International Journal of GEOMATE, Sept., 2022, Vol.23, Issue 97, pp.61-73
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2022.97.3087
Geotechnique, Construction Materials and Environment

POLLUTANT REMOVAL EFFICIENCY OF WICKERED-CONSTRUCTED FLOATING WETLAND IN THE GEDEBAGE POND, INDONESIA

*Wildan Herwindo[1], Dadan Sumiarsa[1], Eko Winar Irianto[2], *Hendarmawan Hendarmawan[1]

[1]Graduate School, Universitas Padjadjaran, Indonesia; [2]Ministry of Public Works and Housing, Indonesia

*Corresponding Author, Received: 24 Dec. 2021, Revised: 16 June 2022, Accepted: 02 Aug. 2022

ABSTRACT: Wickered-constructed floating wetland in the Gedebage pond was built as an integrated tourist attraction with the floating mosque. According to the governing ordinance, it should conform to the quality standard requirements. This study aimed to assess the pollutant removal efficiency of constructed floating wetland from domestic waste in the Cinambo river as an influent on the pond and the pond's ecological status. The assessment of ecological status was based on three methods: 1) the physicochemical index using the pollution index (PI) and the water quality index (WQI), 2) the biological index using phytoplankton diversity including the trophic index, and 3) canonical correspondence analysis (CCA) describes the multivariate correlation between the physicochemical index and the biological index. The results indicated a pollutant removal efficiency of total dissolved solids (TDS) was 46.5-49.5%, of total suspended solids was (TSS) 33.5-39.8%f biochemical oxygen demand (BOD) was 34.0-37.3%, of chemical oxygen demand (COD) was 11.8-17.5%, of total nitrogen (TN), was 76.3-79.6%, of total phosphate (TP) 89.1-89.9%, of boron (B) was 29.7-54.5%, of detergent (MBAS) was 72.9-82.2%, and of dissolved oxygen (DO) was 2.8 to 3.6 times. The ecological status indicated the improvement of water quality from heavily polluted in influent to lightly polluted in the pond (PI) and changed from poor to fair (WQI), the same results with biological index were indicated in moderately polluted after treatment. However, trophic index results showed the pond was in eutrophic to hypertrophic condition. CCA indicated eutrophication was correlated to the abundance of Microcystis and Lyngbya genera.

Keywords: Wickered-constructed floating wetland, Physicochemical index, Biological index, Canonical correspondence analysis

1. INTRODUCTION

Water quantity became the focus of water supply in the 20th century when water availability to water need had the primary role, but in the 21st century, the focus is not only based on the quantity of water. Water has a significant role as the main challenge in water management in terms of water quality degradation [1], population growth [2], and climate change [3].

Degradation of water quality is one of the immediate negative impacts in Indonesia. Water pollution comes from factory sewerage [4], domestic waste [5], and pesticides from agriculture [6]. For tackling water pollution, it has been installed Waste Water Treatment Plant (WWTP) with a centralized system in Indonesia, but the WWTP was built only in 12 cities and only served 10% of Indonesia's population [7]. Water quality problems become more serious when they occur in the lentic (inundated) ecosystem such as lakes and retention basins due to residence time pollutants and recovery period in the lake longer than in the lotic (flowing) ecosystem [8]. One technology that can be developed to improve water quality is the use of wetlands in the form of natural or artificial wetlands. Natural wetlands can be in temporary shallow water bodies such as marshes, swamps, lake margins, extensive river floodplains, coastal beaches, mangroves, fens, and seagrasses [9]. In contrast, the artificial wetland is an engineering system or artificial system in the form of ponds or shallow channels utilizing natural processes that occur in wetland vegetation, media (rocks, gravel, sand), and microbial assemblages to treat wastewater [10]. It was much built and developed starting in the 20th century [11].

Wetlands can reduce the burden of organic and non-organic pollutants, which vary based on the type of pollutant, wetland configuration [12], time retention [13], plant types [14] [15] [16], weather [17], and other specific factors. Floating wetlands are the other artificial wetland technology types that function as a retention basin water supply [18]. They can be installed in most water bodies without significant earthworks [19]. The advantage of wetlands is more potent than other technologies such as fly ash which is only 10% effective in reducing organic content [20]. The other advantage of the wetlands is the technology with economical cost, it is suitable to be applied in developing countries [21] such as Indonesia.

The physicochemical and the biological can be used for ecological assessment [22]. In this study, the physicochemical assessment was based on the pollution index (PI) and the water quality index (WQI). WQI is a single number that expresses water quality by aggregating the measurements of water quality parameters, such as dissolved oxygen, pH, nitrate, phosphate, ammonia, chloride, hardness, metals, etc. The significance of the WQI can be easily appreciated as the water resources play a crucial role in the overall environment. This index has also been recognized as one of the 25 environmental performance indicators of the holistic Environmental Performance Index [23]. One of the biological assessment methods is using phytoplankton diversity. Total concentrations of phytoplankton such as algae can determine the water quality [24] because it has a sensitive reaction to environmental changes [25] and was used in water quality management due to sensitive indicators of ammonia (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-), and phosphate (PO_4^{3-}) [26]. Phytoplankton for water quality assessment had been investigated with the saprobic system first published by Kolkwitz and Marson in the early 1900s [27]. Phytoplankton in water quality indicators is related to the water saprobic index, which is measured based on species found because any types of phytoplankton are a constituent of certain saprobic groups to affect the value of saprobic [28].

As a tourism destination, the Gedebage pond should be maintained to follow Indonesian water quality standards. They are regulated by Class II of Government Ordinance Number 22 of 2021 [29] and have an aesthetic function [30]. The constructed floating wetland at Gedebage pond was built using the Heliconia densiflora plant which functions in phytoremediation [31]. It is also equipped with wickers that function as biofilm that support the bioremediation process [32] [33]. The combination of plant phytoremediation and biofilms are expected to be more optimum in pollutants removal.

This study was conducted to assess pollutant removal efficiency of wickered-constructed floating wetland from the domestic waste influent were indicated by 11 physicochemical parameters and the abundance of phytoplankton, and the use of CCA to determine the multivariate correlation between physicochemical parameters and phytoplankton abundance.

2. RESEARCH SIGNIFICANCE

The focus of this study was to measure pollutant removal efficiency of the wickered-constructed floating constructed wetland from domestic waste influent in two weeks Hydraulic Retention Time (HRT) design and assess the status of water quality based on the physicochemical and biological assessment. This study is important to determine the efficiency of pollutant reduction using a combination of plant phytoremediation and biofilm.

3. METHODOLOGY

3.1. The Study Area

The Gedebage pond is located in Cimincrang Village, Gedebage Subdistrict, Bandung City, West Java Province, about 150 km from Jakarta, the Capital of Indonesia. It is approximately 72,000 m^2 located within x dan y values of zone 48 of universal transverse mercator (UTM) 798611.443 m E and 9231412.368 m S to 798872.331 m E and 9230938.208 m S (Fig. 1). The altitude is approximately 644 m. The mean annual temperature is 23.7 °C, the mean annual precipitation is approximately 169.3 mm, and the mean annual humidity is 76%.

