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Phytoplankton as bioindicators of pollution status in Cirata Reservoir, Indonesia

Asep Sahidin[1*], Isni Nurruhwati[2], Zahidah[3], Heti Herawati[4]
[1] Aquatic Resource Laboratory, Faculty of Fisheries Dan Marine Science, Universitas Padjadjaran, Bandung, Indonesia
[2] Department of Fisheries, Faculty of Fisheries Dan Marine Science, Universitas Padjadjaran, Bandung, Indonesia

Abstract
Cirata Reservoir has various human activities such as tourism, housing, agriculture and aquaculture activities that can cause water pollution. Determination of water pollution can be determined through biological analysis studies using phytoplankton bio indicators. The study aimed to assess the level of pollution in the Cirata Reservoir based on phytoplankton bioindicators. The research was carried out in March 2015-February 2016 in the Cirata Reservoir which was divided into three research stations (inlet, middle and reservoir outlets). Water pollution analysis uses diversity index and saprobika index. The results of the study found 16 genera scattered into four phyla (Chlorophyta, Chrysophyta, Cyanophyta and Euglenophyta) with cyanophyta phyla dominating up to 68.5% of all phyla found. *Microcystis* sp. from the Cyanophyta phylum found with the highest abundance at each station with a value of 4646 ind/l followed by *Anabaena* sp. with a value of 2826 ind/l. Cirata reservoir diversity index (H '= 1.4 to 2.1) and Saprobika index (-1.26 to -2.10). Based on the analysis of pollution with bioindicators of phytoplankton in Cirata Reservoir, it is included in high-very high pollution status with organic elements as the main pollutant.

Keywords: cirata reservoir, pollution, phytoplankton, saprobika index

1. Introduction

Waters Reservoir has a very important role as a supplier of water into the rock layer below the surface of the land that is used as groundwater recharge areas, helping to improve surface water through physical-chemical-biological processes. Besides that the functions of the reservoir as a power plant, irrigation, recreation, water reservoir, regulating the micro climate, fisheries and supporting marine biodiversity (Maznah and Makhlaugh 2014) [15]. The reservoir water source can come from the main river and a number of other springs or from the entry of river water or runoff/rainwater. Judging from the function and source of the reservoir water can easily be degraded water quality can occur due to changes in water quality parameters. These changes can be caused by the presence of waste disposal activities, both industrial waste, agriculture, livestock, tourists, and domestic waste from a residential area into water bodies of a reservoir (Davies 2009) [6].

Reservoir waters are a unity (combination) between physical, chemical and biological components in a water medium in reservoir. The three components interact with each other, if there is a change in one component it will also affect the other components (Basmi 2000; Shekhar 2008) [5, 24]. Reservoirs as a type of living medium for aquatic organisms, often cannot be avoided from the problem of decreasing water quality as an effect of the development of human activities (Wilhm 1975; Offem *et al*. 2011) [26, 19].

Waste has the potential to polluted the aquatic environment and have an impact on aquatic organisms (Kumar 2015) [13]. The impact of this happening, the most important is the aquatic organisms (biological components). As a biological parameter, plankton especially phytoplankton which have an important role in the food chain in aquatic ecosystems are often used as indicators of stability, fertility and water quality. Phytoplankton are microscopic organisms that float in water and have very weak swimming abilities and their movements are always influenced by water currents (Davies 2009) [6]. Phytoplankton is a study to determine the quality of the fertility of a waters that is needed to support the productivity of the waters (Abowei 2012) [13]. However, since 1984 phytoplankton have been used as bioindicators of contamination in the aquatic environment (Kumar 2005) [13] and research with the latest saprobic index model in Indonesia (Indrayani *et al*. 2014) [12], Malaysia (Maznah and Makhlaugh 2014) [15], Mesir (El-Sheekh *et al*. 2010) [8], Nigeria (Abowei *et al*. 2012) [15], and India (Shekhar *et al*. 2008; Kumar 2015) [13].

The phytoplankton community in reservoir waters is usually dominated by species of the Chorophyceae class, Cyanophyceaea and Bacillariophyceae (Seller and Markland 1987) [10, 11]. The dominance of phytoplankton species in reservoir is determined by the comparison of the types of nutrients dissolved in these reservoir. This is caused by each type of phytoplankton having a different response to the comparison of the types of nutrients that exist, especially nitrogen and phosphorus in the medium (Barus 2004; Nontji 2005) [4, 16] and having short life cycles and rapid responses to environmental changes (Apostolopoulou andIgnatiades 1979; Schletterer *et al* 2011) [17, 22]. Based on the basic properties of plankton, this plankton abundance is used to determine the level of saprobitas by looking at the value of SI (Saprobic Index) and saprobic index can be determin for chacking water quality status in the reservoir.

