LEVEL OF POLLUTION AND DETERMINING FACTORS OF WATER HEALTH IN CITARUM RIVER, MUARA GEMBONG, BEKASI, WEST JAVA

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Abstract

The restoration of water quality needs to be monitored on the rivers in Indonesia. Land occupation and land conversion are the main problems that have an impact on the handling of water quality in the Muara Gembong area. The research location was located in Muara Gembong District, Bekasi Regency, West Java. Water quality testing in this study was carried out directly in the field using in situ digital measuring instruments including pH, air temperature, DO, TDS, Phosphate, Brightness and Salinity. Meanwhile, the TSS and BOD parameters were tested in the laboratory at the Secretariat of the Indonesian Biodiversity Conservation Unit (IBCU). The results of the Pollution Index showed that the research location was divided into 2 groups, namely moderate pollution Beting Outfall, Bungin Outfall and Upstream), light pollution (Middle Stream, Bendera Outfall, Outfall Bloom and Outfall Herons). The results of PCA analysis with a variance value of 40.8% showed that the location of the study was holistic by BOD value, phosphate content and salinity as environmental parameters that determined environmental conditions.

Keyword: *Muara Gembong, Water Quality, Polution Index*

1. Introduction

Water quality monitoring needs to be considered for each river in Indonesia. Sources of pollution can occur due to various factors, including industrial activities and human activities. The biggest challenges today often come from human-made activities, such as agricultural activities, plantations, cultivation and household waste. The habits of the surrounding community play an important role in maintaining water quality in the area.

Several functions of watersheds and other landscapes are very meaningful to humans, especially in terms of the availability of natural resources and ecosystem services (such as food sources, housing and water resources). Some of these functions may work synergistically, and some of these functions can also be detrimental or even a source of conflict. Multiple functions separated in time and space can be effective at the same time and place (Bolliger et al., 2011).

Muara Gembong is located on the north coast of Java Island as an estary area, close to DKI Jakarta, and has a relatively high threat of degradation. Since the Indonesian Minister of Agriculture designated it as a protected forest area through Decree No.92 / UM / 54 of 1954, Muara Gembong mangroves have experienced various pressures such as land tenure, land conversion and land conversion/function. In the Muara Gembong area, land tenure and land conversion are major problems in water quality management. Most of the area has been transformed into ponds, rice fields, gardens and even settlements. The aim of scientific research was to provide space for local preservation and development. At the same time, the Indonesian Minister of Forestry issued No. 475 / Menhut-II / 2005, concerning the Transfer of Status to Muara Gembong. This study builds target indicators through analysis of the relationship between the Citarum creek estuary location and water quality using statistical relationships. Hydrological system analysis was carried out by describing the chemical-physical conditions of the watershed in the hydrological transformation process.

2. Materials and Methods

The research location in the field administratively was in Muara Gembong District, Bekasi Regency, West Java. This research was conducted from July to September 2020. Geographically, the research location was located in the north of Java Island (Figure 1). The research method used was purposive stratified sampling method based on the flow of the Citarum River in Muara Gembong. The research location was known as an estuary area. Location 1. Bendera Outfall 5 ° 56'12.6 "South Latitude 106 ° 59'45.6" East Longitude 2. Mekar Outfall 6 ° 01'21.4 "LS 106 ° 59'50.2" East Longitude, Location 3. Middle of River 5 ° 59'25.5 " LS 107 ° 05'02.0 "East Longitude, location 4. Beting Outfall 5 ° 55'28.9" LS 107 ° 02'07.0 "East Longitude, location 5. Bungin Outfall, 5 ° 56'30.0" LS 107 ° 05'53.6 "East Longitude, location 6. Upstream 6 ° 02'14.5 "LS 107 ° 06'45.5" East Longitude.