The influent of the Gedebage pond was taken from the Cinambo river through a side spillway inlet with 0.24 m^3/s, and excess water was drained through the outlet spillway. In general, the upstream of the Cinambo river before the study area was residential. The consequence the influent contains domestic waste. One station (station 0) was selected as the influent reference site, and three stations were selected in the pond, namely station 1, station 2, and station 3. The physicochemical assessment in the river and the pond that was conducted from September to November 2019 before wickered-constructed floating wetland was installed are presented in Table 1.

3.2. The Wickered-Constructed Floating Wetland Design

The wickered-constructed floating wetland was designed using 2x2 m buoyant material made from PVC 4 and 6 inches in diameter and covered with non-woven geotextile in grey color, it was placed on a circular shape around the edge of the Gedebage pond in December 2019 (Fig. 2). The 20 cm plant pots filled with textile material growth media consist of a mixture of 15% polyester, 35% recycled, and 50% fiber. Resisting winds, waves, and water level fluctuations, an anchoring system at 20 MPa concrete strength was added. The maximum 30 cm of height of Heliconia densiflora with 50 cm spacing. The HRT was conducted for 14 days, and the Hydraulic Loading Rate (HLR) was 0.24 m/day, wickers made of non-woven geotextile material with 50 cm length under the buoyant material were conducted to increase biofilm adhesion, and it was assumed surface coverage could be less than 5% [34].

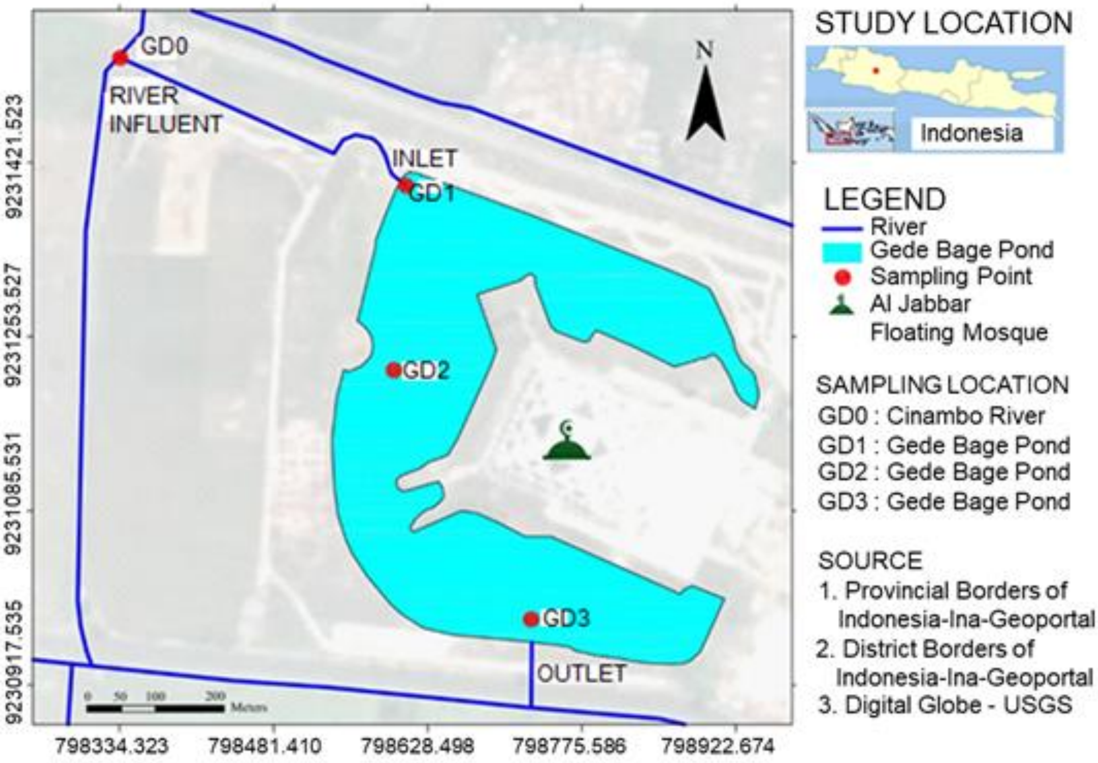

Fig. 1 Sampling Location Map

Table 1. Physicochemical assessment of the influent and the pond before wetland installation

Parameters	Units	Station 0 (Influent)			Station 1			Eff.* (%)	Station 2			Eff.* (%)	Station 3			Eff.* (%)
Temp.	°C	24.833	±	0.208	26.933	±	0.306	-	27.300	±	0.436	-	26.833	±	0.115	-
Ph	-	7.563	±	0.042	8.770	±	0.082	-	8.840	±	0.075	-	8.743	±	0.067	-
TDS	mg/L	604.333	±	17.039	514.000	±	6.083	14.9	583.667	±	11.150	3.4	501.333	±	17.616	17.0
TSS	mg/L	27.333	±	2.082	22.333	±	1.528	18.3	27.000	±	2.000	1.2	20.333	±	0.577	25.6
BOD	mg/L	22.667	±	4.041	18.333	±	1.155	19.1	21.000	±	1.000	7.4	18.333	±	0.577	19.1
COD	mg/L	42.333	±	7.506	34.000	±	2.000	19.7	40.333	±	4.163	4.7	34.000	±	1.000	19.7
DO	mg/L	1.790	±	0.221	4.840	±	0.078	170.4	4.767	±	0.061	166.3	5.100	±	0.101	184.9
TN	mg/L	2.922	±	0.163	2.233	±	0.137	23.6	2.453	±	0.215	16.0	2.148	±	0.046	26.5
TP	mg/L	0.104	±	0.010	0.082	±	0.004	21.2	0.086	±	0.005	17.4	0.078	±	0.002	25.1
B	mg/L	0.967	±	0.076	0.877	±	0.023	9.3	0.930	±	0.056	3.8	0.850	±	0.020	12.1
MBAS	mg/L	0.450	±	0.016	0.253	±	0.069	43.8	0.268	±	0.058	40.5	0.223	±	0.083	50.4

**Eff. = Pollutant removal efficiency*

3.3. Water and Phytoplankton Sampling

The physicochemical samples were taken every two weeks from September to December 2020 during the transition of the dry season to the rainy season on station 0 (798334.914 m E and 9231522.269 m S), station 1 (798607.783 m E and 9231399.062 m S), station 2 (798596.172 m E and 9231220.976 m S), and station 3 (798727.284 m E and 9230980.824 m S) during morning hours (Fig. 1). The sampling referred to purposive sampling, the technique of taking samples based on considerations that focus on specific goals [35]. The samples at station 0 were taken two weeks earlier than at the pond stations, conform to HRT, to determine the effect of wetland on pollutant removal. Water samples were taken and directly measured for water temperature, pH, TDS, and DO using a LUTRON^{TM} (WA-2017SD), real-time data logger, while for the other parameters measurement, the samples were sent to the laboratory to be tested based on the APHA [36], the AOAC [37], and the Indonesian National Standard (SNI).