A reservoir is a lake or artificial water body formed by damming the river flow. The reservoir area is one of the economic areas, many activities are carried out in the reservoir area such as fisheries, tourism, sports and hydropower. One of the reservoirs that has a complex activity is the Cirata Reservoir, so that it will have an impact on the quality of these waters. So it is necessary to monitor the latest water quality in Cirata Reservoir.

2. Material and Methods

This research was conducted in the Cirata Reservoir area, West Java Province, for 11 months starting from April 2015 to March 2016. The location of the sampling stations was determined by three stations using the purposive sampling method. The research station taken as many as three stations, namely the reservoir inlet (ir) is in Cihea Cianjur Regency is the Cirata Reservoir inlet, center reservoir (cr) is in Maleber Cianjur Regency is the middle area of Cirata Reservoir, and Outlet reservoir (or) is in Cipicung Regency, West Bandung District is the outlet of the Cirata Reservoir (Fig. 1).

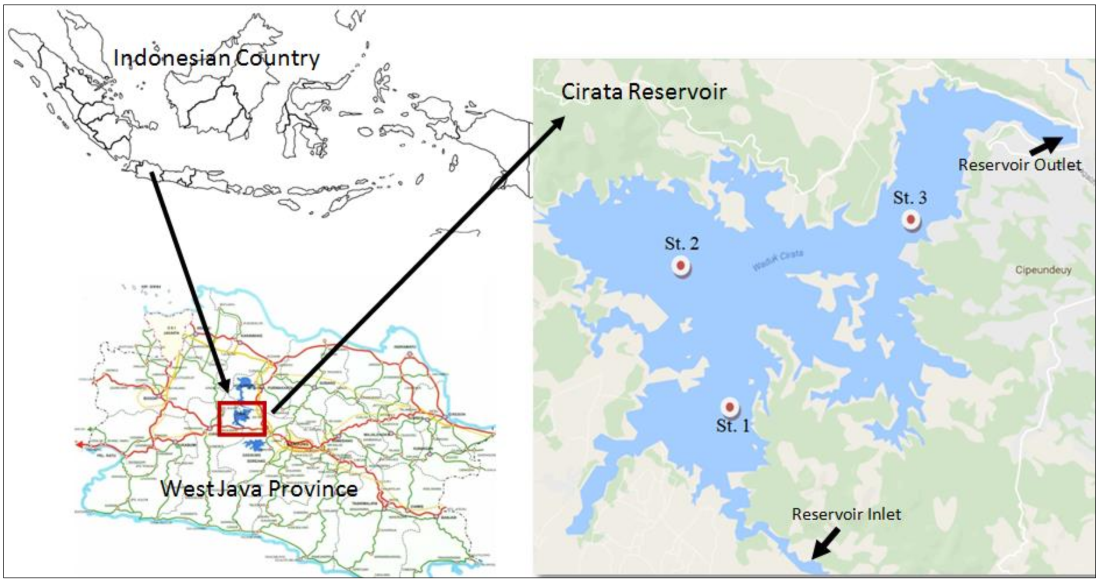

Fig 1: GIS location of sampling sites in Cirata Reservoir

The parameters observed included biological, physical and chemical parameters of the water quality. Biological parameters consist of plankton especially phytoplankton, physical parameters consisting of temperature and brightness, while the chemical parameters consist of pH, DO, CO_2, nitrate and phosphate. phytoplankton sampling by filtering 10 liters of water using plankton net with 200 µm mesh size is equipped with a container bottle. The accommodated phytoplankton is preserved with 4% lugol. Phytoplankton calculation and identification were carried out in the Aquatic Resources Laboratory of the Faculty of Fisheries and Marine Sciences, Padjadjaran University using a microscope and Planktonology identification book (APHA 2005) [2] and The Marine and Fresh Water Plankton (Davis, 1955) [7]. While the chemical parameters are carried out at the PPSDAL Laboratory (Center for Natural Resources and Environmental Research) and physical parameter measurements are carried out direct in sampling site.