Figure 1. Research Location Map

Testing the quality of river water in this study was carried out directly in the field using digital measuring instruments including pH (electrometic principle), water temperature (mechanical expansion principle), DO (membrane polarography principle), TDS (electrometric principle), Phosphate (calorimetric principle), Brightness (measurement of distance units) and Salinity (principle of refraction). As for the TSS (gravimetric principle) and BOD (membrane polarographic principle) parameters, the test was carried out in Laboratory at the Secretariat of the Indonesian Biodiversity Conservation Unit (IBCU).Water quality testing was carried out using methods according to applicable standards. Each sample taken was repeated 3 times on the riverbank, the middle of the river and the other riverbanks. The data that has been obtained from the results of testing the physical and chemical parameters of river water, both in the field and in the laboratory, then analyzed the water quality of the Citarum River by comparing the test results with class II water quality standards based on PP RI No. 82 of 2001 concerning Water Quality Management and Water Pollution Control (see table 1) as a reference for the value of pollution on the pollution index.

Table 1. Class II Water Quality Standards

Lij	Class II	Unit
DO	4	ppm
BOD	3	ppm
P	0.2	ppm
T	22-28	C
pH	6.0-9.0	-
S	-	-
B	2	m
TDS	1000	ppm
TSS	50	ppm

Note: DO, Disolved Oxygen; BOD, Biological Oxygen Demand; P, phosphate; T, temperatut; pH, degree of acidity; S, Salinity; B, Brightness; TDS, Total Disolved Solid; TSS, Total Suspended Solid.

In this study, the determination of pollution was carried out using the Pollution Index method. The calculation formula used the Pollution Index method was as followed:

$$PI_j = \sqrt{\frac{(C_i/L_{ij})^2 M + (C_i/L_{ij})^2 R}{2}}$$

Information

Lij : The concentration of water quality parameters stated in the standard quality of water designation (j)

Ci : Concentration of water quality parameters (i)

PIj : Pollution Index for designation (j)

(Ci / Lij) M : Maximum Ci / Lij value

(Ci / Lij) R : Average Ci / Lij value

The results of the calculation of this Pollution Index can show the level of contamination of the Citarum River by comparing it with the quality standard according to the water class stipulated by PP RI No. 82 of 2001 concerning Water Quality Management and Water Pollution Control. So that information can be obtained in determining whether or not river water can be used for a certain designation according to the water class.

Table 2.Pollution Index Interpretation

IP Score	Description
0 - 1.0	Good condition
1.1 - 5.0	Lightly Polluted
5.1 - 10	Medium Polluted
> 10	Heavy Polluted

PCA (Principal Component Analysis) or also known as principal component analysis. PCA in this study was to generate the analytical value of the survey variables.

$$Y_p = e'_p X$$

Where

Yp : variance,

e'p : eigenvectors and

X : average.

3. Results and Discussions

The results of field samples were analyzed statistically at 7 station locations which were observed based on chemical and physical parameters can be seen in the table below. The minimum value (low), maximum value (high), mean (average), variance and standard variance (data diversity) can be seen in the table 3.

Table 3. Basic Statistics of Water Physics and Chemical Parameters

	Min	Max	Mean	Variance	Stand. dev
DO	5,2	9	6	1	1
BOD	0,16	5,3	2,1	3	2
P	0,12	4	0,83	2	1
T	22,2	31	27	7	3
pH	7	7	7	0,05	0,24
S	0	29	11	138	12
B	0,05	0,46	0,16	0,02	0,14
TDS	1,473	21,767	10,35	672 . 10^{7}	8,197
TSS	6,70 10^{-9}	8,00. 10^{-8}	5,05. 10^{-8}	7,23. 10^{-16}	2,69. 10^{-8}

Note: DO, Disolved Oxygen; BOD, Biological Oxygen Demand; P, phosphate; T, temperature; pH, degree of acidity; S, Salinity; B, Brightness; TDS, Total Disolved Solid; TSS, Total Suspended Solid.

