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Revealing of Macroinvertebrate Communities as Ecological Integrity of Water Quality: A Case Study in Kali Lamong Estuary

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ABSTRAK

Setiap negara mempunyai pencemaran air dan ada berbagai cara untuk menilainya, termasuk parameter fisikokimia dan biologi. Penelitian ini mengkaji kualitas air sungai dengan memanfaatkan makroinvertebrata sebagai indikator pencemaran. Pengambilan sampel sedimen dilakukan menggunakan alat Van Veen Grab sampler untuk mengevaluasi kualitas air menggunakan indikator biologis. Selanjutnya, parameter fisikokimia telah dilakukan di lokasi yang sama dengan lokasi pengambilan sampel sedimen untuk menentukan kualitas air yang terkait dengan makroinvertebrata. Skor Rata-Rata Kelompok Kerja Pemantauan Biologis Per Takson dihitung. Penelitian ini terdiri dari 3 stasiun A, B, dan C dengan 3 titik pengambilan sampel. Daerah tersebut mempunyai 3 taksa dari 8 famili makroinvertebrata: Pachychidae, Viviparidae, Sphaeriidae, Piscicolidae, Neritidae, Chironomidae, Planorbidae, dan Mollanidae. Karena lokasi penelitian di muara sungai, tempat tinggal pachychidae di pesisir pantai, mereka merupakan makroinvertebrata yang paling umum. Viviparidae mendiami perairan sungai. Skor pencemaran air dihitung menggunakan skor Rata-Rata Kelompok Kerja Pemantauan Biologis Per Takson (BMWP-ASPT). Skor BMWP-ASPT dari seluruh stasiun berkisar antara 3,67 hingga 5,33, analisis makroinvertebrata dengan metode BMWP-ASPT titik A1, A2, A3, B1, B2, B3, dan C1 termasuk tercemar sedang dan berat, dan hampir seluruh parameter fisika-kimia mempunyai korelasi dengan BMWP-ASPT, kecuali PO4 yang tidak memenuhi batasan analisis statistik.

Kata kunci: Biomonitoring, BMWP-ASPT, Kali Lamong, Kualitas Air

ABSTRACT

Every country has water pollution and there are various ways to assess it, including physicochemical and biological parameters. This study examined river water quality utilizing macroinvertebrates as pollution indicators. Biological Monitoring Working Party Average Score Per Taxon is calculated. Sediment sampling was conducted using a Van Veen Grab sampler to evaluate water quality using biological indicators. Furthermore, physicochemical parameter has been conducted in the same sites with the sediment samples site for determining water quality associated with macroinvertebrates. This study contains 3 stations A, B, and C with 3 sampling points. The area had 3 taxas of 8 macroinvertebrate families: Pachychidae, Viviparidae, Sphaeriidae, Piscicolidae, Neritidae, Chironomidae, Planorbidae, and Mollanidae. Due to the study's location in the river estuary, where pachychidae reside on the coast, they are the most common macroinvertebrates. Viviparidae inhabit waters of rivers. Water contamination scores are calculated using the Biological Monitoring Working Party Average Score Per Taxon (BMWP-ASPT) score. BMWP-ASPT scores from all stations range from 3.67 to 5.33, macroinvertebrate analysis with BMWP-ASPT method points A1, A2, A3, B1, B2, B3, and C1 include moderately and heavily polluted, and almost all physicochemical parameters have a correlation with BMWP-ASPT, except for PO4, which does not meet the statistical analysis limit.

Keywords: Biomonitoring, BMWP-ASPT, Kali Lamong, Water Quality

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1. INTRODUCTION

Water has hydrological, physical, chemical, and biological qualities and is collected in a natural or artificial container. Water Pollution is the introduction or incorporation of organisms, substances, energy, or other components into the water as a result of human activities over the water quality standards (Indonesian Government Regulation No. 22, 2021). Globally, freshwater ecosystems, specifically those characterized by flowing water (lotic ecosystems), are experiencing significant declines in biodiversity. These declines are

primarily attributed to the loss of habitats and degradation of catchment areas, which are consequences of various human activities. These activities include land conversion for agricultural purposes, establishment of settlements and urban areas, industrial development, construction of dams, and pollution (Dudgeon, 2019; Munir et al., 2016). In biological water quality monitoring, especially for organic contaminants, aquatic macroinvertebrates are a group of organisms that are considered the closest to the requirements and are most widely used as bioindicators of the quality of a water body. Assessing the reaction of the macroinvertebrate community and the associated biomonitoring indices is therefore essential for the provision of accurate management and conservation tools for freshwater ecosystems.