Fig. 2 The wickered-constructed floating wetland in the Gedebage pond

The phytoplankton sampling based on Wardhana was conducted with the same sites and the same period on station 1, station 2, and station 3 spatially within the horizontal and vertical stations. Horizontal samples were conducted on the inlet, middle, and outlet areas. Vertical samples were conducted on surface depth (0,2 m), middle depth (2 m), and 4 m depth on maximum depth. 1.0-liter water samples were collected and filtered using a 25 µm mesh size plankton net and then preserved in 4% formaldehyde [38]. Phytoplankton was observed using the microscope and the Sedgewick Rafter Cell and identified as genera based on the Identification Guidelines [39].

3.4 The Physicochemical Assessment

The physicochemical assessment conducted based on the PI refers to Eq. (1), the PI method was based on two indexes quality, the mean index (R) was the average pollution level of all parameters in one observation, and the maximum index (M) was the dominant parameter in water quality degradation at one observation [40].

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

where PI_j was pollution index for designation j; C_i was the concentration of water quality parameters; L_{ij} was concentration according to water quality standard; $\left(\frac{C_i}{L_{ij}}\right)_M^2$ is maximum of C_i/L_{ij} value; and $\left(\frac{C_i}{L_{ij}}\right)_R^2$ was average of C_i/L_{ij} value.

The criteria of the pollution index were: $0 \leq Pi_j \leq 1$ = conform to quality standard, $1 < Pi_j \leq 5$ = lightly polluted, $5 < Pi_j \leq 10$ = moderately polluted, and $Pi_j > 10$ = heavily polluted [41].

The WQI approach was based on the most common factors described in the following three steps: parameter selection, determination of quality function, and sub-indices aggregation with mathematical expression. The Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) was one of the WQI methods to determine the classification of water pollution refer to Eq. 2 following relation:

$$WQI = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \quad (2)$$

where scope (F_1) = number of variables whose objectives are not met, F_1 = number of failed variables /total number of variables*100; frequency (F_2) = number of times by which the objectives are not met, F_2 = number of failed tests/total number of tests*100; amplitude (F_3) = amount by which the objectives are not met: (a) excursions = (failed test value i/objective) - 1, (b) normalized sum of excursions (NSE) = $\sum_{i=1}^{N} \text{excursion}_i \, / \text{no of tests}$, (c) F_3 = [nse/0.01nse+0.01]. The criteria of CCME WQI are: 95-100 = excellent, 80-94 = good, 60-79 = fair, 45-59 = marginal, and 0-44 = poor [42].

3.5 The Biological Assessment

Phytoplankton was often used as bioindicators of water quality because they are sensitive to environmental changes in water bodies. They also give more evidence concerning alterations in water quality than nutrient or chlorophyll-a concentration [43] [44]. The standard index used to measure biodiversity were the Shannon-Wiener diversity index (H'), uniformity index (E), and the Simpson dominance index (D) [45]. Relations of the Shannon-Wiener diversity index, uniformity index, and the Simpson dominance index were according to Eq. 3, Eq. 4, and Eq. 5:

$$H' = -\sum_{i=1}^{N} Pi.\ln Pi \quad (3)$$

$$E = \frac{H'}{H'Max} \quad (4)$$

$$D = \left(\frac{Ni}{N}\right)^2 \quad (5)$$

where Pi = Ni/N is the share of the i-th species/genera; Ni is the number of the i-th species/genera; N is the total number of organisms, H' max = ln S; and S = total organism. Criteria of diversity index were: H' < 1 = low diversity; $1 \leq H' \leq 3$ = moderately diversity; H' > 3 = high diversity. Criteria of uniformity index were: E < 0.4 = low uniformity; $0.4 \leq E \leq 0.6$ = moderately uniformity; and E > 0.6 = high uniformity. Criteria of dominance index were: $0 \leq D \leq 0.5$ = no dominance and $0.5 < D \leq 1.0$ = there was dominance [46]. Biological parameters for water quality was used according to criteria: $0 \le H' < 1$ = heavily polluted; $1 \le H' < 2$ = moderately polluted; $2 \le H' < 3$ = lowly polluted; and $3 \le H' < 4$ = slightly polluted. Trophic State Index (TSI) was an analysis of fertility status by combining three main parameters, depth of Secchi disk (TSI-SD), total phosphate concentration (TSI-TP), and chlorophyll-a unit (TSI-Chl-a) referred to Eq. 6 to Eq. 9 [47]:

$$\text{TSI (SD)} = 10\left(6 - \frac{\ln \text{SD}}{\ln 2}\right) \quad (6)$$

$$\text{TSI (TP)} = 10\left(6 - \frac{\ln\frac{48}{\text{TP}}}{\ln 2}\right) \quad (7)$$

$$\text{TSI (Chl-a)} = 10\left(6 - \frac{2.04\text{-}0.68\ln\text{Chl-a}}{\ln 2}\right) \quad (8)$$

$$\text{Avg. TSI} = \frac{\text{TSI (SD)+TSI (TP)+TSI (Chl-a)}}{3} \quad (9)$$

where SD = Secchi disk depth (m); TP = value of total phosphate (mg/l); Chl-a = value of chlorophyll-a (mg/m^3). The TSI value was obtained by averaging the sum results with the criteria: TSI < 40 = oligotrophic; $40 \le$ TSI < 50 = mesotrophic; $50 \le$ TSI < 70 = eutrophic; and TSI > 70 = hypertrophic [48].

3.6 Statistical Analysis

The data were analyzed using R 4.1.0 open-source software for canonical correspondence analysis (CCA) between physicochemical parameters and biological indicators, and the significance level was considered at $p < 0.05$.

4. RESULTS AND DISCUSSION

4.1. The Physicochemical Measurement

There were 11 physicochemical parameters measured on Cinambo River as influent (station 0) and on pond stations (stations 1, 2, and 3) consisting of physics (water temperature, pH, TDS, and TSS) and chemical (BOD, COD, DO, TN, TP, B, and MBAS) during observations.

The 3 stations in the pond were determined to determine whether there were pollutant removal differences among the upstream, middle, and downstream parts. The Class II Water Quality Standard and the result of the physicochemical assessment are presented in Tables 2 and 3.

Table 2. Physicochemical standard and assessment of influent

Parameters	Units	Class II River Quality Standard	Class II Lake Quality Standard	Station 0 (Influent)
Temp.	°C	Dev. 3	Dev. 3	24.500 ± 1.700
pH	-	6-9	6-9	7.400 ± 0.170
TDS	mg/L	1000	1000	619.000 ± 20.000
TSS	mg/L	50	50	28.000 ± 26.000
BOD	mg/L	3	3	18.000 ± 4.000
COD	mg/L	25	25	39.000 ± 15.000
DO	mg/L	4	4	1.620 ± 1.170
TN	mg/L	15	0.75	9.873 ± 5.799
TP	mg/L	0.2	0.03	0.727 ± 0.314
B	mg/L	1	1	0.757 ± 0.631
MBAS	mg/L	0.2	0.2	0.578 ± 0.474