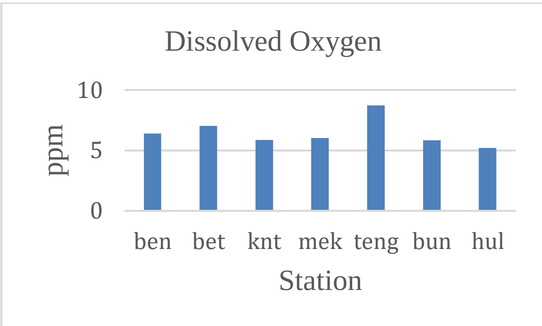

Figure 2. Dissolved Oxygen

Note: (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

Dissolved oxygen parameters were used to determine the organic and inorganic loads of water. Dissolved oxygen content can reduce and oxidize dissolved compounds. Therefore, dissolved oxygen was very important to reduce water pollution. Measurement of DO (Disolved Oxygen) parameters in the Citarum River. The Citarum River in the Muara Gembong area in 7 test stations showed that the value dissolved oxygen was still in the range of quality standards that were considered good according to Class II Standard Standard Types. The Citarum River in the Muara Gembong area in 7 test stations showed that the value dissolved oxygen is still in the range of quality standards that were considered good according to Class II Standard Standard Types.

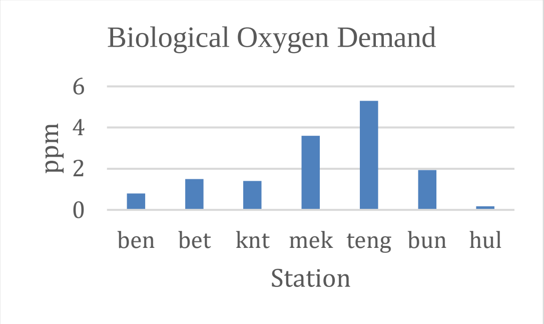

Figure 3. Biological Oxygen Demand

Note: (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

BOD (Biological Oxygen Demand) was the amount of dissolved oxygen needed by decomposing bacteria decomposed organic pollutants in water. The greater the BOD concentration in a water, the higher the concentration of organic matter in the water (Yudo, 2010). The results of monitoring of BOD parameters, stations that did not met quality standards are at the estuary bloom station and the central station with values of 3.6 ppm and 5.3 ppm respectively (See Figure 3). BOD parameter The greater the BOD level, it was an indication that the waters have been polluted. The levels of BOD in water with low levels of pollution and can be categorized as good waters range from 0-10 ppm (Salmin, 2005). The increase in the BOD figure can come from organic materials from domestic waste and other wastes (Rahayu and Tontowi, 2009). The high BOD value was due to the disposal of waste from settlements to rivers and from agricultural land (Anhwange et al., 2012). The quality of Metro River water itself was still within this range or limit, but the greater the BOD level from upstream to downstream indicates that these waters had been polluted due to domestic and agricultural waste discharges.

The results of monitoring of phosphate parameters at each observation station indicated fluctuations at each observation station. Phosphate values that met Class II standards were only at Kuntul Outfall Station and Bungin Outfall Station, which were 0.17 ppm and 0.12 ppm respectively. When compared with the value of phosphate according to type II water quality standards, in terms of phosphate parameters, the water quality of the Citarum River has not met the established water quality standards.

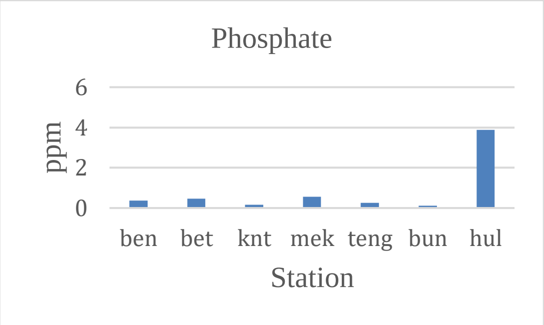

Figure 4. Phosphate

Note: (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

Phosphate was a type of phosphorus that can be used by plants. The properties of phosphorus are very different from other main elements that make up the biosphere, because this element was not present in the atmosphere (Effendi, 2003). In agricultural areas, phosphate comes from fertilizers which enter rivers through drainage and rainwater (Winata et al., 2000). There were still agricultural activities along the Citarum River, Based on the measurement results of the water temperature parameters of the Citarum River in Muara Gembong at each test station location, it showed that there were differences that were relatively unstable (See the graph in Figure 4). When compared with the class II water quality standard (Table 1), which was a deviation of 3 from the natural state, the river water quality condition was still within the standard limit.

