BIO Web of Conferences **87**, 02012 (2024) https://doi.org/10.1051/bioconf/20248702012
ICFAES 2023

Pollution status of Aneuk Laot lake Sabang based on pollution index and saprobic index

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Abstract. Pollution that occurs in lake waters needs special attention from various parties in the management of the lake in the future. The activities occurring around the lake result in an increased inflow of pollution into the lake. The aim of this study is to assess the pollution condition of Lake Aneuk Laot in Sabang by utilizing indicators such as the pollution index, CCME WQI (Canadian Council of Ministers of the Environment Water Quality Index), and saprobic index. The investigation took place in both September 2019 and June 2021, employing the stratified random sampling method with four designated observation stations for the sampling process. Parameter measurements analyzed in the pollution index include temperature, depth, current, TDS, TSS, BOD, COD, DO, phosphate, nitrate, ammonia, sulfide, iron, lead, oil and fat, detergent, pH, e-coliform, and parameters used in the saprobic index include phytoplankton data. Based on the analysis of the Pollution Index and CCME WQI it is determined that the pollution status of Lake Aneuk Laot is heavily polluted for Class I, moderately polluted for Classes 1 and 2, and falls under the good category for Class 4. The saprobic index results show the beta-mesosaprobic category with a result of 2.3 (moderately loaded).

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1 Introduction

The Lake Aneuk Laot (DAL) is a lake that formed from the remains of a dormant volcano's activity and gradually filled with rainwater trapped within it, resulting in the formation of the lake. The lake's surface elevation remains relatively constant, at 25 meters above sea level, and during the rainy season, the water level can rise, although it rarely leads to flooding. According to the findings of [1] Lake Aneuk Laot (DAL) has no surface inlet, and similarly, there is no outlet for the lake. However, it is suspected that the lake has an underground outflow in the form of seepage and water flow through crevices in the lake's bedrock. Lake Aneuk Laot (DAL) holds a crucial role, in line with [2] as a small island like Pulau Weh relies on Lake Aneuk Laot (DAL) as a vital freshwater resource to support all aspects of life for the island's residents.

The waters of Lake Aneuk Laot (DAL) serve as a vital water source for the inhabitants of Sabang. Various activities such as agriculture, livestock farming, the cooling of PLN engines, and recreational facilities around the lake can have negative impacts. These activities are suspected of contributing waste to the water, resulting in a change in the function of Lake Aneuk Laot (DAL), which, in turn, poses a threat to aquatic organisms, especially plankton, which serves as the primary producer in the water. Low-quality water, rendering it unsuitable for various applications, leads to numerous health and environmental repercussions and additionally decreases the overall availability of clean water. The pollution of both surface and groundwater is emerging as a major menace to the accessibility of fresh water resources [3]. This aligns with [4], which asserts that increased human activities in aquatic environments tend to lead to pollution and can disrupt the sustainability of a body of water.

Prior to this, the waters of Lake Aneuk Laot (DAL) were also studied by [5] who noted that the lake's waters were already starting to be polluted due to human waste activities, as evidenced by the high levels of *E. coli*. Similar results were obtained in the research of [6], which found that the microbiological quality of river water and distribution pipes in Aceh Besar Regency and Banda Aceh contained high levels of coliform and fecal coliform. Furthermore, heavy metal pollution is also a dangerous concern. Heavy metals are one of the most commonly encountered environmental pollutants in water, and they can have negative effects on both humans who use the water and the organisms within it [7]. Examining pollution is crucial for establishing the safety of water for various uses. Consequently, numerous studies have explored water pollution, employing indices like the Storet index across different regions. For instance, research conducted by [8] focused on assessing water quality status using methods such as IP, Storet, and CCME WQI. Furthermore, the study conducted by [9] involved the assessment of water quality pollution status, employing the Storet method and various pollution indices.

[10] also undertook a study to assess the water quality status in the Wonokromo River, employing the Storet method and pollution index. The utilization of water quality indices serves the purpose of classifying and comprehending the patterns in changes to water quality status, thereby facilitating the suitable utilization of a water body in accordance with its intended purpose. Widely adopted methods for water quality indices in Indonesia, as stipulated by the Minister of Environment's Decision No. 115 of 2003 concerning Guidelines for Determining Water Quality Status, include the Storet and IP (Index Pollution) methods. Additionally, the CCME WQI (Canadian Council of Ministers of the Environment Water Quality Index), a method developed in Canada, is also employed [11]. Moreover, the saprobic index is another method that can be used to evaluate the degree of water pollution.

