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Improving Hasanuddin University Lake Water Quality by Controlling Contamination Sources and Biological Monitoring Systems

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ABSTRACT

Hasanuddin University Lake in Indonesia is a water tourism destination that offers natural beauty and comfort. In addition, the lake functions as an important scientific development park for the university. Even though its location is on campus, the surroundings of the campus are residential areas and various life activities. Recently, weed growth has occurred, which could be an indication of contamination and may hinder its useful function. Therefore, this study investigates the physicochemical quality of water, the pollution index, and its monitoring, attempting to make the campus lake continue to function sustainably. The research was carried out at the peak of the dry and rainy seasons, with laboratory examinations based on standard methods for quality parameters that follow lake use function standards. The results showed that most of the water quality parameters measured needed to meet the required quality standards. Based on the scoring results using the water pollution index method, lake water is classified as lightly to moderately polluted, which requires protection. The monitoring method is prepared with the addition of a biological indicator system. In line with that, intensification of the diversity of greenery around the lake and environmental management in an integrated manner with the surrounding settlement. The conclusion is that there is a need for complementary monitoring between physicochemical and biological methods and management coordination with the surrounding territories.

1. Introduction

One form of wetlands is a lake, which provides a variety of important ecosystem services [1]. These include biodiversity, carbon sequestration, food production, water supply, and recreation [2]. One of the lakes in Makassar City, Indonesia, is located on the Hasanuddin University campus, named Hasanuddin University Lake (HUL). This lake is a water tourism destination that offers natural beauty and is surrounded by lush trees that present a dark and cool atmosphere. Even though the lake is in

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the lowlands, its natural performance is equivalent to the beauty of the mountainous landscape [3]. Apart from functioning as a tourist spot, HUL also has other important functions: raw water, captive aquatic animals, research sites, and student activities.

Recently, HUL has been indicated to be experiencing environmental degradation due to the discharge of wastewater into the lake [4]. This contamination can cause the quality of lake water to decline so that it does not meet the functional requirements for its use. The presence of water hyacinths on the surface of HUL waters indicates pollution caused by the discharge of wastewater containing organic matter, especially nitrogen and phosphorus [5]. Phosphorus is a major limiting factor for algal growth and eutrophication in lake water [6]. However, lake water quality monitoring has never been carried out; thus, the water hyacinth growth indicator needs to be followed up with investigations of water quality parameters based on standards applicable to lake water. In Indonesia, lake water quality standards are set based on the Government Regulation of the Republic of Indonesia No. 22 of 2021 [7].

This research investigates the water quality of HUL based on the standard and transforms it into a pollution index. In addition, it provides methods for monitoring its quality, aiming to maintain HUL as a public tourism lake and become a university intellectual property. The results can be used locally to improve the quality of the surrounding settlement environment, with university coordination and supervision. Its success can be piloted and replicated in other places.

2. Methodology

2.1 Water Sampling

The study activity includes field observation, water sampling, and water quality parameter analysis. Field observations were carried out to collect data on the existing conditions at HUL. Water sampling and water quality parameter analysis were carried out to determine the concentration of pollutants contained in the water at HUL.

The study was carried out at HUL for the peak dry season in August and the peak rain season in October 2022. The HUL was an artificial lake whose water came from rainwater channeled through several drainage channels. This location has two lakes; the large one has an area of 54,609 m^2, and the small one has an area of 12,123 m^2, depth of less than 10 meters.

2.2 Site Location and Sampling Points

As shown in Figure 1, the water sampling site consisted of nine locations in a large lake, including the middle of the lake (D1A), the lake inlet (D1B, D1C, D1D, and D1E), and the lake outlet (D1F). In addition, the sampling point in a small lake was taken at the inlet (D2G and D2H) and outlet (D2I). The sampling depths were 0.5 meters from the water surface and the bottom of the lake. The Indonesian National Standard, SNI 6989-57-2008, on the method of sampling surface water, states that in lakes with a depth of less than 10 m, samples are taken at two points, the surface and the base, and then mixed [8].