River water quality criteria based on PP No. 22 of 2021 should fulfil class II qualification requirements. Based on previous research, it is stated that Kali Lamong does not fulfil the requirements for class IV qualifications. This is suspected to be pollutants entering the river. Therefore, river quality monitoring activities are needed to determine the status of water quality. The Lamong River Estuary is an excellent location for macroinvertebrate monitoring because of its varied and ever-changing environment (Khadafi et al., 2023). The combination of freshwater and saltwater in this ecosystem generates a unique ecosystem that sustains an extensive variety of macroinvertebrate species (Ni'Am et al., 2021, 2022). Consequently, it is an ideal site for researching their population dynamics, biodiversity, and reactions to alterations in the environment. Moreover, the estuary's intermediary characteristics between a river and the sea provide a chance to study the adaptation of macroinvertebrates to varying levels of saltiness, rates of sediment accumulation, and other ecological elements. Investigating macroinvertebrates inside the Kali Lamong estuary has significant potential to directly influence the overall health of the river and the management of its ecosystem. Through monitoring these organisms, the study can function as an indicator of the estuary's comprehensive biological state. An in-depth comprehension of the population dynamics, spatial dispersion, and biodiversity of macroinvertebrates can yield vital knowledge on the quality of water, stability of habitats, and general ecological well-being of Kali Lamong.

Biomonitoring techniques often employ bioindicators as markers of water body quality. Bioindicators are organismal communities that are sensitive to environmental changes. Changes in environmental conditions will affect the lives of organisms, which can be used as an indication of water body quality. In this study, utilizing bioindicators of invertebrate organisms, we were able to determine macroinvertebrates in the Estuary of Kali Lamong. Macroinvertebrates play a crucial role in the mineralization process and in preserving the stability of the seafloor substrate. Therefore, the presence of macroinvertebrates has a function in water's chemical processes (Thompson &Lowe, 2004). This study attempts to (i) bridge this knowledge by assessing how the macroinvertebrate community correlates with the Biological Monitoring Working Party Average Score Per Taxon (ii) determines river water quality using macroinvertebrates as bioindicators of water pollution.

2. METHODS

2.1. Study Area

In the process of monitoring water quality in water river bodies, periodic testing is needed to determine water quality within a certain period of time. Therefore, time series data is needed. Time series data is consisting of one object but is repeated in several time periods, such as daily, monthly, quarterly, and annually. Time Series is a series of observational data that comes from a fixed source and occurs based on time index t in a row with a fixed time interval (Cryer, 1986). This study was conducted for 14 days with a time interval of once a week (15 and 22 June 2021). The sampling was conducted twice in a row, once per week, to facilitate a comparison between the first and second weeks.

This study was performed in estuary area of river in Surabaya, Indonesia. Kali Lamong river has an upstream in the Kapur Kendang Utara Mountain area, Lamongan district and the downstream or estuary is located in the Madura Strait. Kali Lamong is 89 kilometers long and has seven tributaries. This tributary demonstrates the significance of Kali Lamong as a source of potable water for the residents of Lamongan regency and Gresik regency. Daily, the waters of Kali Lamong are utilized for agricultural, industrial, and domestic activities. Changes in the quality of the waters of Kali Lamong have been significantly impacted by the diverse human activities in the region (Luki Nasiti et al., 2017). Another publication states that the waters around the mouth of Kali Lamong are polluted with heavy metals Cu and Fe (Nindyapuspa &Ni'Am, 2018). The advantages of biomonitoring methods include integrating the entire ecological (chemical, physical and biological), integrating environmental conditions over time. The research uses biomonitoring methods with macroinvertebrate bioindicators that are correlated with the chemical conditions.

2.2. Macroinvertebrates Sampling

Macroinvertebrates were collected at 3 stations where each station has 3 sites from March to April 2021, Bottom substrates for benthic macroinvertebrates were randomly collected in triplicates (Ochieng et al., 2020). Hydraulic data is used as supporting data for sampling site conditions. Data includes river depth and width. The range of river depths is 0.53 - 2.05 m and the average river

width is 42.31 m. The details of hydraulic data provided in table S1. Kali Lamong river water velocity = 223.9 m^3/s (Dewandaru &Lasminto, 2014). According to SNI-6989.57, (2008) if the river water velocity exceeds 150 m^3/s, sampling is carried out at 3 points each at a distance of ¼, ½, and ¾ of the width. Sampling site (figure 1) and details: sites A1, A2, A3 is located at ¼, ½, ¾ width of Station 1 on the river side. Sites B1, B2, B3 is located at ¼, ½, ¾ width of Station 2 on the river side. Then, sites C1, C2, C3 is located at ¼, ½, ¾ width of Station 3 on the river side.

To determine water quality based on biological indicator the sediment sampling was carried out using a Van Veen Grab sampler and sediment samples were put into plastic bags. Sediment sample was collected in same with water samples. The separation procedure is conducted by employing an 18 mesh sieve. The objective of filtration is to reduce the quantity of sediment sample, facilitating its transportation to the laboratory for further investigation. Before being taken to the laboratory, the samples were stored in small bottles and alcohol was added to preserve the macroinvertebrate samples. The last process is identification and grouping carried out in the laboratory.