Source: Government Ordinance No. 22 of 2021

Table 3. Physicochemical assessment at Gedebage pond during observations

Parameters	Units	Station 1	Eff.* (%)	Station 2	Eff.* (%)	Station 3	Eff.* (%)
Temp.	°C	27.800 ± 2.300	-	29.000 ± 1.900	-	28.900 ± 2.100	-
pH	-	8.590 ± 0.940	-	8.770 ± 0.600	-	8.760 ± 0.600	-
TDS	mg/L	331.000 ± 19.000	46.500	325.000 ± 15.000	47.500	312.000 ± 21.000	49.500
TSS	mg/L	17.000 ± 6.000	39.000	19.000 ± 7.000	33.500	17.000 ± 6.000	39.800
BOD	mg/L	12.000 ± 4.000	37.300	12.000 ± 4.000	34.000	11.000 ± 4.000	34.500
COD	mg/L	33.000 ± 7.000	17.500	35.000 ± 10.000	11.800	35.000 ± 11.000	12.400
DO	mg/L	6.230 ± 3.900	283.400	7.280 ± 3.250	347.900	7.500 ± 2.540	361.900
TN	mg/L	2.344 ± 0.505	76.300	2.207 ± 0.570	77.700	2.014 ± 0.471	79.600
TP	mg/L	0.073 ± 0.027	89.900	0.079 ± 0.045	89.100	0.077 ± 0.041	89.400
B	mg/L	0.532 ± 0.310	29.700	0.431 ± 0.272	43.100	0.345 ± 0.249	54.500
MBAS	mg/L	0.157 ± 0.081	72.900	0.129 ± 0.053	77.600	0.103 ± 0.035	82.200

**Eff. = Pollutant removal efficiency*

The sampling conducted during the dry to rainy transition season to the rainy season observed an average water temperature of 24.5 ± 1.7 °C at station 0, which means the deviation at this station was 1.7 °C. It conforms to the Class II quality standard of the river that the maximum deviation was 3 °C. The lowest average temperature at pond stations was 27.8 ± 2.3 °C at station 1 and the highest was 28.9 ± 2.1 °C at station 2. The water temperature at station 3 was 28.9 ± 2.1 °C, almost the same temperature as station 2.

Compared to Class II Quality Standards of Lake/Pond, the water temperature deviations at all stations were not exceeded the maximum deviation of 3 °C within the range of 1.7 to 2.3 °C and conform to the standard. There was an increase in pond water temperatures compared to the influent temperature. These indications can increase the accumulation of chemical substances by aquatic organisms such as phytoplankton [49]. In the same condition with the water temperature, the highest water pH was 8.77±0.60 at station 2 and the lowest was 7.40±0.17 at station 0. All water pH conforms to the standard between 6-9.

Based on observations, there was a relationship between water temperature and pH, higher water temperatures related to higher pH values. The highest pH and water temperature were obtained at station 2, while the lowest pH and water temperature were at station 0. Dissolved minerals were usually measured as total dissolved solids (TDS) [50]; compared to the influent, TDS in the pond decreased between 46.5 to 49.5% and conformed to the standard. The highest removal was at station 3 and the lowest was at station 1. It was caused by TDS being absorbed in the pond before the downstream. TSS can adsorb inorganic and organic chemical elements or compounds dissolved. The adsorption process is physicochemical and plays a role in reducing the concentration of dissolved chemical compounds [51]. In the pond, the highest TSS was 19±7 mg/L at Station 2, and the lowest was at station 1 and station 3 with 17±6 mg/L, it was indicated that station 1 and station 3 in the pond had better water quality than station 2 because many pollutant elements were absorbed; however, all stations conform to the standard. BOD, a characteristic that indicates the amount of dissolved oxygen required by microorganisms, and COD, the amount of oxygen needed to decompose all organic matter in water [52], have a linear correlation [53].

The highest decomposition of BOD between influent and pond was at station 1 with 37.3%. The lowest was 34.0% at station 2, the highest removal of COD was 17.5% at station 1 and the lowest was 11.8% at station 2. However, the standard of BOD and COD at all stations exceeded the water quality standard caused by the BOD, and COD influent concentrations were exceeded the ability of pollutants removal of wickered-constructed floating wetland.

DO, the amount of dissolved oxygen in the water that comes from photosynthesis and absorption of the atmosphere, in whole pond stations DO values were increased 2.8 to 3.6 times compared to the influent. It indicates there was water quality improvement from not conformed the standard in the influent to confirming the standard (> 4) at the pond. There were 79.6% and 89.4% maximum total nitrogen and phosphate reduction compared with influent. Nitrogen and phosphorus are the main causes of eutrophication [54].

Based on the observations, the highest TN (sum of ammonia, nitrate, nitrite, and organic nitrogen) was 2.344±0.505 mg/L at station 1 and TP was 0.079±0.045 mg/L at station 2, the possibility of eutrophication was in that station. Pesticide is one of the water pollutants, one of the elements that can detect pesticides is boron [55]. boron removal compared to influent was 29.7 to 54.5%, the highest concentration was 0.532±0.310 at station 1 and the lowest was 0.345±0.249 mg/L at station 3, the boron concentration at all stations conform to the standard. MBAs detect anionic detergent that was most widely used in society, especially for household clothes washing [56]. MBAs concentration in the influent exceeds the standard. However, removing pollutants by wickered-constructed floating wetland can raise the status of water quality to be conformed with the standard. The reduction of MBAs was 72.9% at station 1, 77.6% at station 2, and 82.2% at station 3.

Based on observations, there was pollutant removal efficiency of the influent in the pond before installation of the wickered-constructed floating wetland that could be caused by deposition of the pollutant. But differences in pollutant removal efficiency between the influent and the pond before and after the installation of the wickered-constructed floating wetland occurred.

The pollutant removal efficiency before installation (Table 1) was between 9% to 1.8 times at Station 1 and Station 3, and between 1% to 1.6 times at Station 2, while the efficiency after the installation was between 11% to 3.6 times at Station 1 and Station 3, and between 33% to 3.4 times at Station 2 (Table 3). Generally, the wickered-constructed floating wetland can increase the efficiency by two times.

4.2. Assessment of The Physicochemical Index

The pollution index (PI) indicated significant water quality improvements in the pond with wickered-constructed floating wetland application. A heavily polluted condition in influent improved to lightly polluted in the pond. A comparison of PI at pond stations indicates the most unpolluted was at station 3 and the most polluted was at station 2 (Table 4). CCME WQI method indicated the same result as the PI method. There was significant water quality improvement from poor to fair water criteria at pond stations. The most unpolluted and polluted were at station 3 and station 2 (Table 5).

Table 4. PI at Gedebage pond

Station	PI	Criteria
0	17.52	Heavily polluted
1	2.99	Lightly polluted
2	3.01	Lightly polluted
3	2.87	Lightly polluted

Table 5. CCME WQI at Gedebage pond

Station	CCME WQI	Criteria
0	44.36	Poor
1	71.64	Fair
2	71.12	Fair
3	72.95	Fair

4.3. The Phytoplankton Diversity

Due to their short life cycle, phytoplankton responds quickly to environmental changes. It is a valuable indicator of water quality and pollution control [57]. According to the observations, 46 genera were found at station 1, and 44 genera were found at station 2 and station 3. The dominant genera was a blue-green algae Microcystis of Cyanophyta division [58] (Table 6). The abundance of Microcystis can raise the occurrence of eutrophication even harmful alga bloom [59] [60]. Microcystic dominance at station 2 compared to the other stations indicate the lowest water quality was at this part, the same result as the physicochemical assessment.