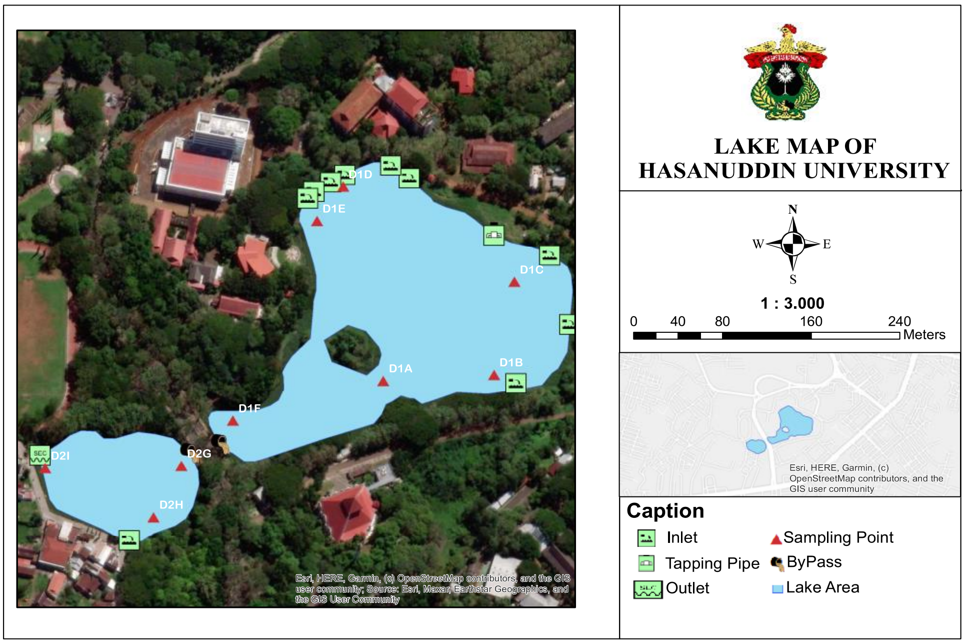

Fig. 1. Water sampling site at Hasanuddin University Lake

2.3 Water Quality Assessment

The water quality parameter analysis included Total Suspended Solid (TSS), Acidity (pH), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen, and Total Phosphate. These parameters follow the Class II quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 on the implementation of environmental protection and management [7]. Class II quality standards were clean water, whose designation was used for recreational water infrastructure, freshwater fish farming, animal husbandry, and irrigating crops. Therefore, all quality parameters were analysed in the laboratory following standard methods [9].

Meanwhile, determining the water pollution index method follows the Regulation of the Minister of Environment and Forestry Number 27 of 2021 [10]. The calculation of the water pollution index is carried out using the formula:

$$PI_j = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)^2_M + \left(\frac{C_i}{L_{ij}}\right)^2_R}{2}} \quad (1)$$

where

PI_j = pollution index
C_i = parameter concentration measurement results
L_{ij} = quality standards
M = maximum
R = average

Based on the calculation of the water pollution index, water quality can be classified into four categories, as presented in Table 1.

Table 1
Classification of water pollution index

No.	Value	Categories
1	0 ≤ PIj ≤ 1,0	Meet quality standards
2	1,0 ≤ PIj ≤ 5,0	Light polluted
3	5,0 ≤ PIj ≤ 10	Moderately polluted
4	PIj ≥ 10	Heavily polluted

3. Results
3.1 Water Quality Parameters

Data analysis of HUL water quality parameters shows that most of the measured parameter values do not meet the required quality standards. The detailed data is presented in Table 2 and Table 3.

Table 2
HUL water quality data for the dry season

Parameters	Unit	Sampling Location									Quality Standars*
		D1A	D1B	D1C	D1D	D1E	D1F	D2G	D2H	D2I	
TSS	mg/L	49.5	52	7 3.5	51	42.5	83.5	43	62.5	63.5	Maks. 50
pH	-	8.7	8.9	7.4	8.6	7.9	9	9.7	9.7	9.6	6-9
DO	mg/L	3.97	3.17	6	6.55	6.94	8.04	5.56	6.01	6.05	Min. 4
BOD	mg/L	21.33	22.82	27.28	4.96	4.46	8.93	7.94	24.30	31.74	Maks.3
COD	mg/L	63.35	53.35	70.02	76.69	66.69	68	65	73.36	70.02	Maks. 25
TN	mg/L	6.66	3.75	7.27	4.22	3.23	1.34	4.24	8.79	8	Maks. 0.75
TP	mg/L	0.13	0.15	0.13	0.17	0.14	0.13	0.13	0.11	0.13	Maks. 0.03