This research was conducted in February 2021 which was experiencing high rainfall due to the influence of the western monsoon. During field sampling, researchers experienced significant weather changes from heavy rain to dry heat in the same day, so that the temperature research data tended to be relatively unstable due to significant weather changes at the time of this sampling. Therefore, This physical parameter was not used further in the Pollution Index analysis in order to reduce data errors. Temperature data was used as the saturation point of dissolved oxygen content in water in determining the range of water oxygen in the Pollution Index analysis.

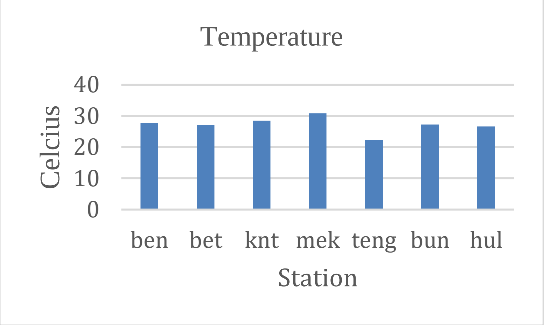

Figure 5. Temperature

Note: (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

The results of monitoring pH parameters at each observation station show the pH value at all stations in safe conditions, where the value was within the class II quality standard with a pH value range between 6-9, then the water quality condition of Citarum River when viewed from pH parameters water was still within the water quality standard limit according to its allotment.

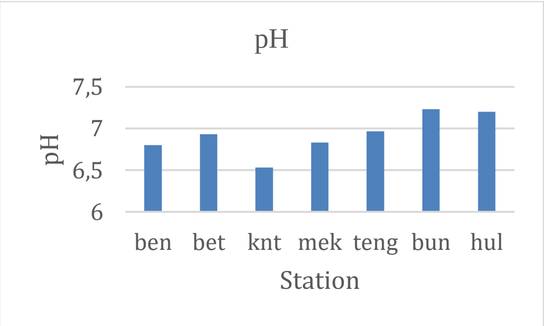

Figure 6. pH

Note: (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

The fluctuation in pH value was influenced by the presence of organic and inorganic waste discharges into the river (Yuliastuti, 2011). The increase in the pH value of Citarum River water was due to the activity of disposing of organic waste originating from domestic waste and waste originating from agricultural activities around the river that enter the Metro River. Normal water that meets the requirements for life has a pH of around 6.5–7.5 (Wardhana, 2004). The pH value of uncontaminated water was usually close to neutral (pH 7) and fulfills the life of almost all aquatic organisms (Syofyan et al., 2011). So that the average pH value of Citarum River water at each station ranges from 6.5-7.2, it fulfills the requirements for the life of aquatic organisms.

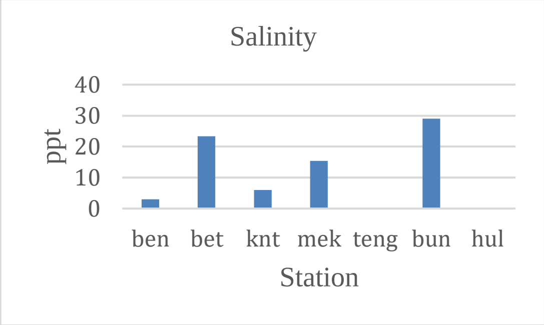

Figure 7. Salinity

Note: (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

The salinity values in this study were obtained with an average range between 0-29 ppt. This salinity level was related to the existence of the research location on the distance from the sea. However, some stations experience a few anomalies such as at the Bendera Outfall and egret estuary stations which were closed to the value of 0 or bargain, because the time before sampling the samples there was heavy rain, so that it affected the drop in salinity levels even though the location was in the estuary end facing the open sea. This parameter was not used in the analysis of quality standards because salinity was not a parameter studied in monitoring class II water quality standards.