4.4. Assessment of The Biological Index

Based on the Shannon-Wiener diversity index H', uniformity index E, and the Simpson dominance index, all pond stations have moderate diversity and low uniformity. There was no dominance, which indicated the pond was in moderate condition with the most polluted in the middle part compared to the other parts. Nevertheless, the TSI method indicated the pond was in eutrophic condition at stations 1 and 3 which was between 50 to 70 TSI index, even hypertrophic conditions at station 2 because it exceeded 70 TSI index (Table 7). Eutrophic to hypertrophic in the pond was caused by the TN and TP concentrations were exceeded the standard (Table 2 and 3), which was evidenced by the dominance of Microcystis (Table 6).

Table 6. Phytoplankton Diversity

Division/Genera	Sta. 1	Sta. 2	Sta. 3
Bacillariophyta			
Achnanthidium	22	87	6
Aphanocapsa	1029	1353	888
Cyclotella	85	55	14
Diatoma	2	30	25
Melosira	16	8	19
Navicula	6	1	5
Nitzschia	25	2	11
Synedra	260	223	120
Chlorophyta			
Botryococcus	685	771	658
Chlamydomonas	170	107	113
Chlorella	18	1	16
Chlorogonium	12	5	4
Chodatella	8	3	2
Closterium	16	3	0
Coelastrum	38	1	11
Crucigenia	88	94	22
Elakatothrix	11	11	3
Eudorina	5	2	2
Gloeocystis	62	1	2
Hydrodictyon	1	2	1
Monoraphidium	13	16	7
Oocystis	44	48	17
Oscillatoria	71	143	38
Planktosphaeria	40	0	85
Scenedesmus	80	131	29
Spirogyra	18	8	0
Staurastrum	66	0	0
Staurodesmus	27	0	16
Tetraspora	2	1	9
Ulothrix	1	4	1
Volvox	153	116	52
Cryptophyta			
Cryptomonas	9	2	7
Cyanophyta			
Anabaena	37	447	145
Chroococcus	135	64	59
Homoeothrix	34	3	6
Lyngbya	19	1050	0
Merismopedia	58	66	7
Microcystis	2072	2429	1064
Mougeotia	18	10	9
Pseudanabaena	0	0	35
Raphidiopsis	7	31	16
Spirulina	0	8	5
Synechococcus	1464	760	513
Euglenophyta			
Euglena	32	22	18
Phacus	13	5	13
Trachelomonas	79	70	110
Pyrrophyta			
Gymnodinium	8	25	7
Peridinium	145	145	142
Total of Individual	*7204*	*8364*	*4332*
Total of Genera	*46*	*44*	*44*

Table 7. Diversity index, uniformity index, dominance index, and TSI

Station	H'	E	D	TSI
1	2.40	0.27	0.08	69.40
2	2.36	0.26	0.08	70.69
3	2.41	0.29	0.06	69.06

4.5. CCA between The Physicochemical Parameters and The Biological Indicators

CCA was conducted to measure the degree of closeness of the relationship between a group of dependent variables (physicochemical parameters) consisting of physics and chemical variables and a group of independent variables (biological indicators) of phytoplankton and to describe the structure of the relationship in the cluster of dependent variables and the cluster of independent variables [58].

In this study, there were 9 independent variables selected from the population of phytoplankton genera that exceeded 2% based on empirical sampling size: Aphanocapsa, Synedra, Botryococcus, Anabaena, Lyngbya. Microcystis, Synechococcus, and Peridinium, 3 physics variables (TDS, TSS, and water temperature), and 8 chemical variables (pH, BOD, COD, DO, TN, TP, B, and MBAS). Canonical functions were analyzed based on the smallest number of canonical variables between the relation of the independent and dependent variables. There were 3 canonical functions between phytoplankton and physics. There were 8 canonical functions between phytoplankton and chemical.

4.5.1. The requirement assumptions

The assumptions in this analysis were (i) linearity, which can be done by a Mahalanobis plot between the dependent variable group and the independent variable group. The linearity assumption is met if the plot is a linear pattern. In the testing, the following results were linear (Fig. 3 and Fig. 4), and (ii) multivariate normal, which can be done by the correlation testing between the value of Mahalanobis distance and the Chi-square test. In the testing, r of independent variable of phytoplankton = 0.8868 and p-value = 0.001, r of dependent variable of physics = 0.9923 with p-value = 0.000, and r of chemical = 0.9706 with p-value = 0.000.

According to those values, the Mahalanobis distance and Chi-square had a significant correlation, phytoplankton, physics, and chemical data were normally multivariate distributed, and (iii) no multicollinearity between the variable group data, both dependent and independent variables, it was conducted by checking the correlation value among the variables.

In the testing, the correlation values of phytoplankton, physics, and chemical were less than 0.5, which conformed to non-multicollinearity.

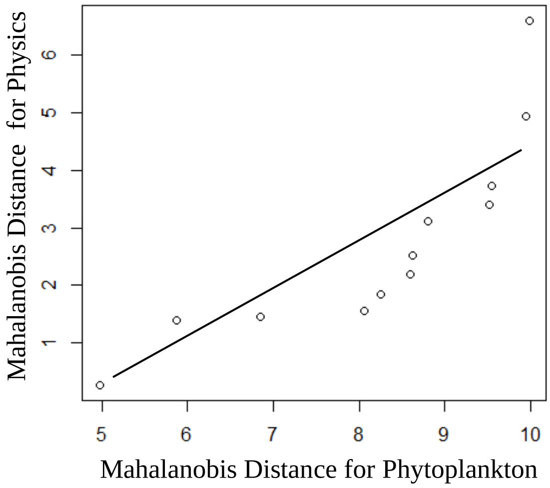

Fig 3. Mahalanobis plot of phytoplankton to physics

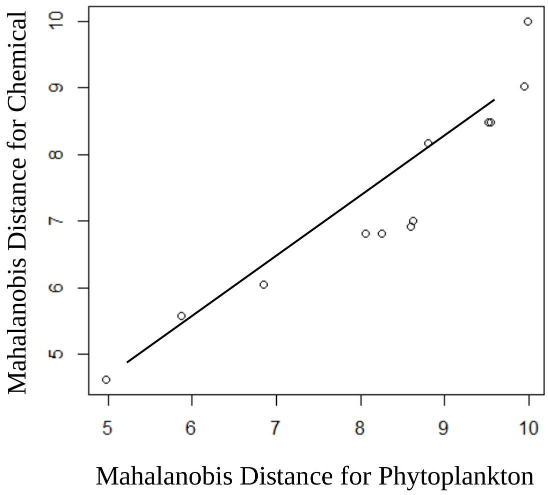

Fig 4. Mahalanobis plot of phytoplankton to chemical

4.5.2. Canonical Correlation Significance Test

The results of the Wilks' lambda test (Table 8) between phytoplankton and physics parameters and Pillai-Bartlett test (Table 9) between phytoplankton and chemical parameters were: Based on the Wilks' lambda and Pillai-Bartlett test, only the first function of 3 canonical functions to physics and 3 to 6 functions of 8 canonical functions phytoplankton to the chemical have p-values < 0.05 and were used for the conclusion.