The data in this study were analyzed descriptively in the form of tables and images. Phytoplankton samples obtained were calculated as abundance, species diversity and dominance index:

Abundance of plankton in Cirata Reservoir is calculated using the following formula (APHA, 2005) [2]:

$$N = \frac{1}{Vd} x \frac{Ja}{Jb} x \frac{Vt}{Vs} xF$$

Where:
N = Abundance of plankton (ind/l)
Vd = Volume of filtered water (10 l)
Vt = Filtered water volume (30 ml)
Ja = Area of container (1000 mm^2)
Jb = The total area of view is analyzed (100 mm^2)
Vs = The volume of water analyzed (3 ml)
F = Number of biota found (ind)

The diversity is analyzed by the following formula (Mason, 2002) [14]:

$$H' = - \Sigma \text{ Pi ln Pi}$$

Where;
H = Species diversity
Pi = 1st type proportion in the community (ni/N)
ln = Number of species to i
N = The total number of all species

The Diversity Index value (H) ranges from:
$0 < H' < 2$ = Small diversity
$2 < H' < 3$ = Medium diversity
$H' > 3$ = Large diversity.

While the dominance index is analyzed by the following formula (Odum, 1994) [18]:

$$C = (ni/N)^2$$

Where;
C = Domination index
Ni = Number of individual species to i
N = Total number of individuals

Saprobik Index (SI) can be calculated using the formula Dresscher and Mark (1974):

$$SI = (C + 3D + B - 3A) / (A + B + C + D)$$

Where;
SI = Saprobic index
A = Number of genera /Polisaprobic organism species
B = Number of genera/α – mesosaprobic organism
C = Number of genera/ β – mesosaprobic organism
D = Number of genera/ oligosaprobic organism

Tropic Saprobic index can be calculated using the formula:

$$TSI = \{(nC + 3nD + nB - 3nA) / (nA + nB + nC + nD)\} \times \{(nA + nB + nC + nD + nE) / (nA + nB + nC + nD)\}$$

Where;

N = The number of individual organisms in each saprobitas group

nA = The number of individual organisms in polisaprobic group

nB = The number of individual organisms in α – mesosaprobic group

nC = The number of individual organisms in β – mesosaprobic group

nD = The number of individual organisms in oligosaprobic group

nE = The number of individual organisms besides A, B, C, dan D

Table 1: Classification of pollution levels based on the saprobic index

Pollutant load	Pollution level	Saprobic phase	Saprobic index
Many organic compounds	Very hight	Polisaprobic	-3 to -2
		Poli/ α– mesosaprobic	-2 to -1,5
Organic and anorganic compounds	Hight	α– meso/ Polisaprobic	-1,5 to -1
		α– mesosaprobic	-1 to -0,5
	Moderate	α /β mesosaprobic	-0,5 to 0
		β/α mesosaprobic	0 to +0,5
A little organic and anorganic compounds	Low	β mesosaprobic	+0,5 to +1
		β meso/oligosaprobic	+1 to +1,5
	light	Oligo/ β mesosaprobic	+1,5 to +2
		Oligosaprobic	+2 to +3

3. Result and Discussion

Water Quality at Cirata Reservoir

Based on the measured water quality parameters (Tab. 3), it can be seen from all parameters of temperature, pH, dissolved oxygen, total phosphate, nitrate and ammonia that there is no signifikan difference. This means that the condition of the waters quality both inlet, center and outlet has a uniform distribution of water quality.

Table 3: Average and Water Quality Range of Cirata Reservoir

Parameter	Reservoir inlet	Reservoir center	Reservoir outlet
Suhu (^{o} C)	29.3 (25,5-31,0)	30 (29-31)	30,6 (30-31,2)
Kecerahan (cm)	110 (80-145)	119 (100-130)	124 (100-150)
pH	6,9 (5,5-8,1)	6,8 (5,5-7,8)	6,4 (4,3-7,5)
DO (mg/l)	6,8 (5,0-8,0)	6,9 (5,6-8,9)	7,6 (4,5-9,8)
Phosphat (PO_4) (mg/l)	0,065 (0,061-0,077)	0,061 (0,061-0,074)	0,068 (0,063-0,071)
Nitrat (NO3-N) (mg/l)	1,171 (1,143-1,400)	1,257 (1,247-1,286)	1,229 (1,171-1,600)
Amoniak (mg/l)	0,174 (0,117-1,037)	0,221 (0,121-0,600)	0,153 (0,153-0,495)

A signifikan difference is only in the brightness parameter. Inlet of reservoir has the lowest brightness with a value of 80 cm and the highest brightness is found at reservoir outlet which is 120 cm. This is because Cirata Reservoir inlet, there are still many organic materials carried away from the river that have not been sedimentated, causing turbidity in high water. Unlike Cirata Reservoir outlet, this allows turbidity-causing materials to be installed in the inlet and middle of the water. So that the water that reaches the outlet reservoir is relatively clearer.