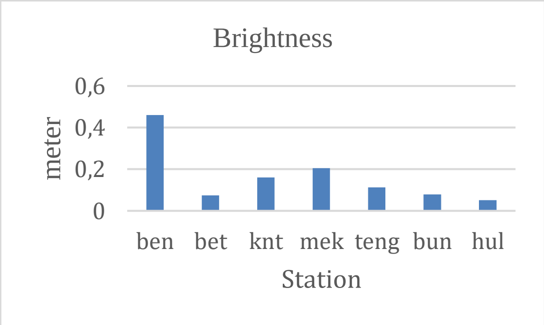

Figure 8. Brightness

Note: (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

Measurement of brightness parameters at all research locations has shown unexpected values in accordance with existing quality standards. The brightness value measured using a sechi disk was too low its value (Mankovsky, 2019). This indicated the low ability of the waters to absorb sunlight, this is due to the influence of turbidity that occurs in the Citarum River.

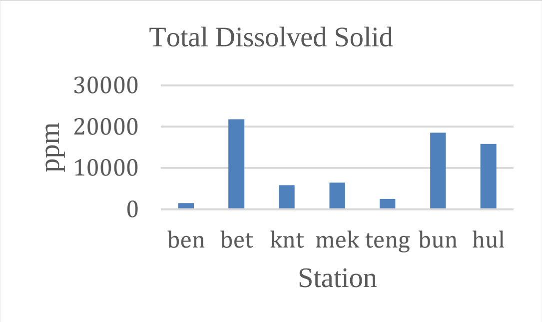

Figure 9. Total Dissolved Solid

Note: (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

TDS (Total Dissolved Solid) at all research location stations in all areas exceeds the permitted standard threshold, where the quality standard threshold was 1000 ppm. The TDS content of these waters reflected the solutes in the waters, the higher the TDS value of a waters, the potential to carry high concentrations of solutes and has the potential to pollute an aquatic environment (Liu et al., 2020).

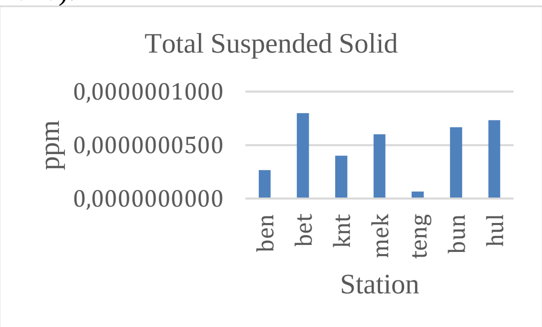

Figure 10. Total Suspended Solid

Note: (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

TSS (Total Suspended Solid) at each observation station shows results that are in accordance with class II quality standards. TSS consists of silt and fine sand and microorganisms, which are mainly caused by soil erosion or soil erosion that is carried into water bodies (Effendi, 2003). thus causing the soil solids that enter the river flow through the run off to increase.

Table 4. Pollution Index Analysis Results

Station	Pi	Interpretation
Upstream	5.38	Moderately Polluted
Middle	4.10	Lightly Polluted
Bendera Outfall	1.40	Lightly Polluted
Mekar Outfall	3.76	Moderately Polluted
Beting Outfall	5.58	Moderately Polluted
Bungin Outfall	5.29	Moderately Polluted
Kuntul Outfall	3.51	Lightly Polluted

Pollution Index analysis which was evaluated at the research location shows the varying levels of pollution. The tributary of the Citarum river that was studied empties at Muara Gembong, consisting of 4 estuaries plus upstream and middle. The level of pollution that can consist of moderate and lightly polluted based on class II quality standards, namely water whose designation can be used for water recreation infrastructure / facilities, freshwater fish farming, livestock, water to irrigate crops and / or other uses requiring water that is used for water recreation. equal to these uses (KLH, 2001). Detailed interpretation of each location can be seen in the table below 4.