4.5.3. The Canonical Load

The canonical load is the correlation of the variable to the canonical variable [61]. The first function used in the canonical load between phytoplankton variable and physics parameters (Table 10) were:

Table 8. Wilks' lambda test

Iteration	Stat	p-value
1 to 3:	7.945210 x 10^{-18}	0.03368964
2 to 3:	5.963672 x 10^{-3}	0.47426455
3 to 3:	1.418195 x 10^{-1}	0.41450226

Table 9. Pillai-Bartlett test

Iteration	Stat	p-value
1 to 8:	6.714108292	0.38653561
2 to 8:	5.714108292	0.13964084
3 to 8:	4.714108292	0.04917096
4 to 8:	3.714108292	0.02016041
5 to 8:	2.714108292	0.01279334
6 to 8:	1.714108292	0.01841611
7 to 8:	0.714108292	0.09958583
8 to 8:	0.006281681	0.95096960

Table 10. The canonical load between phytoplankton to physics parameters

Phytoplankton	[,1]
Aphanocapsa	-0.4307685
Synedra	-0.5890071
Botryococcus	-0.5272172
Chlamydomonas	-0.4447150
Anabaena	-0.2280256
Lyngbya	-0.2164656
Microcystis	-0.2321767
Synechococcus	-0.4556224
Peridinium	-0.7990365

Physics	[,1]
TDS	-0.9847767
TSS	-0.2950914
Water Temp.	-0.2123025

The canonical load of the phytoplankton variable correlated to the first canonical function was Peridinium, taken based on the maximum value, with the correlation value was -0.7990. In contrast, the canonical load of the physics correlated to the first canonical function was TDS, with a correlation value was -0.9848. It was indicated that values at the pond were mostly indicated by phytoplankton genera of Peridinium.

The canonical loads between phytoplankton to chemical parameters are presented in Table 11. The canonical loads of the third to the sixth between phytoplankton and chemical parameters were:

- The canonical loads of the third canonical function were Peridinium and pH, with the correlation values were 0.6903 and 0.9990.
- The canonical loads of the fourth canonical functions were Synedra and B, with the correlation values were -0.8197 and -0.6607.
- The canonical loads of the fifth canonical functions were Microcystis and TP, with the correlation values were -0.4787 and 0.5593.
- The canonical loads of the sixth canonical functions were Lyngbya and TP, with the correlation values were 0.4360 and 0.2378.

Table 11. The canonical load between phytoplankton to chemical parameters

Phytoplankton	[,3]	[,4]
Aphanocapsa	0.172297	-0.257676
Synedra	0.115043	-0.819650
Botryococcus	0.181865	-0.138857
Chlamydomonas	0.279849	-0.617727
Anabaena	0.027232	-0.107569
Lyngbya	-0.005787	0.078027
Microcystis	0.161956	-0.650789
Synechococcus	0.188435	-0.642634
Peridinium	0.690344	-0.220932

Phytoplankton	[,5]	[,6]
Aphanocapsa	-0.036875	0.408530
Synedra	0.261292	0.109158
Botryococcus	-0.276910	0.398083
Chlamydomonas	0.297656	-0.199807
Anabaena	-0.183078	0.362412
Lyngbya	-0.140440	0.436036
Microcystis	-0.478748	0.026079
Synechococcus	0.428180	-0.105552
Peridinium	-0.090454	0.125734

Chemical	[,3]	[,4]
pH	0.998990	-2.99 x10^{-10}
BOD	0.431591	-2.45 x 10^{05}
COD	0.780258	-2.40 x 10^{05}
DO	0.826642	1.79 x 10^{05}
TN	-0.064389	-1.40 x 10^{05}
TP	-0.395680	3.44 x 10^{05}
B	-0.091377	-6.61 x 10^{05}
MBAS	0.173853	-3.84 x 10^{05}

Chemical	[,5]	[,6]
pH	-4.93 x 10^{-11}	-1.85 x 10^{-08}
BOD	7.29 x 10^{04}	4.88 x 10^{04}
COD	-2.65 x 10^{05}	-1.31 x 10^{05}
DO	6.82 x 10^{04}	-6.76 x 10^{04}
TN	1.85 x 10^{05}	1.30 x 10^{05}
TP	5.59 x 10^{05}	2.38 x 10^{05}
B	1.34 x 10^{05}	-1.52 x 10^{04}
MBAS	-5.79 x 10^{04}	-2.17 x 10^{05}

The canonical load between the phytoplankton variable and physicochemical parameters indicated that the phytoplankton genera of Peridinium had the greatest influence on pH value, Synedra affected boron value, and Microcystis and Lyngbya had the greatest effect on eutrophication because it had the closest correlation to total phosphate.

5. CONCLUSIONS

The wickered-constructed floating wetlands indicated an ability to reduce pollutants varying from 11% to three times of the 11 parameters measured and observed to have two times pollutant removal efficiency compared to the deposition of the pollutant naturally, but several parameters such as BOD, COD, TN, and TP were not conformed yet to the standard because they exceed the pollutant absorption capacity of wickered-constructed floating wetlands. It is recommended that if the water pollutants exceed the absorption capacity, the value of the HLR needs to be descended. In this case, increasing the number of floating wetlands or combining wickered-constructed floating wetlands with conventionally constructed wetlands that have existed previously on the pond, is advised.

Based on the physicochemical index, the trend of ecological status was changed from heavily polluted to lightly polluted. The biological index also indicated that the ecological status of the Gedebage pond was lightly polluted, however, the trophic status indicated eutrophication in the pond as indicated by the total nitrogen and phosphorus concentrations exceeding the standard. It indicated the abundance of the genera Microcystis and Lyngbya. CCA also indicated a correlation between the abundance of the genera of Microcystis and phosphorus values which means the Microcystis genera from the Cyanophyta division and the Lyngbya from the Cryptophyta division can be a bio-indicator for eutrophication because they have a positive correlation with the phosphorus value.

Station 2, in the middle of the pond, had the lowest water quality compared to the other stations. It was due to the condition of the water being more laminar/lentic compared to other stations, which proves the water pollution in lentic waters needs more attention than in flowing/lotic waters.

In the future, a comparison between wickered-constructed floating wetland and without wicker in measuring differences in pollutant removal efficiencies needs to be addressed.

6. ACKNOWLEDGEMENTS

The study was supported by the Water Environment Experimental Station, Research Center for Water Resources, Ministry of Public Works and Housing, Indonesia.

7. REFERENCES

[1] Chowdhury, S., Water quality degradation in the sources of drinking water: an assessment based on 18 years of data from 441 water supply systems. Environmental monitoring and assessment, Vol. 190, Issue 7, 2018, pp.1-18.

[2] Qasim, A.H., International water model under productivity conditions: the case of the Tigris and the Euphrates. GEOMATE Journal, Vol. 17, Issue 62, 2019, pp.29-34.

[3] Elshinnawy, I.A., and Almaliki, A.H., Reservoir Hydrologic Routing For The Hydrodynamic Of Al-Manzala Lake, Egypt. GEOMATE Journal, Vol. 21, Issue 83, pp.157-165.

[4] Salim, N., Water Quality Analysis In A River In Sub Watershed Jatiroto East Java, Indonesia. GEOMATE Journal, Vol. 22, Issue 89, 2022, pp.106-113.