2.3. Biological Scoring Method

Biotic index methods often used in Indonesia to determine water quality based on macroinvertebrates are the Extended Trent Biotic Index (ETBI) and the Biological Monitoring Working Party Average Score Per Taxon (BMWP-ASPT) and Diversity Index. The categorization of BMWP scores may not always align with the categorization of the water quality index and habitat quality index due to the presence of certain habitat alterations (Ortega et al., 2021). The principle of biotic index assessment for the BMWP-ASPT method is to identify the most tolerant macroinvertebrate families according to the BMWP-ASPT. The detailed calculation stage is listed in table S2 and the scoring clasification provided in Table 1.

Table 1. BMWP-ASPT Classification Score

Class	BMWP-ASPT Score	Description
I	8 – 10	Unpolluted
II	6 – 7.9	Slightly polluted
III	4 – 5.9	Moderately polluted
IV	2 – 3.9	Heavily polluted
V	0 – 1.9	Very heavily polluted

Taken from (Arisandi, 2012)

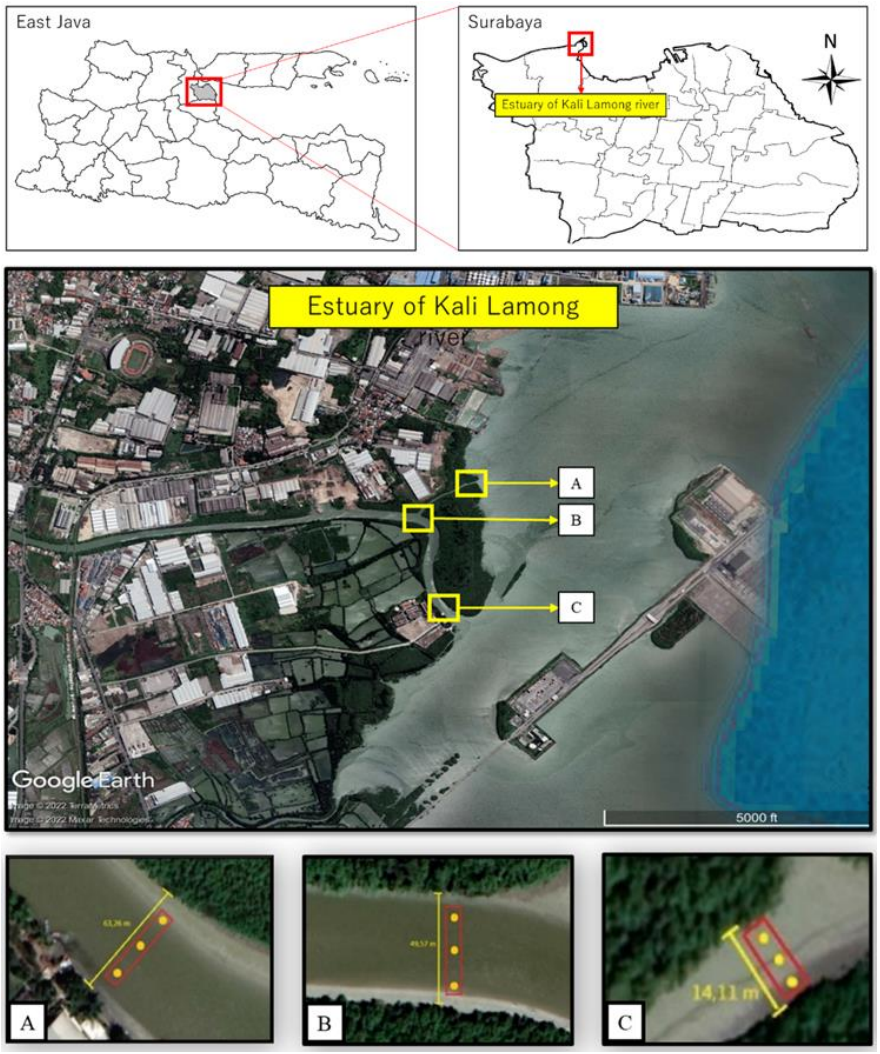

Figure 1. Study Area. Yellow Squares Represent the Station and Yellow Dots Represent the Sites in Each Station