The saprobic index is used as a tool to measure water quality and evaluate the impact of organic pollution on aquatic ecosystems. A higher saprobic index value indicates lower water quality because a high value suggests a dominance of organisms tolerant to organic pollution, with sensitive organisms becoming rare or absent. Conversely, a lower value indicates better water quality with a higher presence of sensitive organisms.

One of the biotic components that can serve as a reference for assessing aquatic life i plankton, which plays a role as a bioindicator in aquatic environments. According to [12] the presence of plankton in a body of water is crucial within the aquatic ecosystem, particularly phytoplankton, as they are autotrophic, meaning they can convert inorganic nutrients into organic matter required by living organisms through the process of photosynthesis. Additionally, the discovery of plankton in a body of water contributes to the inventory of plankton biodiversity data, which may not have been fully revealed. Therefore, it is important to have scientific information about this research study to understand the changes in the conditions of Lake Aneuk Laot (DAL) in accordance with its designated class, Based on [13] concerning Environmental Protection and Management. Hence, the objective of this study is to assess the pollution status of Lake Aneuk Laot (DAL) using indicators such as the pollution index (IP), CCME WQI, and saprobic indices.

2 Methodology

2.1 Sampling Area

The investigation took place in the waters of Lake Aneuk Laot (DAL), Sabang City, Aceh Province, during September 2019 and June 2021. Water quality sample analysis was conducted at the Standardization Research Institute in Banda Aceh, while plankton identification was carried out at the Marine Biology Laboratory of the Faculty of Marine and Fisheries at Syiah Kuala University. The research location is illustrated on Map 1.

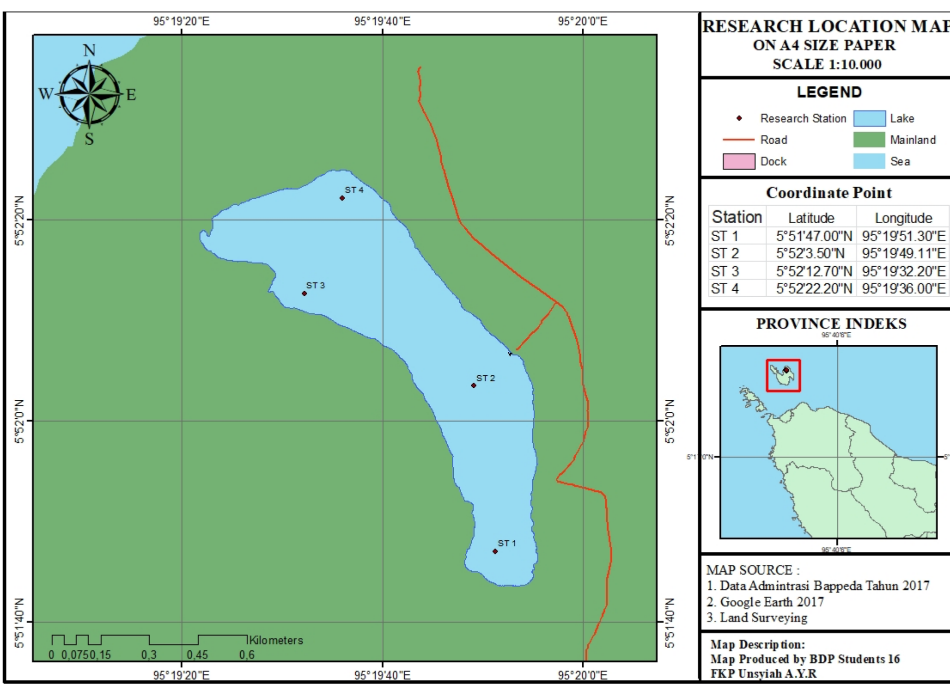

Fig. 1. Location of the research

The method for determining observation stations using the stratified random sampling method. This research was conducted at 4 (four) stations located in the waters of Lake Aneuk Laot, Sabang City, based on the differences in activities along the lake's shoreline, namely: Station 1 (considering the presence of protected forests around the lake and community activities); Station 2 (dock area and recreational activities); Station 3 (PDAM water intake area) and Station 4 (residential area).