[5] Nugroho, F.L., Rusmaya, D. and Damayanti, M., Comparison Of Cod And Tss Removals From Artificial River Water By Mudballs Made With Activated Em1 And Em4 Solutions. GEOMATE Journal, Vol. 16, Issue 55, 2019, pp.28-33.

[6] Craig, I.P., Bundschuh, J. and Thorpe, D., Pesticide sustainable management practice (SMP) including porous biochar/geopolymer structures for contaminated water remediation. GEOMATE Journal, Vol. 9, Issue 18, 2015, pp.1523-1527.

[7] Hendrawan, D., Widarnako, S., Moersidik, S.S. and Triweko, R.W., Evaluation of centralized WWTP and the need of communal WWTP in supporting community-based sanitation in Indonesia. European Scientific Journal, Vol. 9, Issue 17, 2013.

[8] Han, J.H., Kim, B., Kim, C. and An, K.G., Ecosystem health evaluation of agricultural reservoirs using multi-metric lentic ecosystem health assessment (LEHA) model. Paddy and water environment, Vol. 12, Issue 1, 2014 pp.7-18.

[9] Davidson, N., Middleton, B., McInnes, R.J., Everard, M., Irvine, K., Van Dam, A.A. and Finlayson, C., Introduction to the wetland book 1: Wetland structure and function, management, and methods. In The Wetland Book I: Structure and function, management and methods, Springer, 2018 (pp. 3-14).

[10] Rahmadyanti, E., Wiyono, A. and Firmansyah, G.A., Integrated system of the biofilter and constructed wetland for sustainable batik industry. GEOMATE Journal, Vol. 18, Issue (70), 2020, pp.138-148.

[11] Vymazal, J., Constructed wetlands for wastewater treatment. Water, Vol. 2, Issue 3, 2010, pp.530-549.

[12] Lucke, T., Walker, C. and Beecham, S., Experimental designs of field-based constructed floating wetland studies: A review. Science of the Total Environment, 660, 2019, pp.199-208.

[13] Pavlineri, N., Skoulikidis, N.T. and Tsihrintzis, V.A., Constructed floating wetlands: a review of research, design, operation and management aspects, and data meta-analysis. Chemical Engineering Journal, Vol. 308, 2017, pp.1120-1132.

[14] Zhang, C.B., Liu, W.L., Pan, X.C., Guan, M., Liu, S.Y., Ge, Y. and Chang, J., Comparison of effects of plant and biofilm bacterial community parameters on removal performances of pollutants in floating island systems. Ecological Engineering, Vol. 73, 2014, pp.58-63.

[15] Keizer-Vlek, H.E., Verdonschot, P.F., Verdonschot, R.C. and Dekkers, D., The contribution of plant uptake to nutrient removal by floating treatment wetlands. Ecological Engineering, 73, 2014, pp.684-690.

[16] Chance, L.M.G., Van Brunt, S.C., Majsztrik, J.C. and White, S.A., Short-and long-term dynamics of nutrient removal in floating treatment wetlands. Water Research, Vol. 159, 2019, pp.153-163.

[17] Ulrich, U., Hörmann, G., Unger, M., Pfannerstill, M., Steinmann, F. and Fohrer, N., Lentic small water bodies: Variability of pesticide transport and transformation patterns. Science of The Total Environment, 618, 2018, pp.26-38.

[18] Yan, C., Zhuang, T., Bai, J., Wen, X., Lu, Q. and Zhang, L., Assessment of as, cd, Zn, Cu and Pb pollution and toxicity in river wetland sediments and artificial wetland soils affected by urbanization in a Chinese delta. Wetlands, Vol. 40, Issue 6, 2020, pp.2799-2809.

[19] Schwammberger, P., Walker, C. and Lucke, T., Using floating wetland treatment systems to reduce stormwater pollution from urban developments. GEOMATE Journal, vol. 12, Issue 31, 2017 pp.45-50.

[20] Lee, S.I., Lim, S.S., Lee, K.S., Park, W.K., Shin, J.D., Yoon, K.S., Kim, H.Y. and Choi, W.J., Coal fly ash enhanced planted-floating bed performance in phosphorus-contaminated water treatment. Ecological Engineering, Vol. 73, 2014, pp.276-280.

[21] Kivaisi, A.K., The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review. Ecological Engineering, Vol. 16, Issue 4, 2001, pp.545-560.

[22] Chazanah, N., Muntalif, B.S., Sudjono, P., Rahmayunita, I. and Suantika, G., Determinant parameters for upstream ecological status assessment of Citarum River, Indonesia. GEOMATE Journal, Vol. 15, Issue 50, 2018, pp.205-216.

[23] Lumb, A., Sharma, T.C. and Bibeault, J.F., A review of genesis and evolution of water quality index (WQI) and some future directions. Water Quality, Exposure, and Health, Vol. 3, Issue 1, 2011, pp.11-24.

[24] Pang, S., Zhang, S., Lv, X., Han, B., Liu, K., Qiu, C., Wang, C., Wang, P., Toland, H. and He, Z., Characterization of the bacterial community in biofilm and sediments of wetlands dominated by aquatic macrophytes. Ecological Engineering, Vol. 97, 2016, pp.242-250.

[25] Liu, X., Xiao, W., Landry, M.R., Chiang, K.P., Wang, L. and Huang, B., Responses of phytoplankton communities to environmental variability in the East China Sea. Ecosystems, Vol. 19, Issue 5, 2016, pp.832-849.

[26] McGenity, T.J., Timmis, K.N., and Fernández, B.N. eds., Hydrocarbon and lipid microbiology protocols. Berlin/Heidelberg, Germany: Springer, 2016.

[27] Traversetti, L., Scalici, M., Ginepri, V., Manfrin, A. and Ceschin, S., Concordance between macrophytes and macroinvertebrates in a Mediterranean river of central Apennine region. Journal of Environmental Biology, Vol. 35, Issue 3, 2014, p.497.

[28] Utomo, Y., Priyono, B. and Ngabekti, S., Saprobitas of Juwana River Waters Based on Plankton Bioindicators. Unnes Journal of Life Science, Vol. 2, Issue 1, 2013, pp.28-35.

[29] The Republic of Indonesia, Government Ordinance of Republic of Indonesia No. 22 of 2021 Implementation of Environmental Protection and Management.

[30] Do, Y. and Kim, J.Y., An assessment of the aesthetic value of protected wetlands based on photo content and its metadata. Ecological Engineering, 150, 2020, p.105816.

[31] Henny, C., Kurniawan, R. and Akhdiana, I., Floating treatment wetlands and submerged vegetation for water quality improvement of an urban lake in megacity Jakarta, Indonesia. In IOP Conference Series: Earth and Environmental Science, Vol. 308, Issue. 1, IOP Publishing, 2019, pp. 012005.

[32] Zhao, Y., Liu, D., Huang, W., Yang, Y., Ji, M., Nghiem, L.D., Trinh, Q.T. and Tran, N.H.,

Insights into biofilm carriers for biological wastewater treatment processes: Current state-of-the-art, challenges, and opportunities. Bioresource Technology, Vol. 288, 2019. pp.121619.