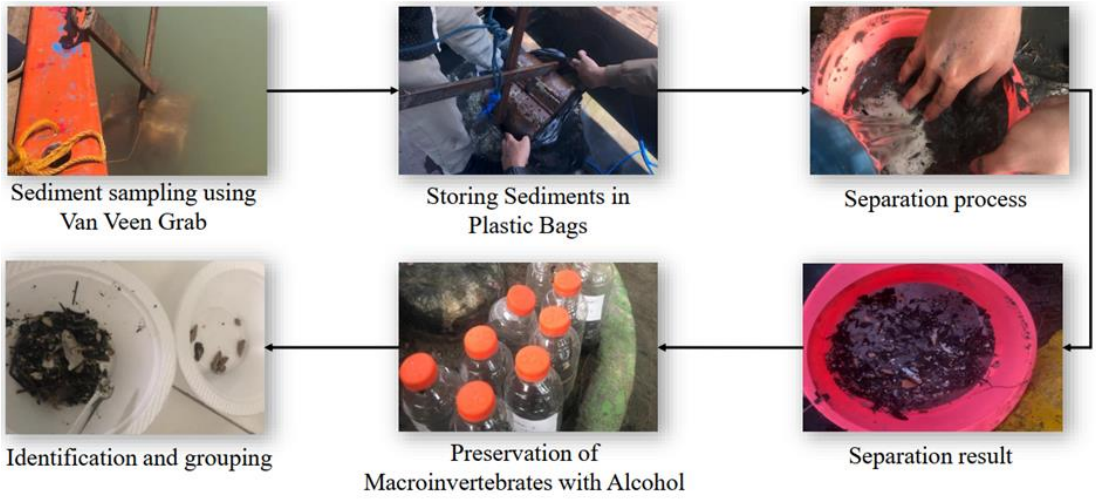

Figure 2. Macroinvertebrates Extraction from Sediment Samples

2.4. Physicochemical Status

Based on previous study, the dissolved oxygen parameter shows that the river water quality in Lamong is categorized as class II (Indonesian Government Regulation No. 22, 2021; Ni'Am et al., 2022) and the results of the current study show parallel with previous study by (Ni'Am et al., 2021, 2022). The ammonia parameter also states that the river water quality at the Estuary of Kali Lamong is categorized as class II (Ni'Am et al., 2021). Some sampling sites there is a value of dissolved oxygen that exceeds class II, it was the dissolved materials in the water absorb heat which results in increased water temperature, so that the amount of dissolved oxygen in the water decreases (Rahayu et al., 2009). In this study we also measured the physicochemical quality of the water of Kali Lamong estuary, including salinity, pH, BOD and PO4. Water sampling was carried out at the same point as sediment sampling, the method of water sampling refers to the previous research by Kristiandita, (2017). Before conducting the water sample all equipment has been prepared including protective glove and a liter bottle to store water samples. The sample was carried out directly into the water body by dipping all parts of the bottle and directing the bottle against the flow of the river. Additionally, water samples in the bottle are labeled according to the sampling point and give for further analysis in the laboratory.

3. RESULTS AND DISCUSSIONS

3.1. Macroinvertebrate Community

Macroinvertebrates are widely favored as indicators in biotic indices and biological methodologies because of their sizable dimensions, cost-effectiveness, sampling simplicity, straightforward identification, and extended life span (Metcalfe, 1989). 3 taxa of 8 families of macroinvertebrates were found in the location such as *Pachychidae, Viviparidae, Sphaeriidae, Piscicolidae, Neritidae, Chironomidae, Planorbidae, and Mollanidae* (figure 3a). The most common macroinvertebrate species are *Pachychidae* and *Viviparidae*. This is due to the location of the study being in the estuary of the river where the type of *pachychidae* has a habitat on the coast and the detailed number of macroinvertebrates can be seen in table S3. According to Sari, (2016), generally freshwater which is the habitat of gastropods *(Viviparidae)* is starting from irrigation canals, rice fields, rivers, swamps, lakes and community-made. In other hand, fish ponds and *Pachychidae* inhabits freshwater system, which is a brackish water snail found in estuaries and coastal habitats (Glaubreht, M. & Kőhler, 2004).

3.2. Status of Water Quality Based on BMWP-ASPT

Based on figure 3b. the results of macroinvertebrate analysis with the BMWP-ASPT method at points A1, A2, A3, B1, B2, B3 and C1 are moderately polluted and the detailed of scoring can be seen in table S3. The BMWP assigned scores based on the assessed sensitivity of the most pollution-tolerant species within each taxonomic group (Neachell, 2014). While points C2 and C3 are heavily polluted. Visually, the color of the water, which is dominated by murky brown, is clear evidence that the water of the Kali Lamong Estuary is moderately polluted to heavily polluted. Our hypothesis is that water pollution carried out by industries around the estuary of Kali Lamong is the main factor of water pollution and there are some local residents who throw garbage and domestic waste into the river. Another activity is the frequent passing of ships owned by factories around the Kali Lamong banks. It is also one of the factors causing the level of pollution in the Kali Lamong Estuary which visually makes the ship's body looks rusty. Furthermore, local government regulations should be given more attention and regular audits should be conducted to suspected industries to improve the water quality of the Kali Lamong estuary.

Macroinvertebrate distribution patterns in estuarine environments are influenced by several factors such as water quality, habitat, environmental conditions, predation, and genetic factors. Understanding these patterns is essential for assessing water quality and identifying potential

sources of pollution in estuarine ecosystems. By comparing macroinvertebrate abundance and diversity in different areas, researchers can identify areas with poor water quality or habitat conditions, prioritize areas for further investigation and remediation efforts, and track the effectiveness of pollution control measures over time. However, some authors recommend utilizing other indexes such as ASPT (Average Value Per Taxon) instead of BMWP. It is important to point out the calculation of the BMWP main value instead of the ASPT is more practical in terms of analysis, as it provides greater accuracy in assessing, but loses sensitivity to distinguish pollution effects as it does not distinguish natural pollution or anthropic effects (Roche et al., 2010).