*Class II quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 on the implementation of environmental protection and management

Table 3
HUL water quality data for the rainy season

Parameters	Units	Sampling Location									Quality Standars*
		D1A	D1B	D1C	D1D	D1E	D1F	D2G	D2H	D2I	
TSS	mg/L	34	72	112	48	174	126	50	72	178	Maks. 50
pH	-	7.19	7.64	7.64	7.33	7.34	7.99	8.55	8.54	7.98	6-9
DO	mg/L	0.6	6.75	5.36	5.56	4.07	5.46	6.84	5.75	4.07	Min. 4
BOD	mg/L	19.1	10.42	11.9	2.73	14.88	14.14	11.41	6.7	10.42	Maks.3
COD	mg/L	100	56	67.2	78.4	64	72	65.6	62.4	126.4	Maks. 25
TN	mg/L	14.58	7.60	11.23	7.36	4.67	4.47	2.09	2.53	1.45	Maks. 0.75
TP	mg/L	0.09	0.08	0.07	0.06	0.05	0.04	0.05	.0.05	0.04	Maks. 0.03

*Class II quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 2021 on the implementation of environmental protection and management

Data from laboratory analysis showed that the water samples of HUL obtained from nine sampling sites had a concentration of TSS of 42.5–83.5 mg/L in the dry season and 34–178 mg/L in the rainy season, as shown in Figure 2. According to Enawgaw and Lemma [11], high TSS was found during the rainy season; this might be due to the high runoff of solid particles from the watershed/catchment area of the lake and may be due to siltation, deterioration, heavy precipitation, and mixing runoff rain water that carried mud, sand, etc. mixed in the lake water. The highest concentration of TSS was found at location D2I, with a concentration of 178 mg/L. The location was an outlet of a small HUL that accumulated solids carried by the water flow. Based on the quality standards for lake water and the measured concentration of TSS, the water quality in HUL is categorised as Class III, whose designation can be used for freshwater fish farming, animal husbandry, and irrigating crops [7].

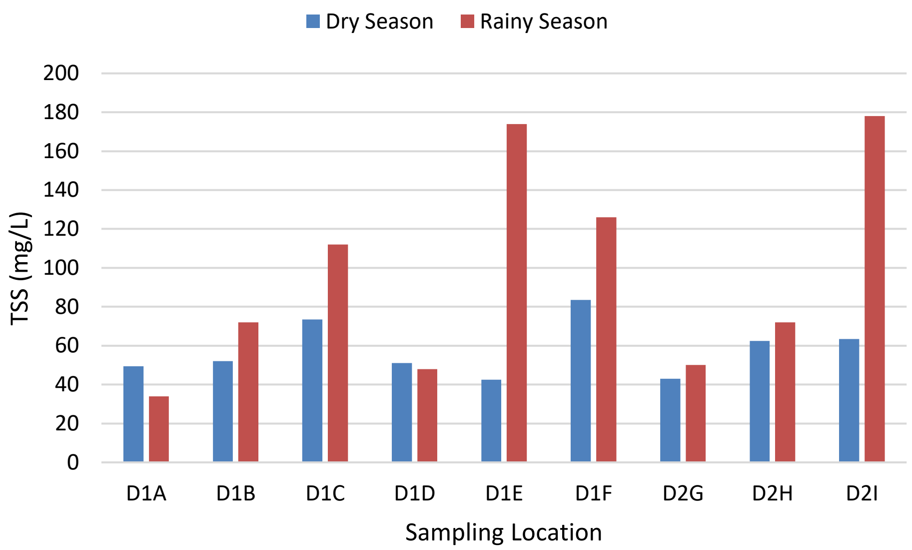

Fig. 2. Total suspended solids value

Data on pH measurements at nine sampling sites in HUL were 7.4–9.7 in the dry season and 7.19–8.55 in the rainy season, as shown in Figure 3. Most sampling sites have a pH range that meets the class I–IV lake water quality standards. Three sampling sites with high pH values ranging from 9.6 to 9.7 were located in the outlet parts of HUL 1 and HUL 2 and wastewater inlets from settlements. The study conducted by Pereira *et al.,* [12] revealed that the degree of acidity greatly affects the toxicity of polluted materials and the solubility of some gases, such as oxygen. In addition, the pH of water can be affected by natural variables such as soil minerals, vegetation, rainfall, and temperature.