[33]Edwards, S.J. and Kjellerup, B.V., Applications of biofilms in bioremediation and biotransformation of persistent organic pollutants, pharmaceuticals/personal care products, and heavy metals. Applied microbiology and biotechnology, Vol. 97, Issue 23, 2013, pp.9909-9921.

[34] Pusparinda L., and Santoso I. B., Literature Study of Floating Treatment Wetland Planning in Indonesia, JTITS, vol. 5, issue 2, 2016, pp. A471–A475.

[35] Palinkas, L.A., Horwitz, S.M., Green, C.A., Wisdom, J.P., Duan, N. and Hoagwood, K., Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. Administration and policy in mental health and mental health services research, Vol. 42, Issue 5, 2015. pp.533-544.

[36] Bridgewater L. L., Eds., Standard methods for the examination of water and wastewater, 23rd edition. Washington, DC: American Public Health Association, 2017.

[37] Feldsine, P., Abeyta, C. and Andrews, W.H., AOAC International methods committee guidelines for validation of qualitative and quantitative food microbiological official methods of analysis. Journal of AOAC International, Vol. 85, Issue 5, 2002, pp.1187-1200.

[38] Takarina, N.D., Nurliansyah, W. and Wardhana, W., Relationship between environmental parameters and the plankton community of the Batuhideung Fishing Grounds. Biodiversitas Journal of Biological Diversity, Vol. 20, Issue 1, 2019, pp.171-180.

[39] Bellinger, E.G. and Sigee, D.C., Freshwater algae: identification, enumeration, and use as bioindicators. John Wiley & Sons, 2015.

[40] Marganingrum D., River Water Quality Assessment using The Results of Two Different Methods Index. vol. 23, issue 3, 2013, pp. 11.

[41] Suriadikusumah, A., Mulyani, O., Sudirja, R., Sofyan, E.T., Maulana, M.H.R. and Mulyono, A., Analysis of the water quality at Cipeusing river, Indonesia using the pollution index method. Acta Ecologica Sinica, Vol. 41, Issue 3, 2021, pp.177-182.

[42] Tyagi, S., Sharma, B., Singh, P. and Dobhal, R., Water quality assessment in terms of water quality index. American Journal of water resources, Vol. 1, Issue 3, 2013, pp.34-38.

[43] Yusuf, Z.H., Phytoplankton as bioindicators of water quality in Nasarawa reservoir, Katsina State Nigeria. Acta Limnologica Brasiliensia, Vol. 32, 2020.

[44] Amengual-Morro, C., Niell, G.M. and Martínez-Taberner, A., Phytoplankton as a bioindicator for waste stabilization ponds. Journal of Environmental Management, Vol. 95, 2012, pp.S71-S76.

[45] Sirait, M., Rahmatia, F., & Pattulloh, P., Comparison of Diversity Index and Dominant Index of Phytoplankton at Ciliwung River Jakarta. Jurnal Kelautan: Indonesian Journal of Marine Science and Technology, vol. 11, issue 1, 2018, pp. 75-79.

[46] Ulfah, M., Fajri, S.N., Nasir, M., Hamsah, K. and Purnawan, S., Diversity, evenness and dominance index reef fish in Krueng Raya Water, Aceh Besar. In IOP Conference Series: Earth and Environmental Science, Vol. 348, Issue. 1, IOP Publishing, 2019, pp. 012074).

[47] Cunha, D.G.F., do Carmo Calijuri, M. and Lamparelli, M.C., A trophic state index for tropical/subtropical reservoirs (TSItsr). Ecological Engineering, Vol. 60, 2013, pp.126-134.

[48] Pratiwi, N., Imran, Z., Ayu, I. P., Iswantari, A., And Wulandari, D. Y., The phosphorus load and the variation of the trophic states of Cirata Reservoir (West Java, Indonesia) from 1988 to 2017. Biodiversitas Journal of Biological Diversity, vol. 21, issue 9, 2020.

[49] Schabhüttl, S., Hingsamer, P., Weigelhofer, G., Hein, T., Weigert, A. and Striebel, M., Temperature and species richness effects in phytoplankton communities. Oecologia, Vol. 171, Issue 2, 2013, pp.527-536.

[50] Devesa, R. and Dietrich, A.M., Guidance for optimizing drinking water taste by adjusting mineralization as measured by total dissolved solids (TDS). Desalination, Vol. 439, 2018, pp.147-154.

[51] Li, Z. and Yang, P., February. Review of physicochemical, chemical, and biological processes for pharmaceutical wastewater. In IOP Conference Series: Earth and Environmental Science, Vol. 113, Issue. 1, IOP Publishing, 2018, pp. 012185).

[52] Lee, J., Lee, S., Yu, S. and Rhew, D., Relationships between water quality parameters in rivers and lakes: BOD5, COD, NBOPs, and TOC. Environmental monitoring and assessment, Vol. 188, Issue 4, 2016, pp.1-8.

[53] Lotfi, K., Bonakdari, H., Ebtehaj, I., Mjalli, F.S., Zeynoddin, M., Delatolla, R., and Gharabaghi, B., Predicting wastewater treatment plant quality parameters using a novel hybrid linear-nonlinear methodology. Journal of environmental management, Vol. 240, 2019, pp.463-474.

[54] Huang, J., Xu, C.C., Ridoutt, B.G., Wang, X.C. and Ren, P.A., Nitrogen and phosphorus losses and eutrophication potential associated with fertilizer application to cropland in China. Journal of Cleaner Production, Vol. 159, 2017, pp.171-179.

[55] Li, W.K., Feng, J.T. and Ma, Z.Q., Nitrogen, sulfur, boron and flavonoid moiety co-incorporated carbon dots for sensitive fluorescence detection of pesticides. Carbon, Vol. 161, 2020, pp.685-693.

[56] Utomo, W. P., Nugraheni, Z. V., Rosyidah, A., Shafwah, O. M., Naashihah, L. K., Nurfitria, N., and Ullfindrayani, I. F., Reduction of Anionic Surfactant and Phosphate Levels in Laundry Wastewater in the Keputih Area, Surabaya using Activated Carbon. Akta Kimia Indonesia, Vol. 3, issue 1, 2018 , pp. 127-140.

[57] Wu, N., Schmalz, B. and Fohrer, N., Study progress in riverine phytoplankton and its use as bio-indicator–a review. Austin Journal of Hydrology, Vol. 1, Issue 1, 2014, p.9.

[58] Sahoo, D. and Seckbach, J. eds., The algae world. Dordrecht: Springer Netherlands, 2015.

[59] Harke, M.J., Steffen, M.M., Gobler, C.J., Otten, T.G., Wilhelm, S.W., Wood, S.A. and Paerl, H.W., A review of the global ecology, genomics, and biogeography of the toxic cyanobacterium, Microcystis spp. Harmful Algae, Vol. 54, 2016, pp.4-20.

[60] Kimambo, O.N., Gumbo, J.R. and Chikoore, H., The occurrence of cyanobacteria blooms in freshwater ecosystems and their link with hydro-meteorological and environmental variations in Tanzania. Heliyon, Vol. 5, Issue 3, 2019, p.e01312.

[61] Härdle, W.K., and Simar, L., Canonical correlation analysis. In Applied multivariate statistical analysis, Springer, Berlin, Heidelberg, 2015, pp. 443-454.