The moderate level of pollution that occured at the Hulu, Mekar Outfall, Beting Outfall and Bungin Outfall stations is caused by chemical factors in the form of high dissolved phosphate content. The moderate level of pollution that occurs in the upstream part was due to the phosphate, brightness and TDS values that exceed the permissible threshold. The moderate level of pollution that occurs in Mekar Outfall was due to the BOD, phosphate, brightness and TDS values that exceed the permissible threshold. The moderate level of pollution that occurs in Beting Outfall was due to the phosphate, brightness and TDS values that exceed the permissible threshold. The moderate level of pollution that occurs in Bungin Outfall is due to the brightness and

TDS values that exceed the permissible threshold.

The level of light pollution that occurs was at the central station, Bendera Outfall and Kuntul Outfall. The pollutant factors that contribute to the center station include BOD, phosphate, brightness and TDS. The pollutant factors that contribute to the Bendera Outfall station include phosphate, brightness and TDS. Pollutant factors that contributed to Kuntul Outfall station include brightness and TDS.

Table 5. Eigenvalues and Main Component Variances according to Standard Error

PC	*Eigenvalue*	*% variance*
1.	3.7573	46.966
2.	1.89242	23.655
3.	1.37745	17.218

The results of the PCA multivariate analysis used in this study were carried out to obtain parameters that play an important role in field conditions in the Citarum Tributary of the Muara Gembong area. PCA analysis functions to reduce data that were considered unaffected and form data from new dimensions so that the main parameters that play an important role in it can be identified. The Eigenvalues that appear with a power of more than 1.00 can be used as the main component which will be used further in the analysis of the load value. The eigenvalues of PC1 (F1) were 3.757, the eigenvalues of PC2 (F2) were 1.892 and the eigenvalues of PC3 (F3) were 1.377. These three main components will be considered in the load value analysis (see table 5).

Table 6.Main Component Payload Value

	PC 1	PC 2	PC 3
DO	-0.32237	0.44543	0.24926
BOD	-0.29425	0.50353	0.22846
P	0.276	-0.38504	0.5464
pH	0.32097	0.19233	0.41506
S	0.27436	0.42811	-0.50036
B	-0.30573	-0.36171	-0.36094
TDS	0.47578	0.22055	-0.048207
TSS	0.48496	0.0068484	-0.17855

Note: DO, Disolved Oxygen; BOD, Biological Oxygen Demand; P, phosphate; pH, degree of acidity; S, Salinity; B, Brightness; TDS, Total Disolved Solid; TSS, Total Suspended Solid.

The load values on PC1, PC2 and PC3 can be observed in table 6. A load value of more than 0.5 (+/-) is used as a parameter formed in the new dimension and was considered to has an influence on field conditions statistically. When seen in Table 6, it can be seen from PC2 that the BOD load value has the largest contribution to water conditions. PC3 shows the value of phosphate load and salinity which has the largest contribution to water conditions. In Table 6 it can be seen that the phosphate and salinity values are positive (phosphate) and negative (salinity), this condition is called the inversely proportional value. Salinity relates to station location to sea distance. The farther from the sea, the lower the salinity value, as well as phosphate, the higher the phosphate, the lower the salinity value (inversely). This explains that high phosphate values tend to come a lot from the terrestrial environment rather than from the marine environment. PC1 in the results of this analysis did not provide sufficient contribution compared to the load values on PC2 and PC3.