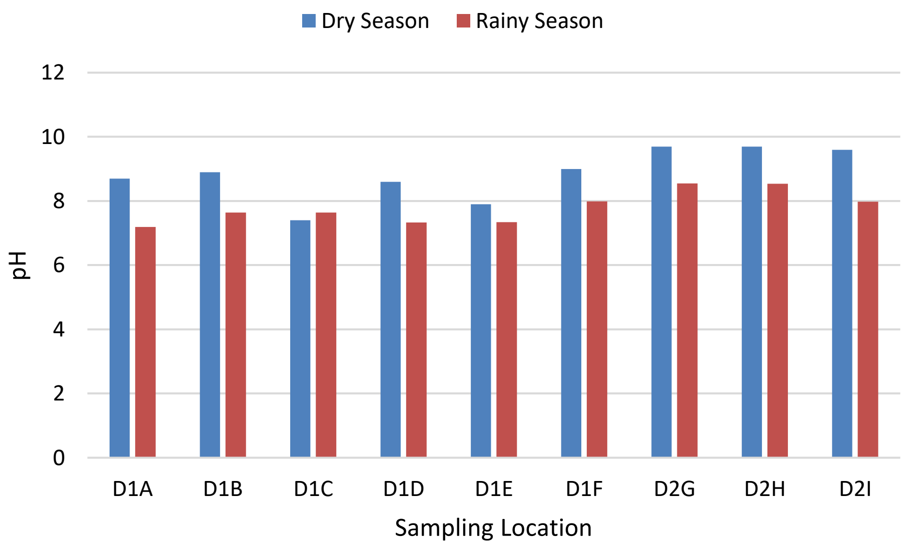

Fig. 3. Acidity levels value

Data from DO measurements at nine sampling sites in HUL were in the range of 3.17–8.04 mg/L in the dry season and 3–6.84 mg/L in the rainy season, as shown in Figure 4. Most sampling sites have a DO value that allows aquatic biota to survive to meet the quality standards of class I and II lake water, whose designation can be used for raw drinking water, recreational water facilities, freshwater fish farming, animal husbandry, and irrigating crops [7]. The lake's high level of dissolved oxygen is an indicator of good water quality [13].

The DO is essential for all aquatic organisms' growth, breeding, and metabolic processes. In addition, dissolved oxygen also plays a role in the decomposition of organic matter in water [14]. Therefore, low DO in a body of water is likely due to the decay of dead aquatic plants at the bottom of the sediment. The value of DO is closely related to BOD and COD because a higher BOD and COD will lead to a decrease in DO in the waters. When the DO concentration is below 5–6 mg/L in fresh water, the level required by the aquatic organism is hypoxic. Anoxia and hypoxia are the leading causes of stress, poor appetite, slow growth, susceptibility to disease, and death [15].