According to Table 2, macroinvertebrate investigations are carried out in several countries, the difference in the selection of sampling techniques is due to the existing conditions of the sediment sampling location. We also provide suspected pollution sources to recognize potential pollutants, and almost all water body conditions are under class III or moderately polluted. In addition, when comparing BMWP and ASPT, the results show that ASPT levels the system in water quality classification, and each version of the application differs significantly because each region has a different number of taxa (Zeybek et al., 2014). Furthermore, for determination water quality using BMWP-ASPT cannot be used as a comparable each other because the environmental conditions and tax found are also different.

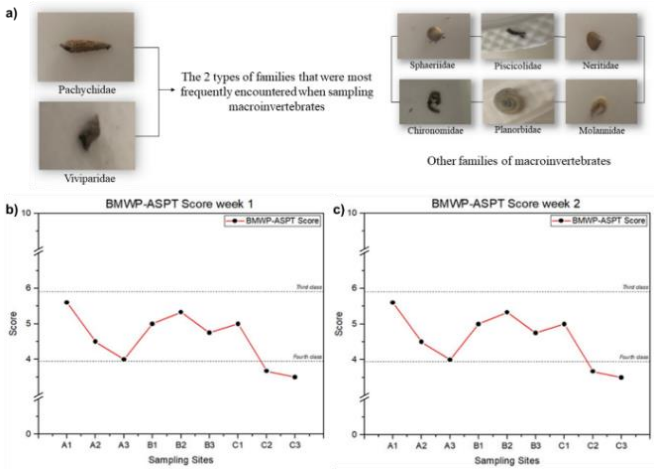

Figure 3. Macroinvertebrates Communities. a) Macroinvertebrates Found in the Estuary of Kali Lamong b) BMWP-ASPT Class Category Week I and c) BMWP-ASPT Class Category Week II

Table 2. BMWP-ASPT as Bioindicator Water Quality in the Worldwide

Country	Sampling tool	Habitat sample	Suspected pollution sources	BMWP-ASPT Indexing	Types of taxa found	References
Greece	Surber sampler and standard pond net	Sediments from the River	Hydropower in an upland stream	Unpolluted-Slightly Polluted	*Annelida, Mollusca, and Arthropoda*	(Rumbos &Kungolos, 2014)
Turkey	NR	Sediment of River	Nature conservation area	Slightly polluted	*Gastropoda, Bivalvia, Oligochaeta, Hirudinea, Crustacea, and Insecta*	(Zeybek et al., 2014)
Turkey	Ekman grab	Sediment of River	Residential, industrial and agricultural area	Moderately polluted	*Imnodrilus Hoffmeisteri, Chironomus (Camptochironomus) tentans, Psammoryctides Albicola, Physella Acuta, Nais Elinguis, and Stylaria Lacustris*	(Arslan et al., 2016)
Turkey	Kick net	Sediment of River	Settlements, industrial and intensive agriculture-livestock	Unpolluted	*136 taxa were found, dominated by Diptera and Oligochaeta*	(Özbek et al., 2023)
Colombia	Gredges and nets	Sediment of greatest watershed	NR	Slightly polluted-Moderately polluted	*Acari, Coleoptera, Hemiptera, Tricoptera, Odonata, Lepidoptera, Diptera, Ephemeroptera, Oligochaeta, Hirudinidae, and Gastropoda*	(Castellanos Romero et al., 2017)
Brazil	NR	Sediment of River	Agriculture-livestock (rural area)	Slightly polluted	*Coleoptera, Diptera, Ephemeroptera, Hemiptera, Odonata, Plecoptera, and Trichoptera*	(Zequi et al., 2019)
China	Surber net	Sediment of River	NR	Undefined	*Clitellata, Hirudinea, Oligochaeta, Arachnida, Insecta, Malacostraca, Bivalvia, and Gastropoda*	(Liu et al., 2024)
Indonesia	Van veen grab	Sediment of river estuary	Industrial area	Moderately polluted	*Mollusca, Hirudinea, and Tricopthera*	This study

Note: NR = Not Reported

3.3. Physicochemical Characteristics of Kali Lamong Estuary

The physicochemical parameters of the Kali Lamong estuary are important indicators of its environmental condition and ecological health. Temperature fluctuations affect the speeds at which organisms carry out metabolic processes and interact with each other, while pH levels have an impact on the availability of nutrients and the overall health of aquatic organisms. Species distribution and community composition are determined by changes in salinity, which are influenced by tides and the inflow of freshwater. Adequate quantities of dissolved oxygen are crucial for the survival of aquatic organisms, as insufficient levels can result in hypoxia. Turbidity, which is influenced by the presence of suspended particles, has an impact on the ability of light to penetrate water and on the level of primary productivity. Eutrophication can be triggered by high quantities of nutrients, especially nitrogen and phosphorus. Elevated levels of heavy metals present a threat to the well-being of aquatic creatures and the overall health of ecosystems. Monitoring and comprehending these physicochemical characteristics are crucial for efficient management and conservation measures in the Kali Lamong estuary, guaranteeing the maintenance of its biodiversity and environmental quality.