The results of PCA analysis showed that the main parameters affecting the health of the waters were the phosphate value and TSS value. Phosphate values affect many stations, especially upstream stations (see graph in Figure 11), where this upstream area was the first source of water input before connecting to the center and to various other estuaries in Muara Gembong. The TSS value in this study contributed to the health of the waters at the research location, especially at Beting Outfall and Bungin Outfall. The results of this PCA analysis as a whole had a variance value of 40.8%.

4. Conclusions

The results of this research can be concluded as followed:

- The results of the Pollution Index showed that the research location was divided into 2 groups, namely moderate pollution (Beting Outfall, Bungin Outfall and Upstream), light pollution (Middle, Bendera Outfall, Mekar Outfall and Kuntul Outfall).
- The results of PCA analysis with a variance value of 40.8% showed that the research location was holistically affected by the BOD value, phosphate content and salinity as the dominant environmental parameters determining environmental conditions.

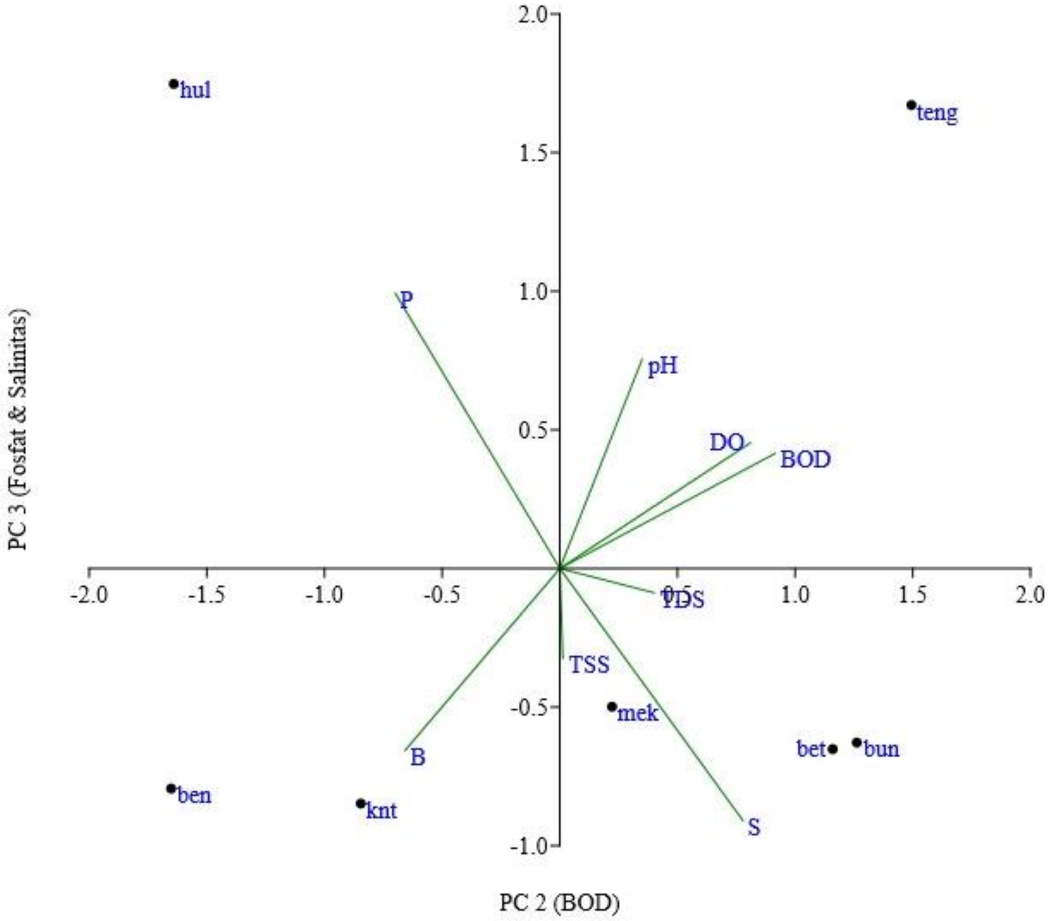

Figure 11. Graph of the value of environmental parameters at various stations.

