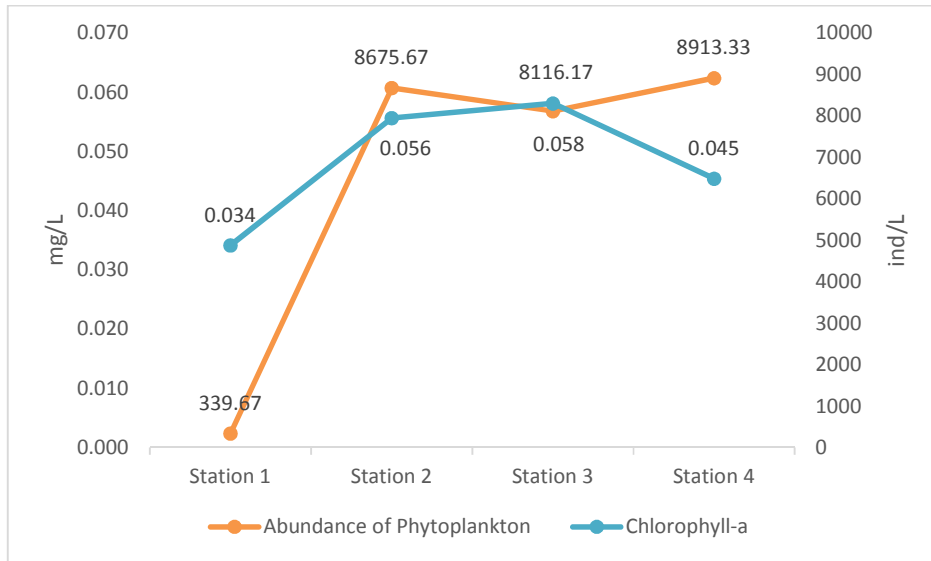

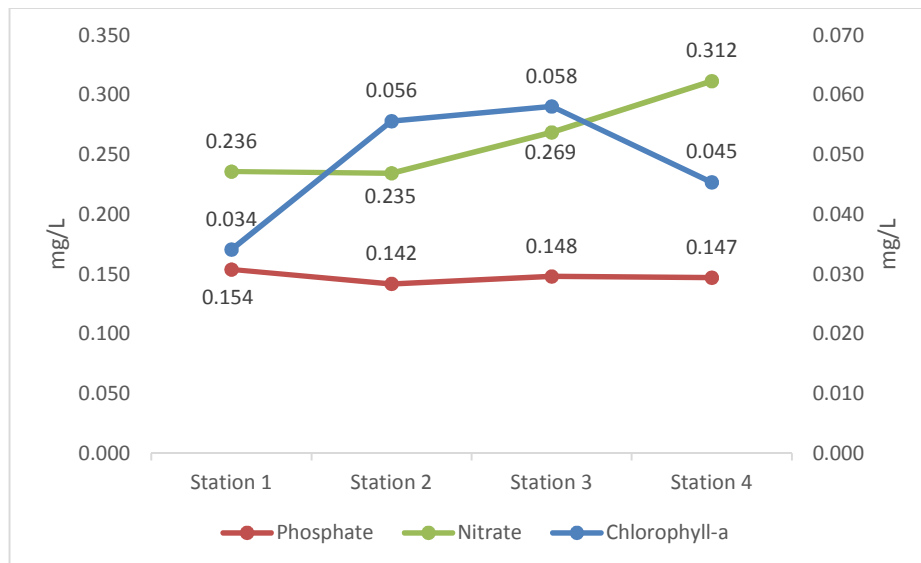**Fig. 2. Relation between chlorophyll-a and abundance of phytoplankton**

Fig. 3. Relation between chlorophyll-a and nutrient

Table 2. Category of Water Productivity

Parameter	Category			
	Oligotrophic	Mesotrophic	Eutrophic	hypertrophic
Transparancy (m)	≥ 10	≥ 4	≥ 2,5	< 2,5
Nitrate (mg/L)	≤ 0,65	≤ 0,75	≤ 1,9	> 1,9
Phosphate (mg/L)	< 0,01	< 0,03	< 0,10	≥ 0,10
Chlorophylll-a (mg/L)	< 0,002	< 0,005	< 0,015	≥ 0,200
Abundance of Phytoplankton (ind/L)	0 - 2000	2000 – 15000	> 15000	-

Sources:[24], [21], [25], [26]

4. CONCLUSTION

Primary productivity based on chlorophyll-a average of chlorophyll-a consentration in Ciburuy Lake has an ranging from 0.024 - 0.065 mg/L, and Ciburuy Lake can be categorizes is eutrophic to hypertrophic water.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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