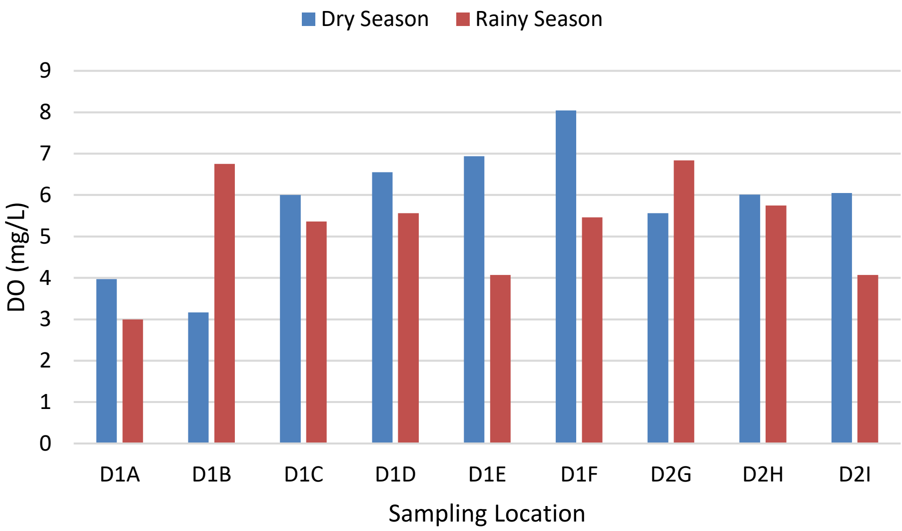

Fig. 4. Dissolved oxygen value

Data from BOD measurements at nine sampling sites in HUL were 4.46–41.74 mg/L in the dry season and 2.73–19.10 mg/L in the rainy season, as provided in Figure 5. Based on the quality standards for lake water and measurable BOD concentrations, the water quality in HUL at several sampling locations is categorised as Class IV, whose designation can only be used to irrigate crops [7]. High levels of BOD indicate the condition of a body of water polluted by waste generated from human activities. In addition, high BOD concentrations mean how large the content of pathogenic microorganisms is. Pathogenic organisms can cause various human diseases [16].

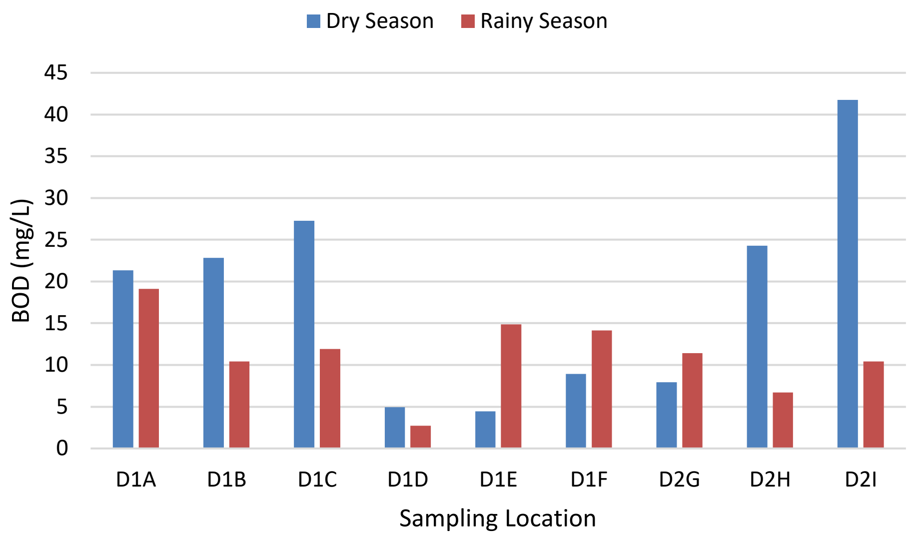

Fig. 5. Biochemical oxygen demand value

Data from COD measurements at nine sampling locations in HUL are in the range of 53.35–76.69 mg/L in the dry season and 56–126.4 mg/L in the rainy season, as provided in Figure 6. Therefore, based on the quality standards for lake water and measurable COD concentrations, the water quality in HUL at several sampling locations is categorized as Class IV, whose designation can only be used to irrigate crops [7].

The results of measurements of BOD and COD concentrations were below 100 mg/L each and showed a BOD/COD ratio below 0.3 in the rainy and dry seasons, respectively. At this status, the quality of organic matter in lake waters was stable, where the decomposition of organic matter can be neglected [17]. This means that the decline in lake water quality was not primarily caused by organic matter.