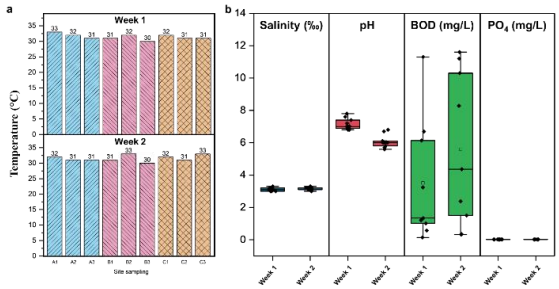

Figure 4. Physicochemical Analysis. a) Physical Parameter; b) Chemical Parameter

During the sampling period, the ambient air temperature was recorded as 33 °C. The subsequent examination of the temperature parameter of values between 31 and 32 °C. Typically, there exists a linear correlation between water temperature and air temperature (Yang &Peterson, 2017). The salinity value has a range of 3 - 3.3%, the pH value has a range of 5.6 - 7.8 and several sampling points of BOD values in the first and second range at 10-11 mg/L lift. This is due to the deeper the water depth in the river, it will be difficult for sunlight to enter the riverbed. This will affect aquatic plants that need sunlight to photosynthesize to produce oxygen in the water. Dissolved oxygen levels also fluctuate daily and seasonally, depending on the mixing and turbulence of water masses, photosynthetic activity, respiration, and waste entering the water body (Hefni Effendi, 2003).

The phosphate level in this study was less than 0.023 mg/L. Phosphate levels in water are used as one of the supporting parameters in determining water quality. This is because the presence of phosphate affects the growth of organisms such as algae and phytoplankton. The greater abundance of these organisms in the water can cause low oxygen content and other important nutrients so that the survival of aquatic biota in water bodies is disrupted. So that the presence of benthic macroinvertebrates in the water also decreases (Risamasu et al., 2012). In conclusion, the water quality at the Lamong River estuary is included in class III (Indonesian Government Regulation No. 22, 2021). Although the Kali Lamong Estuary exceeds the current river water quality standards (level III), anthropogenic activities have a significant impact on the water quality parameters. In order to preserve adequate water quality standards, it is imperative to conduct routine monitoring and treatment.

3.4. Correlation Between BMWP-ASPT and Physicochemical Parameter

Process of determining the relationship between water quality and the value of water chemistry and biotic indices, then a correlation analysis is carried out with a hypothesis test using a correlation distribution. The biotic indices and physicochemical factors typically exhibit mutual support (Zeybek et al., 2014). According to Tampo et al., (2021) the presence of certain macroinvertebrate taxa can illustrate pollution levels, with their diversity and composition providing insight into pollution loads. Through the analysis of the correlation between chemical constituents (such as pH, dissolved oxygen, COD, BOD concentrations) and biological indicators (such as macroinvertebrate diversity, abundance, and species composition), researchers can create significant correlations. Therefore, this correlation study greatly contributes to the overall research objective by offering a detailed understanding of how chemical parameters impact the biological elements in the water system. Correlation analysis was carried out by using the OriginLab application.

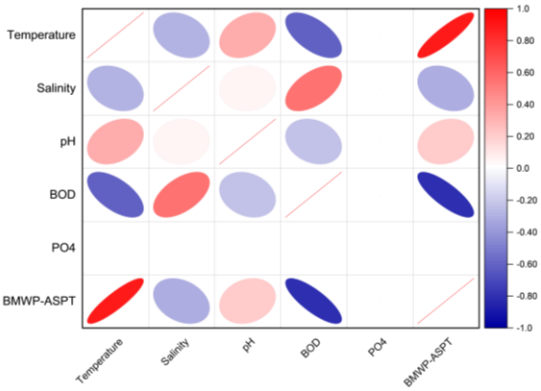

Figure 5. Spearman's Correlation of Relevant Variables. Red and Blue Color Represents Strong Correlation (P>0.001), and White Color Represents Weak Correlation (P>0.05)

The correlation coefficient has a value (r) of -1 ≤ r ≤ 1. The price of r = -1 states that there is a perfect indirect linear relationship (negative correlation) between the value of X and the value of Y. For r = 1, there is a perfect direct linear relationship (positive correlation) between X and Y (Sudjana, 2005). Other (r) values move between -1 and +1 where a negative sign (-) states an indirect correlation and a positive sign (+) a direct correlation. Other (r) values move between -1 and +1 where a negative (-) sign indicates an indirect correlation, and a positive (+) sign indicates a direct correlation. PO4 has no correlation value because the PO4 value is less than the detection limit of 0.05. The behavior of phosphorus in the estuarine system is complex, being impacted by several dynamic processes and interactions. The intricate structure of nutrient dynamics within estuarine ecosystems might lead to phosphate concentrations that do not regularly or directly correlate with physicochemical characteristics. Comprehending these intricacies is essential for precise analysis and efficient control of water quality in the Lamong River Estuary.