Note: DO, Disolved Oxygen; BOD, Biological Oxygen Demand; P, phosphate; T, temperatut; pH, degree of acidity; S, Salinity; B, Brightness; TDS, Total Disolved Solid; TSS, Total Suspended Solid. (ben, Bendera Outfall; Mek, Mekar Outfall; teng, Middle; bet, Beting Outfall, bun, Bungin Outfall; hul, Upstream, knt, Kuntul Outfall)

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References

Anhwange, B.A., E.B. Agbaji, and E.C. Gimba. 2012. “Impact Assessment of Human Activities and Seasonal Variation on River Benue, within Makurdi Metropolis”. *Journal of Science and Technology*, *2*. 248-254.

Bolliger, J., Battig M., Gallati J., Klay A., Stauffacher M., Kienast F., 2011. Landscape multifunctionality: a powerful concept to identify effects of environmental change. Reg. Envi-ron. Change 11, pp. 203–206. Springer.

Effendi, H. 2003. *Telaah Kualitas Air: Bagi Pengelolaan Sumber Daya Alam dan Lingkungan Perairan*. Penerbit Kanisius, Yogyakarta.

KLH. 2001. *Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 tentang Pengelolaan Kualitas Air dan Pendendalian Pencemaran Air*. Kementrian Lingkungan Hidup Republik Indonesia, Jakarta.

Liu, W., Ma, L., Abuduwaili, J., & Lin, L. 2020. Distributions, Relationship and Assessment of Major Ions and Potentially Toxic Elements in Waters of Bosten Lake, the Former Largest Inland and Freshwater Lake of China. *Water*, *12*(10), 2859.

Mankovsky, V. I. 2019. Influence of the Composition of Suspended Matter on the Secchi Disk Depth. *Atmospheric and Oceanic Optics*, *32*(3), 284-288.

Rahayu, S. Dan Tontowi. 2009. "Penelitian Kualitas Air Bengawan Solo Pada Saat Musim Kemarau". *Jurnal Sumber Daya Air, 5*. 127-136.

Salmin. 2005. "Oksigen Terlarut (DO) dan Kebutuhan Oksigen Biologi (BOD) sebagai Salah Satu Indikator Untuk Menentukan Kualitas Perairan". *Jurnal Oseana, 30*. 21-26.

Surat Keputusan Menteri Kehutanan No. 475/Menhut-II/2005 tahun 2005 tentang Alih Status Kawasan Hutan Lindung Ujung Krawang (Muara Gembong).

Surat Keputusan Menteri Pertanian No. 92/UM/54 tahun 1954 tentang Penetapan Hutan Lindung Muara Gembong.

Syofyan, I., Usman, dan P. Nasution. 2011. "Studi Kualitas Air Untuk Kesehatan Ikan Dalam Budidaya Perikanan Pada Aliran Sungai Kampar Kiri". *Jurnal Perikanan dan Kelautan, 16*. 64-70.

Wardhana, W.A. 2004. *Dampak Pencemaran Lingkungan*. Penerbit Andi, Yogyakarta.

Winata, I.N.A., A. Siswoyo, dan T. Mulyono. 2000. "Perbandingan Kandungan P dan N Total Dalam Air Sungai di Lingkungan Perkebunan dan Persawahan". *Jurnal Ilmu Dasar, 1*. 24-28.

Yudo, S. 2010. Kondisi kualitas air Sungai Ciliwung di wilayah DKI Jakarta ditinjau dari paramater organik, amoniak, fosfat, deterjen dan bakteri coli. *Jurnal Air Indonesia*, *6*(1).

Yuliastuti, E. 2011. *Kajian Kualitas Air Sungai Ngringo Karanganyar dalam Upaya Pengendalian Pencemaran Air*. Tesis. Program Pascasarjana Universitas Diponegoro, Semarang.