Abundance of phytoplankton

Biological parameters in determining water quality begin with calculating abundance, diversity and dominance index. The results of identification of plankton in Cirata Reservoir were found in 4 classes consisting of 16 genera consisting of four classes namely Chlorophyceae (9 genera), Cyanophyceae (4 genera), Basillariophyceae (2 genera) and Euglenophyta (1 genus). (Tab. 1). The abundance of the highest genus in phytoplankton species at inlet, middle and outlet reservoir was found in the genus *Microsystis* with abundance of 5.758 x 103 ind/l; 3,662x103 ind/l and 4,518 x103 ind/l, followed by *Anabaena* and *Oscilatoria* (Fig. 2).

Table 1: Composition of phytoplankton in Cirata Reservoir (ir = inlet reservoir; cr = center reservoir; or = outlet reservoir)

Fhylum	Genera	ir (Ind/l)	cr (Ind/l)	or (Ind/l)
Chlorophyta	*Chlorococcum*	42	-	61
	Cosmarium	249	316	362
	Gloelocystis	280	229	280
	Microspora	163	133	217
	Pediastrum	156	171	216
	Scenedesmus	136	134	198
	Selenastrum	-	-	43
	Spyrogyra	144	147	190
	Ulathrix	1009	1353	1342
Cyanophyta	*Anabaena*	3174	2211	3091
	Merismopedia	295	224	242
	Microcystis	5758	3662	4518
	Ocilatoria	2592	1966	2765
Chrysophyta	*Navicula*	49	-	37
	Nitzschia	234	243	302
Euglenophyta	*Euglena*	543	328	128
Number of individual abundance		14824	11117	13992
Number of Genera		14	13	16

Abundance of plankton in Cirata Reservoir (Fig. 1) shows the difference in inlet, center and outlet reservoir. Based on the calculation of plankton abundance in the Cirata Reservoir, which is the sampling site in the Cirata Reservoir inlet, shows the highest plankton abundance ranging from 13290 - 18500 ind/l, compared to other sampling site during the study. This is presumably because this sampling site is a acumulated place for nutrient inputs which is an agricultural area and housing. The outlet reservoir, which is the sampling site shows the lowest abundance during the study, ranging from 9470 - 14980 ind/l. this is possible due to the low concentration of nutrients, because nutrients have been used and sedimentated in the inlet and center of the reservoir.

Base on abundance of reservoir inlet, the fertility stasus was included in Eutrof with an average abundance of 16646 ind/l and center and outlet (abundance of averages 13384 ind/l and 11742 ind/l) fertility included in mesotrophic status. this fertility refers to (Welch 1952; Davies 2012) [25] that plankton abundance 2000-15000 ind/l is included in the mesotropic status and abundance > 15000 ind/l, water status including eutrophy to hypertrophy.

The number of plankton taxa found during the study (Fig. 1), shows at inlet reservoir was found with the highest number of taxa ranging from 16-20 taxa. While the lowest number of taxa is found at outlet reservoir with a range of 14-18 taxa. The high nutrient at reservoir inlet and the low nutrient at reservoir outlet are the high reasons or the low number of taxa found at each sampling site. This is consistent with the statement of Rahayu *et al*. (2007) [21], that plankton in a waters (taxa and abundance) is determined by nutrients concentrated in the waters.

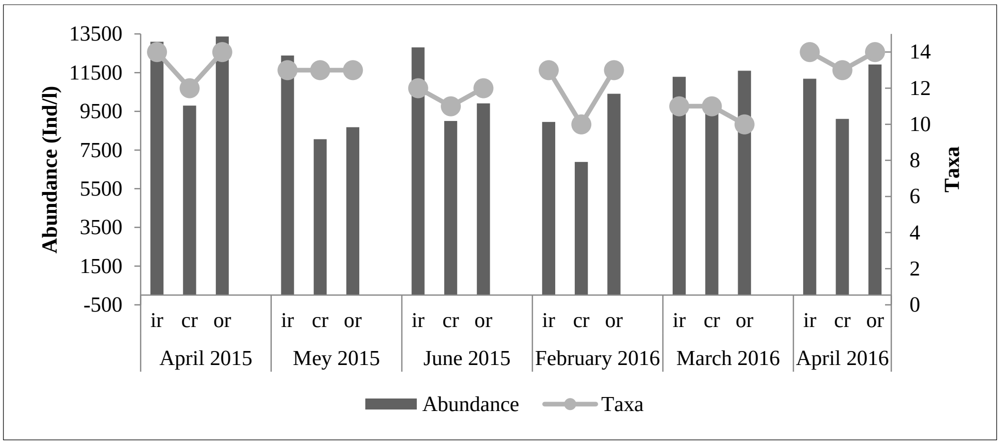

Fig 1: Abundance and taxas of phytoplankton at Cirata Reservoir (ir = inlet reservoir; cr = center reservoir; or = outlet reservoir)