4. CONCLUSION

Determination of water quality through the BMWP-ASPT method as a biotic index using macroinvertebrates obtained moderately polluted water quality in Estuary Kali Lamong. The macroinvertebrates found along the Muara Kali Lamong sampling point consisted of 8 different families namely Sphaeriidae, Molannidae, Neritidae, Pachychidae, Viviparidae, Piscicolidae, Chironomidae and Planorbidae. The results of statistical analysis compare the determination of water quality with the biological indicator method and physicochemical parameters. The physicochemical parameters have a correlation with BMWP-ASPT, only the PO4 parameter has no correlation because the PO4 value does not fulfil with the limit detection during statistical analysis. Understanding physicochemical variables and macroinvertebrates is an effective technique for monitoring river water quality. We suggest conducting water quality assessments using physicochemical and biological monitoring in the upstream Kali Lamong to determine the interaction between the presence of macroinvertebrates in the Kali Lamong estuary and upstream Kali Lamong River as bioindicators.

REFERENCES

Arisandi, P. (2012). Bone River Water Quality Study with the Biomonitoring Method. *Proceedings of the National Seminar on Chemistry UNESA*, 1–12.

Arslan, N., Salur, A., Kalyoncu, H., Mercan, D., Barişik, B., &Odabaşi, D. A. (2016). The use of BMWP and ASPT indices for evaluation of water quality according to macroinvertebrates in Küçük Menderes River (Turkey). *Biologia*, *71*(1), 49–57. https://doi.org/10.1515/biolog-2016-0005

Castellanos Romero, K., Pizarro Del Río, J., Cuentas Villarreal, K., Costa Anillo, J. C., Pino Zarate, Z., Gutierrez, L. C., Franco, O. L., &Arboleda Valencia, J. W. (2017). Lentic water quality characterization using macroinvertebrates as bioindicators: An adapted BMWP index. *Ecological Indicators*, *72*, 53–66. https://doi.org/https://doi.org/10.1016/j.ecolind.2016.07.023

Cryer, J. D. (1986). *Time Series Analysis*. Duxbury Press.

Dewandaru, G. G. T., &Lasminto, U. (2014). Studi Penanggulangan Banjir Kali Lamong Terhadap Genangan di Kabupaten Gresik. *Jurnal Teknik POMITS*, *3*(2), 2–7.

Dudgeon, D. (2019). Multiple threats imperil freshwater biodiversity in the Anthropocene. *Current Biology*, *29*(19), R960–R967. https://doi.org/10.1016/j.cub.2019.08.002

Glaubreht, M. & Kőhler, F. (2004). Radiating in a river: systematics, molecular genetics and morphological differentiation of viviparous freshwater gastropods endemic to Kaek River, central Thailand (Cerithioidea, Pachychilidae).

Hefni Effendi. (2003). Telaah Kualitas Air Bagi Pengelolaan Sumber Daya Alam dan Lingkungan Perairan. Kanisius.

Indonesian Government Regulation No. 22. (2021). Pedoman Perlindungan dan Pengelolaan Lingkungan Hidup. *Sekretariat Negara Republik Indonesia*, *1*(078487A), 483. http://www.jdih.setjen.kemendagri.go.id/

Khadafi, S., Ni'am, A., &Alamsyah, G. (2023). K-Means Algorithm Grouping for Visualizing Potential of Hydrogen (pH) Data in Kali Lamong River. Icatech, 69–75. https://doi.org/10.5220/0012108900003680

Kristiandita. (2017). Biological Monitoring Party Average Score Per Taxon (Bmwp Aspt) Dalam Analisis Kualitas Air Saluran Kalibokor Di Wilayah.

Liu, G., Qi, X., Lin, Z., Lv, Y., Khan, S., Qu, X., Jin, B., Wu, M., Oduro, C., &Wu, N. (2024). Comparison of different macroinvertebrates bioassessment indices in a large near-natural watershed under the context of metacommunity theory. *Ecology and Evolution*, *14*(2), e10896. https://doi.org/https://doi.org/10.1002/ece3.10896

Luki Nasiti, E., Rahayu, Y., &Indah, N. (2017). Kualitas Perairan Kali Lamong Berdasarkan Keanekaragaman Plankton. *LenteraBio: Berkala Ilmiah Biologi*, *6*(3).

Metcalfe, J. L. (1989). Biological water Quality Assessment of running waters based on macroinvertebrate communities: History and present status in Europe. *Environmental Pollution*, *60*(1), 101–139. https://doi.org/https://doi.org/10.1016/0269-7491(89)90223-6

Munir, T., Hussain, M., &Naseem, S. (2016). Water pollution-a menace of freshwater biodiversity: a review. *Journal of Entomology and Zoology Studies*, *4*(4), 578–580. https://www.researchgate.net/publication/308165134

Neachell, E. (2014). Book Review - Environmental flows: Saving rivers in the thrid millennium. *River Research and Applications*, *30*(January), 132–133. https://doi.org/10.1002/rra

Ni'Am, A. C., Aulady, M. F. N., Hamidah, N. L., &Prasetya, K. D. (2022). Analysis of distribution dissolved oxygen concentration in Kali Lamong river estuary, Surabaya during pandemic Covid-19. *AIP Conference Proceedings*, *2534*(December). https://doi.org/10.1063/5.0106238