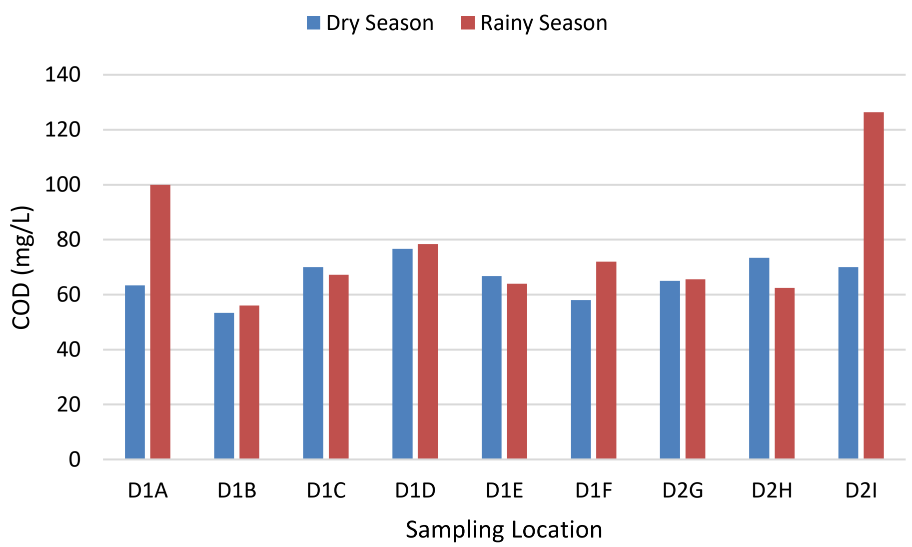

Fig. 6. Chemical oxygen demand value

Data Figure 7 showed that HUL water samples obtained from nine sampling sites have a total nitrogen value in the range of 1.34–8.79 mg/L in the dry season and 1.45–14.58 mg/L in the rainy season. The lake's condition with such a TN range causes its use only to irrigate the crop. A high concentration of total nitrogen indicates a greater level of organic matter pollution in water. Organic waste usually comes from community activities or wasted food waste. Therefore, N and P are the main factors influencing eutrophication rates in lakes [18].

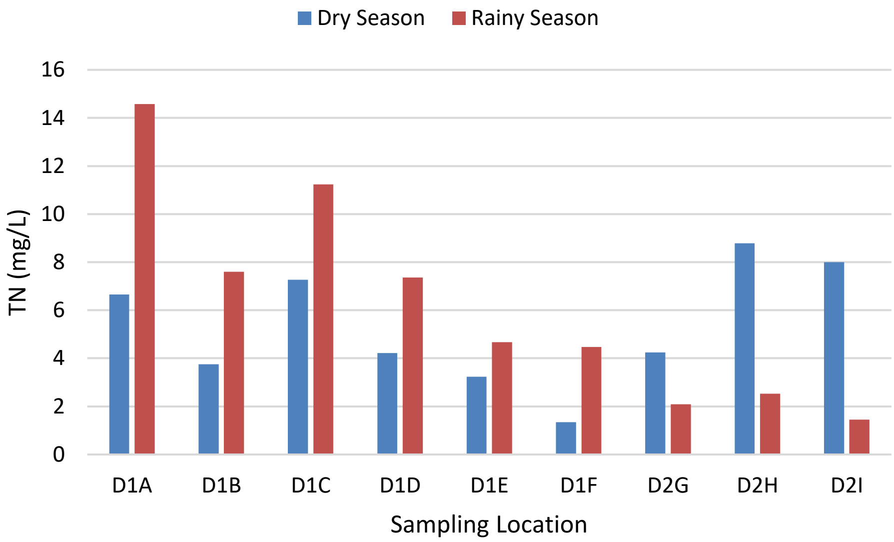

Fig. 7. Total nitrogen value

Figure 8 measures the total phosphate water of HUL at nine sampling sites, ranging from 0.11-0.17 mg/L in the dry season and 0.04-0.09 mg/L in the rainy season. Based on the quality standards for lake water and the measured concentration of TP, the water quality in HUL is categorised as Class III-IV, whose designation can be used for freshwater fish farming, animal husbandry, and irrigating crops [7]. Waters containing sufficiently high levels of phosphates, exceeding the normal needs of aquatic organisms, will cause eutrophication. High phosphate levels have a severe long-term effect on freshwater ecosystems and require significant efforts to reduce their concentration [19].