2.2 Research procedur

The sampling procedure was conducted quantitatively, employing plankton filtering equipment with plankton net no. 25. Water samples were collected using a Van Dorn water sampler. Plankton observation was executed using the census method, and identification was carried out with the aid of the plankton book [14], along with identification guides for marine diatoms and dinoflagellates [15], and marine phytoplankton [15]. The measured parameters encompassed physical, chemical, and biological factors, including temperature, visibility, Dissolved Oxygen, pH, nitrate-nitrogen (NO3-N), and total phosphate.

2.3 Data Analysis

2.3.1. The pollution index method

The pollution index is examined through two quality indices. The first is the average index (IR), representing the overall pollution level of all parameters in a single observation. The second is the maximum index (IM), indicating the specific parameter that predominantly contributes to a decline in water quality in a given observation [16]. The Pollution Index (IP) for designation j is calculated using the following formula:

$$IPj = \sqrt{\frac{(\frac{Ci}{Lij})^2\ maksimum + (\frac{Ci}{Lij})^2\ rata\text{-}rata}{2}} \quad (1)$$

Note:
IPj : Pollution Index for designation j
Ci : Concentration of parameter test result
Lij : Concentration of the parameter according to the quality standard of water designation j
j : Class of designation
(Ci/Lij)m : Maximum Ci/Lij value
(Ci/Lij)r : Average Ci/Lij value

which classifies water quality into four classes, as listed in Table 1.

Tabel 1. Pollution Index Categories

No	Score IP	Description
1.	0 – 1.0	Meets water quality standards
2.	1.1 – 5.0	Slight pollution
3.	5.1 – 10	Moderate pollution
4.	>10	Heavy pollution

Source: [17]

2.3.2. Canadian Council of Ministers of The Environment Water Quality Index (CCME WQI)

The CCME index is one of several water quality indices created by the Canadian Council of Ministers of the Environment [18]. As outlined in [19], the method developed by the CCME comprises three elements.

1. F1 (Scope), expresses the percentage of variables that do not meet the quality standard, at least for one time period (failed variables) relative to the number of variables measured:

$$F1 = [\frac{number\ of\ failed\ variables}{total\ number\ of\ variables} \quad (2)$$

2. F2 (Frequency), expresses the percentage of tests for each parameter that do not meet quality standards (failed tests).

$$F2 = \left[\frac{number\ of\ failed\ tests}{total\ number\ of\ tests}\right] \times 100 \quad (3)$$

3. F3 (Amplitude), expresses the number of times a failed test value does not meet the quality standard. F3 is calculated in three steps, namely:

a) The amount of time that the respective concentration is greater or less than the minimum quality standard. This is called "excursion". If the test value is more than the quality standard:

$$excursion\ i = \left[\frac{failed\ test\ value}{objective}\right] - 1 \quad (4)$$

b) If the test value is less than the quality standard:

$$excursion\ i = \left[\frac{objective}{failed\ test\ value}\right] - 1 \quad (5)$$

c) total excursion value in each measurement

$$F3 = [\frac{nse}{0{,}01\ nse + 0{,}01}] \quad (6)$$

Note: nse = *normalised sum of the ecursions*

Then the CCME water quality index is calculated by the formula:

$$\text{CCME WQI} = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{1{,}732}\right) \quad (7)$$

Determination of water quality categories based on the CCME WQI method as follows [20]

Table 2. Water quality category based on CCME WQI method

Value	Status	Category
0 – 44	Poor	Water quality is consistently under threat and often compromised, with conditions typically deviating from natural and desirable levels.
45 – 64	Lack	Water quality is frequently jeopardized and compromised, with conditions commonly deviating from natural and desired levels.
65 – 79	Moderate	Water quality is generally safeguarded, but occasionally, it faces threats and disturbances, leading to conditions that may deviate from natural or desired levels.

80 – 94	Good	Water quality is safeguarded under the assumption that the level of threats and disturbances is minimal, resulting in conditions that rarely deviate from natural or desired levels.
95 – 100	Very good	Ensuring water quality protection suggests that, in the absence of threats and disturbances, water conditions closely mirror their initial or natural state. This index value can be achieved when all measurements of quality standards consistently align over time.