Ni'Am, A. C., Prasetya, K. D., &Utami, R. P. (2021). Analysis of Ammonia in Kali Lamong River Estuary Surabaya during Pandemic Covid-19. *Journal of Physics: Conference Series*, *2117*(1). https://doi.org/10.1088/1742-6596/2117/1/012020

Nindyapuspa, A., &Ni'Am, A. C. (2018). Distribution of heavy metals (Cu and Fe) in sea water of Gresik coastal area. *E3S Web of Conferences*, *31*, 2017–2019. https://doi.org/10.1051/e3sconf/20183104012

Ochieng, H., Odong, R., &Okot-Okumu, J. (2020). Comparison of temperate and tropical versions of Biological Monitoring Working Party (BMWP) index for assessing water quality of River Aturukuku in Eastern Uganda. *Global Ecology and Conservation*, *23*, e01183. https://doi.org/10.1016/j.gecco.2020.e01183

Ortega, G. M., Gallardo, C. E., López-López, E., Sedeño-Díaz, J. E., Hernández, M. L., Arroyo-Damián, M., &Moncayo-Estrada, R. (2021). Water Quality Analysis in a Subtropical River with an Adapted Biomonitoring Working Party (BMWP) Index. *Diversity*, *13*(11), 1–16. https://doi.org/10.3390/d13110606

Özbek, M., Aygen, C., Taşdemir, A., Yildiz, S., Topkara, E. T., &Çil, E. A. (2023). Determination of the ecological status of an Aegean river (Türkiye) using benthic macroinvertebrates as an indicator of water quality. *Environmental Monitoring and Assessment*, *195*(10), 1231. https://doi.org/10.1007/s10661-023-11834-1

Rahayu, S., Rudy Hartono, W., Meine Van, N., Indra, S., &Bruno, V. (2009). Monitoring Air di Daerah Aliran Sungai. *Word Agroforestry Centre ICRAF Asia Tengara*, 104 p. http://apps.worldagroforestry.org/downloads/Publications/PDFS/B16396.pdf

Risamasu, F. J. L., Prayitno, B., Pembahasan, H., &Metode, M. (2012). Kajian Zat Hara Fosfat, Nitrit, Nitrat dan Silikat di Perairan Kepulauan Matasiri, Kalimantan Selatan. *ILMU KELAUTAN: Indonesian Journal of Marine Sciences*, *16*(3), 135–142. https://doi.org/10.14710/ik.ijms.16.3.135-142

Roche, K. F., Queiroz, E. P., Righi, K. O., &deSouza, G. M. (2010). Use of the BMWP and ASPT indexes for monitoring environmental quality in a neotropical stream. *Acta Limnologica Brasiliensia*, *22*(1), 105–108.

Rumbos, C. I., &Kungolos, A. (2014). Evaluation of water quality of a mountainous Stream (Pelion, Central Greece) using benthic macroinvertebrates. *Fresenius Environmental Bulletin*, *23*(11A), 2904–2908.

Sari, W. P. (2016). Studi Preferensi Habitat Siput Tutut (Bellamya javanica) di Desa Amonggedo Kabupaten Konawe [The study of tutut snail habitat preferences (Bellamya javanica) at Amonggedo Village , District of Konawe]. 1(1), 111–112.

SNI-6989.57. (2008). Tentang Metode Pengambilan Contoh Air Permukaan. In *SNI, 6989.57:2008*.

Sudjana. (2005). *Teknik Analisis Regresi dan Korelasi Bagi Para Peneliti*. PT. Tarsita.

Tampo, L., Kaboré, I., Alhassan, E. H., Ouéda, A., Bawa, L. M., &Djaneye-Boundjou, G. (2021). Benthic Macroinvertebrates as Ecological Indicators: Their Sensitivity to the Water Quality and Human Disturbances in a Tropical River. *Frontiers in Water*, *3*(September), 1–17. https://doi.org/10.3389/frwa.2021.662765

Thompson, B., &Lowe, S. (2004). Assessment of macrobenthos response to sediment contamination in the San Francisco Estuary, California, USA. *Environmental Toxicology and Chemistry*, *23*(9), 2178–2187. https://doi.org/10.1897/03-233

Yang, D., &Peterson, A. (2017). River water temperature in relation to local air temperature in the Mackenzie and Yukon basins. *Arctic*, *70*(1), 47–58. https://doi.org/10.14430/arctic4627

Zequi, J. A. C., Espinoza, A. A., deAlmeida Paccola, J., &Lopes, J. (2019). Aquatic insect communities in small stream in the south of Brazil. *Environmental Monitoring and Assessment*, *191*(7), 408. https://doi.org/10.1007/s10661-019-7536-7

Zeybek, M., Kalyoncu, H., Karakaş, B., &Özgül, S. (2014). The use of BMWP and ASPT indices for evaluation of water quality according to macroinvertebrates in Değirmendere Stream (Isparta, Turkey). *Turkish Journal of Zoology*, *38*(5), 603–613. https://doi.org/10.3906/zoo-1310-9