Pollution status in cirata reservoir

The range of phytoplankton diversity index in this study was used in determining the criteria for water quality in the related waters scope, which refers to Wilhm (1975; El Syeekh *et al*. 2010). Besides using the diversity index approach, in determining the quality of the waters also used an approach based on saprobic coefficients (Tab.3). The results of the same study in the Cirata reservoir by Garno (2005) [9] also found that the microsystis genus had the highest abundance. The presence of Cyanophyta species, such as Mycrosystis (Tab.1) on all sampling site, is thought to be because it is an indicator of species in medium-heavy polluted waters. Species of Mycrosystis has a wide tolerance range for organic matter pollution and can act as an indicator in conditions of moderate polluted to heavily polluted (Aprisanti *et al*., 2013) [3].

Table 3: Plankton index in Cirata Reservoir

Station	H’	D	IS
Inlet reservoir	0.41	0.35	-2.10
Center reservoir	0.44	0.40	-1,30
Outlet reservoir	0.46	0.37	-1.26

Note: H’=Diversity index; D=Dominance index; IS= Saprobic index

The Diversity Index and dominance index in the Cirata Reservoir are shown in Table 2. The diversity index in all sampling sites ranges from 0.41 - 0.46, while the dominance index in the Cirata Reservoir ranges from 0.35 - 0.40 (Table 2). Based on the results of these studies the diversity index is included in the low category. This is in accordance with the statement of Odum (1994) [18] that plankton diversity 0 <H <1 is included in the low category. Likewise, the dominance index shows no significant difference between sampling sites. Each dominance index sampling site is classified as low, indicating that there is no genera with higher abundance than other genera.

In addition, according to Stirn (1981) in Basmi (2000) [5] this shows that the condition of the phytoplankton community in these sampling site is in low community stability (H` <1). In connection with industrial and organic waste originating from households, the condition of the community in these sampling sites will experience changes depending on the size of the waste entering the waters. Referring to the Shannon-Wiever index (1963), in general the Cirata waters at the time of the study were under moderate to heavily water conditions pollution.

The saprobic coefficient approach (Tab. 3) shows the level of water pollution at the reservoir inlet (IS = -2.10) in the highly polluted category with the saprobic phase on *polisaprobic*. This phase means that there is a change in the pollution conditions of many organic elements into the inlet waters of the reservoir. While the saprobic phase changes are also shown in the middle of the reservoir and reservoir outlet in the saprobic phase in *α-meso/polisaprobic*. The sabrobic phase included in the category of degree of contamination is rather high. Basmi (2000) [5] describes ammonia (NH3) to produce the final product, nitrate (NO3). In this phase it can also cause abundant phytoplankton in certain types. Conditions such as those shown in the center and outlet of the reservoir indicate a change in contaminated conditions, while the contaminants can be in the form of organic or inorganic materials.

In generaly, the waters of the Cirata Reservoir from the

reservoir inlet to the reservoir outlet area towards the downstream show a pattern of reservoirs which begins with the state of active decomposition until the recovery of water conditions, with pollutants in the form of organic and inorganic materials. However, the concentration of waste disposal which is continuously and increasing will cause the aging of the water bodies until the waters are no longer able to restore, which ultimately affects the aquatic organisms inside.
The saprobitas value of the water is an illustration of the level of pollution of a water which is measured by the content of nutrients and pollutants. Increasing nutrient content to the estuary area of the river can lead to phytoplankton blooms which result in increased water turbidity and decreased brightness (Basmi 2000) [5]. However, sufficient nutrient content will increase phytoplankton productivity. Increasing phytoplankton productivity will support increased productivity of other organisms that have higher trophic levels. Saprobitas is measured by phytoplankton indicators, because each type of phytoplankton is a constituent of certain saprobic groups that will affect the saprobitas value. The type of phytoplankton found is an appropriate bioindicator to determine the condition of the river, if there is pollution (Persoone and De Pauw, 1978) [20]. The existence of saprobic organisms as indicators of a aquatic is also determined by the quality of the aquatic environment. Each type of saprobic organism will occupy certain aquatic and its existence is determined by the waters quality, namely the physical properties and chemical properties of the waters (Davis 1955) [7].

4. Conclusion

Cirata Reservoir diversity index (H '= 1.4 s / d 2.1) and Saprobika index (-1.26 to -2.10). Based on the analysis of pollution with bio-indicators of Cirata Reservoir phytoplankton, it is included in high to very high pollution status with organic elements as the main pollutant.

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