2.3.3. Saprobik Index

The saprobic index is a metric employed to quantify the number of species classified under the organic pollution status in water bodies. This index relies on the presence of organisms in water to assess its status [21]. The Saprobic Index (SI) is determined through the application of the subsequent formula.

$$\mathrm{SI} = \frac{1C + 3D + 1B - 3A}{1A + 1B + 1C + 1D} \tag{8}$$

Note:

SI: Saprobic Index

A: Cyanophyceae organism group

B: Dinophyceae organism group

C: Chlorophyceae organism group

D: Bacillariophyceae organism group

Based on the dominant saprobic organisms in a water body, pollution levels can be divided into four categories, as shown in the following table 3.

Table 3. Relationship between saprobic coefficient (SI) and pollution levels [22]

Saprobity level	Saprobiotic index (SI)	Degree of organic pollution
Oligosaprobic	1.0–<1.5	Not to lightly loaded
Oligosaprobic–beta-mesosaprobic	1.5–<1.8	Lowly loaded
Beta-mesosaprobic	1.8–<2.3	Moderately loaded
Beta-mesosaprobic–alfa-mesosaprobic	2.3–<2.7	Critically loaded
Alpha-mesosaprobic	2.7–<3.2	Heavily polluted
Alpha-mesosaprobic–polysaprobic	3.2–<3.5	Very heavily polluted
Polysaprobic	3.5–4.0	Excessively polluted

Source: [22]

3 Result

The pollution index is among the techniques employed to assess the quality status of a water body. As outlined in [13] regarding Environmental Protection and Management, water quality classification comprises four classes. Class I designates water suitable for drinking water sources. Class II is designated for recreational water facilities, freshwater fish farming, livestock, and agriculture. Class III is earmarked for freshwater fish farming, livestock, and agriculture. The outcomes of the pollution index analysis are detailed in Table 4.

Table 4. Pollution status of Lake Aneuk Laot based on the pollution index

No	Class	Pollution Index	Status
1.	Class I	5.9	Moderate pollution
2.	Class II	2.8	Slight pollution
3.	Class III	2.4	Slight pollution
4.	Class IV	0.9	Meets water quality standards

The CCME WQI is a method that compares the results of water quality analysis values to the reference. The results of the CCME index analysis are presented in Table 5.

Table 5. Pollution status of lake aneuk laot based on CCME index

No	Water quality class	Score CCME Index	Status
1.	Class I	32.9	Poor
2.	Class II	48.7	Lack
3.	Class III	71.3	Moderate
4.	Class IV	89,7	Good

Saprobic index value obtained from the results of the analysis based on the relationship between the water saprobity coefficient (X) with the level of water pollution [22] associated with phytoplankton communities classified the occurrence of organic and inorganic material pollution is moderately loaded or beta-mesosaprobic with saprobic value 2.3. Saprobic index values are presented in Table 6.

Tabel 6. Saprobic index values of Aneuk Laot lake

Code	Class phytoplankton	Number of species
A	Cyanophyceae	5
B	Dinophyceae	2
C	Chlorophyceae	4
D	Bacillariophyceae	13
SI (Saprobic Index)		2.3

4 Discussion

The status of Aneuk Laot Lake is included in moderately polluted conditions in class I, lightly polluted in classes II and III, and good water conditions in class IV. Based on the analysis of water quality standards using the pollution index, several parameters are indicated that do not meet water quality standards, namely DO, BOD, COD, TSS,and total phosphate. Thus, the waters of Aneuk Laot Lake are less suitable for use as clean water for consumption, household use, recreational infrastructure / facilities as well as fisheries, agriculture and livestock. The average value of TSS value in Aneuk Laot Lake waters is 102.25 mg/L. These results have exceeded the quality limit for class III water classification for lake waters based on [13] which is 100 mg/L. Lake waters that are utilized by the community as the main source of clean water if they contain high levels of TSS will have an impact on the health of living things if consumed continuously. In addition, excessive TSS levels in lake waters will interfere with the photosynthesis process and result in the death of aquatic organisms [23].