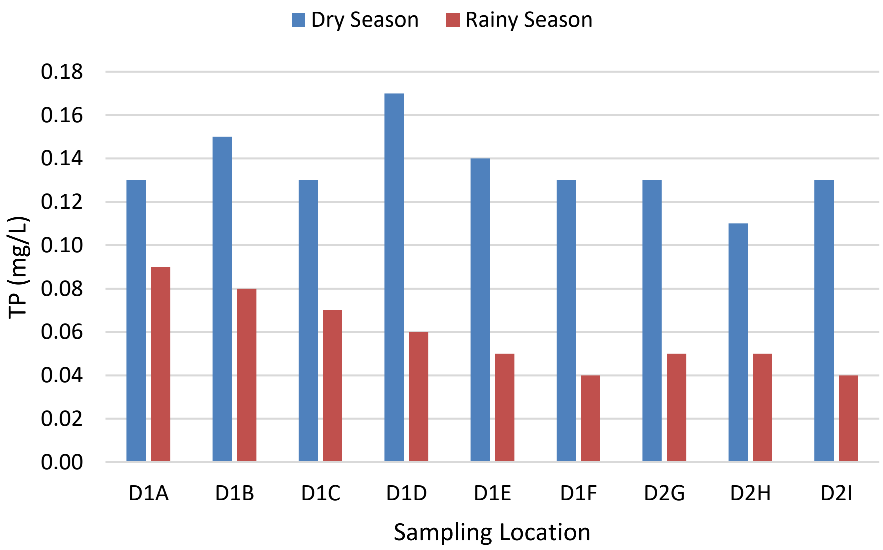

Fig. 8. Total phosphate value

3.2 Water Quality Parameters

Water quality status is the level of water quality that indicates a polluted or good condition at a water source within a certain time by comparing the established quality standards. Decree of the Minister of Environment Number 115 of 2003 concerning Guidelines for Determining Water Quality Status states that water quality is a condition of water quality that is measured and tested based on certain parameters and using certain methods based on laws and regulations [20].

This study's determination of water quality status used the pollution index method. This method is used to assess the quality of the waters and the suitability of the designation of such waters. In addition, water pollution index information can be used as a reference in carrying out water quality improvement actions. The water pollution index data is then converted to obtain the water quality index value, namely by multiplying the weight of the index value by the percentage of meeting the quality standard. Meanwhile, the rate of meeting quality standards is obtained from the summing sample points that meet the quality standards against the number of samples in percent; the results are provided in Figure 9.

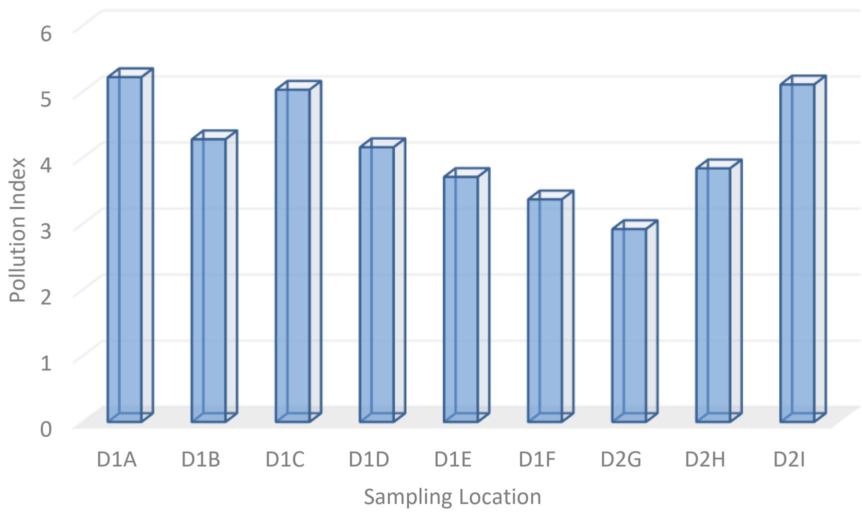

Fig. 9. Water pollution index

Based on the results of data analysis at nine sampling locations, it is known that the pollution index in the waters of HUL ranges from 2.92 – 5.22. This value means that HUL is currently lightly polluted to moderately polluted based on the assessment of class II lake water quality standards according to the Republic of Indonesia government regulations No. 22 of 2021 [7]. Pollution index >5 is classified as moderate, while pollution index <5 is classified as light.

The calculation results showed that the water quality index of the HUL was 43.33 points or less. Therefore, it is necessary to carry out integrated environmental management around HUL so that the water is not contaminated and can be used following its designation. Pollution of water resources and biodiversity loss are serious problems in ecosystems [21].

3.3 Improvement Methods

Efforts to improve the water quality of HUL were now in progress as follows. First was the provision of wastewater treatment plants (WWTP) in residential areas and buildings around the lake.