The average value of total phosphate content in Aneuk Laot Lake Waters is 0.3 mg/L. These results have exceeded the quality limit of lake waters based on Government Regulation No. 22 of 2021 for water classification class I - III which ranges from 0.01 - 0.1 mg/L. According to [24] one of the causes of high phosphate levels in waters can come from domestic waste containing detergents [24]. Excessive levels of total phosphate in waters are not only harmful to these waters, but also harmful to living things if consumed for a long time. According to [25] waters with high phosphate levels will trigger rapid growth of aquatic plants. In addition, if these waters are utilized by living things as a source of drinking water continuously, it will have an impact on digestive problems [26].

The average COD content in Aneuk Laot Lake for classes I-IV surpasses the threshold established by Government Regulation No. 22 of 2021, which is 80 mg/L. Elevated COD levels are expected to be inversely proportional to the DO content in the waters. High COD can disrupt the life of aquatic biota and can even cause death in fish and aquatic plants [27]. According to the findings from the research cited in [28], the lake area within the Jayapura City expo arena is categorized as moderately polluted, as determined by the pollution index. This is because seven parameters exceed the quality standard values, namely temperature, BOD, COD, sulfide, lead, copper and phenol. Pollution that occurs in the Lake expo arena area is thought to come from domestic waste and erosion. The research conducted by [29] in Kandung Suli Lake, Kapuas Hulu Regency, indicates that several parameters, including TSS, BOD, and COD have surpassed the quality standard threshold. The discovery of food remnants that settle to the bottom of the waters and the activities of the community around the location are thought to be a source of contributing to the increasing concentration of TSS, BOD and COD in the waters.

Water quality research using the pollution index was also conducted by [30] based on the quality status assessment, Danau Sunter is classified as lightly polluted for class III water quality standards. The test results of the BOD and temperature parameters in Lake Sunter do not meet the quality standard criteria. The increased BOD concentration can be attributed to the deposition and accumulation of organic matter at the bottom of the water, resulting from tourism and household activities. The accumulation of organic matter at the water's bottom can intensify the decomposition process by microbial organisms, subsequently diminishing the dissolved oxygen content.

Based on the analysis of water quality standards in Aneuk Laot Lake using CCME WQI, there are several parameters that exceed the predetermined quality standard values, namely TSS, BOD, COD, DO, total nitrogen and total phosphate. COD and total phosphate parameters are the parameters with the highest concentration values in Aneuk Laot Lake waters. The same research results were conducted by [31], in Lake Batur Bangli Regency, it is known that the COD, total phosphate and dissolved residue parameters have exceeded the quality standard limits based on Bali Governor Regulation No. 16 of 2016. The entry of large amounts of organic compound discharges sourced from community activities, agriculture and fish farming is indicated as the cause of increasing concentrations of COD, total phosphate and dissolved residues in the waters.

The findings from the study conducted by [32] indicate that using the CCME index on Lake Toba, Sipinggan Village is classified as waters with fair to very poor conditions for class I. This is attributed to several parameters that fail to meet quality standards, specifically TSS, BOD, and coliform. The highest TSS concentration obtained a value of 75.3 mg/L, this has exceeded the predetermined quality standard threshold. Waste from agricultural activities in the form of organic and inorganic materials and solids cause TSS concentrations in waters to increase.

Saprobic index (IS) is an index used to calculate the number of species belonging to the status of organic pollution in waters, this index uses the presence of organisms present in the waters to determine the status of waters [21]. Aneuk Laot Lake (DAL) waters have a moderate level of organic and inorganic pollution (beta-mesosaprobic), meaning that there are organic pollutants that have undergone decomposition. The same research was also conducted by [33] the saprobic index in Lake Matano showed that the status of waters with moderate to very light pollution levels with organic and inorganic pollutants dominated by mesosaprobic conditions. This condition is relatively similar to the research conducted by [34], the saprobic index in Lake Toba has a plankton community showing a level of pollution that is classified as very mild to mild with a small load of organic and inorganic pollution that takes place in the mesosaprobic /oligosaprobic phase.

5 Conclusion

The analysis of the Index Pollution and CCME WQI, it is determined that the pollution status of Lake Aneuk Laot is heavily polluted for Class I, moderately polluted for Classes 1 and 2, and falls under the good category for Class 4. The saprobic index results show the beta-mesosaprobic category with a result of 2.3 (moderately loaded).

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