Residential and university wastewater sources are each channeled through a sewer piping network system. From the sewer, wastewater enters the wastewater treatment unit, where the effluent is discharged into the nearest river or reused for irrigation of the greenspace surrounding the HUL [22]. In this case, residential and university wastewater sources do not have the potential to worsen HUL water quality.

Second, the existing greening of barriers around the lake and channels could be intensified with plant diversity to enhance plants' capacity to attenuate wastewater toxicity [23]. In addition, small constructed wetlands could be beneficial to treat WWTP effluent; hence resource recovery is achieved onsite.

Third, the monitoring activities address biological indicator systems and conventional physicochemical monitoring for water quality [16]. This biological indicator monitoring system provides respiration test equipment (Figure 10) for pond water and fish aquariums, both of which work onsite.

The monitoring method Figure 10 is the process of respiration of biota in pond water, which emits carbon dioxide gas (CO_2). The aforementioned physicochemical observation data presented inorganic nitrogen and phosphate that can inhibit microbial respiration [24,25]. This method also serves as training for Environmental Engineering students at Hasanuddin University. They can perform the A respiration test, which requires titration analysis of the KOH sample in a laboratory. In addition, the B respiration test observes the water level in a volumetric glass. When method A finds precipitates of potassium carbonate (K_2CO_3), or method B results in a decrease in water level, it is a sign of healthy pool water; vice versa. This biological indicator method can work almost daily; thus, problems can be solved more quickly, besides completing physicochemical monitoring.

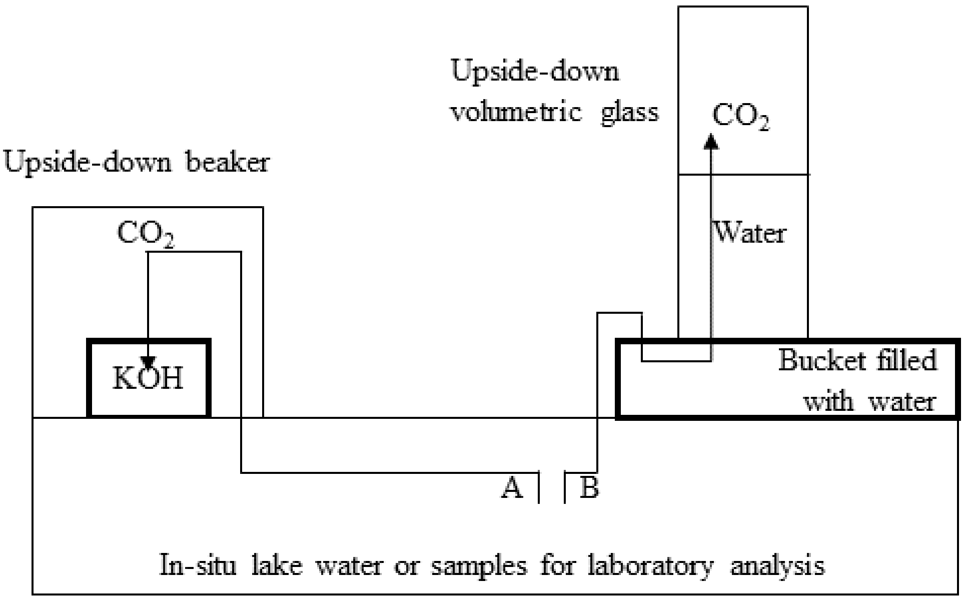

Fig. 10. Respiration test equipment onsite

4. Conclusions

The contamination content of HUL water samples generally did not meet the class II lake water quality criteria required by government standard regulations. HUL's water quality is currently in the category of slightly polluted to moderately polluted, which could be caused by inorganic substances. To a certain extent, inorganic substances can inhibit biological respiration; hence, it is necessary to monitor physicochemical and biological indicators that complement each other. In line with that, it is required to manage the environment of the lake and surrounding settlements in an integrated manner in university coordination. Therefore, good environmental management is needed to support various HUL functions sustainably. Ecological management must be carried out in an integrated manner by university campus managers and all building owners around the HUL, such as settlements, schools, offices, and hospitals. The activities of these places generate wastewater which may decrease the water quality in HUL.

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