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Evaluation of Spatial Pollutant Distribution in River Water Using Oxygen Levels, EPT, and Biotic Index Indicators

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ABSTRACT
River water pollution has now become a serious problem for society with population growth. The development of various industries and pesticides usage. One of the rivers in Lamongan, namely Kaliotik is heavily polluted. One of the rivers in Lamongan, namely Kaliotik is heavily polluted. Therefore, the research aim is to analyze the distribution of Kaliotik river water quality pollution zones. The research type is a quantitative descriptive analysis, with the research design used the true experimental time series design. Identification of river pollution zones along the Kaliotik river is based on the self-purification zone. contamination zone is identified based on the content of BOD, COD, DO as well as microscopic and biometric tests of the diversity of water organisms. River water quality assessment using Biotilics is carried out by calculating the diversity of family types, the diversity of EPT types, percentage of EPT abundance, and the Biotilic Index. The research results showed that Station I had a biotilic index of 2.45, Station II 2.66, Station III 2.82, Station IV 2.82, and Station V 2.97. Based on these values, it can be concluded that the Kaliotik river is in a heavily polluted condition and falls within the polluted zone, indicating poor water quality and significant ecological degradation.

1. INTRODUCTION

Water pollution in rivers has now become a serious problem for society with population growth, the development of various industries, and the use of pesticides by farmers (Anawar & Chowdhury, 2020); (Wijaya et al., 2013); (Gamage et al., 2021); (Sturiale et al., 2020). Rapid urbanization is always accompanied by urban river pollution due to incompatibility with the development of waste treatment systems and water conservancy projects (Zhang et al., 2019). River water quality in several areas is greatly influenced by human activities, especially around rivers (Yogafanny, 2015). The accidental discharge and introduction of pollutants into the environment is a serious problem, especially when the biodegradation activity of natural microbiota is insufficient to remove or neutralize them (Pozdnyakova et al., 2022). Urbanization often leads to inadequate waste management systems and impacts river water quality (Aitken et al., 2024; Chiwaridzo, 2024). Studies have shown that human activities significantly affect river ecosystems, leading to deteriorating water quality (Odume, 2020). The self-purification capacity of rivers, as discussed by (Midyurova et al., 2021; Travin et al., 2019; Zhang et al., 2019), highlights natural processes that mitigate pollution, but these processes can be overwhelmed, as noted by (Chan et al., 2018).

Poor raw water quality is caused by environmental pollution such as water pollution by organic waste, inorganic waste, and chemical waste. Kaliotik river is one of 42 rivers that flow in Lamongan with a length of 12.50 km. This river water is used for bathing, washing, and irrigation for residents' agriculture (BPS Lamongan, 2021). Management decisions must consider enforcing environmental functions that prevent degradation and ensure the stability of river ecosystems (Manuel, 2022). One of the tributaries of the Lamongan river, which is usually called Kaliotik, is also one of the polluted basins. The Kaliotik river is starting to show signs of pollution such as an unpleasant odor and blackened water color (Shaleh et al., 2021). Protein and fat intake increases ammonia and nitrate content, which ultimately reduces dissolved oxygen (DO) (Pamungkas, 2016). Waste from fish markets often produces fluids such as blood, fish skin or scales, fish organs, and fish fins from processing. The Kaliotik river is 12.5 km long, not all of which is polluted. This is in accordance with Hendrasarie & Cahyarani (2010), that water bodies clean themselves of polluting elements or what is known as self-purification. According to Zubaidah et al. (2019), the self-purification process can be carried out in river flows even though they do not reach the clean water zone through the DO and BOD levels of the water (Nugraha et al., 2020). The worsening of the self-purification process of river water poses a risk to the long-term availability of water resources (Pratiwi et al., 2023).

Biota in river water is an indicator that can provide an idea of whether the river is polluted or not. Macroinvertebrates help determine water quality because certain taxa and species are more or less tolerant of pollution. These organisms are very important for ecosystems because they function as primary consumers, detritivores, and prey and play an important role in nutrient cycles (Erta et al., 2021) and (Andreano, 2020). Benthic macroinvertebrates, especially aquatic insects, can be used to assess different levels of river ecological health, as some of them are less tolerant of pollution, particularly members of the Ephemeroptera, Plecoptera, and Trichoptera (EPT) (Unger et al., 2021). Decrease in dissolved oxygen, especially in the dry season, species diversity decreases at all stations, which consequently causes an increase in the Hilsenhoff Biotilic index classified as poor level (Alnoiji et al., 2022). In the same vein, benthic macroinvertebrate indicators are useful tools for water quality assessment because they are less mobile and have varying responses to the overall environmental stress of aquatic ecosystems (Huh & Lee, 2023). According to research conducted by (Alnoiji et al., 2022), it shows that there is a significant positive correlation between the DO and EPT wealth indices. Biota is spread throughout the river body from upstream to downstream of the river. If no biota is found in this area, the river is certainly polluted with pollutants (Midyurova et al., 2021). According to research conducted (Akamagwuna et al., 2019), the lowest abundance of EPT organisms occurred in a group of highly disturbed locations. Therefore, it is necessary to research to analyze the distribution of Kaliotik river water quality pollution zones.

Studies (Huh & Lee, 2023), have identified correlations between dissolved oxygen (DO) levels and EPT diversity, underlining their importance in assessing ecological health. Despite existing research, gaps remain in understanding specific pollution zones along the Kaliotik river (Chatto Paylangco et al., 2021). While general trends are known, detailed spatial analyses of pollution gradients are lacking. The relationship between nutrient inputs (e.g., from fish market waste) and water quality parameters like DO, BOD, and COD needs further investigation, especially in localized contexts such as Lamongan. Additionally, there is a need to explore how seasonal variations (e.g., dry seasons affecting DO levels and species diversity) impact pollution gradients and biotic communities (Liu et al., 2014). Understanding these dynamics can provide insights into the resilience of river ecosystems and their capacity for self-purification.

The urgency of studying the Kaliotik river lies in its vital role for local communities for domestic use, agriculture, and recreation (Zhang et al., 2019). The visible signs of pollution, coupled with scientific evidence of declining water quality parameters (Chatto Paylangco et al., 2021), underscore the immediate need for effective environmental management strategies. Without intervention, continued degradation poses risks to both ecosystem health and human well-being. Addressing these gaps through comprehensive spatial assessments and integrating ecological indicators like EPT can guide targeted conservation efforts and policy interventions. This research is critical for informing sustainable development practices and safeguarding water resources in rapidly urbanizing areas like Lamongan. By focusing on these aspects, the research aims to contribute valuable data-driven insights that can support evidence-based decision-making and foster community-driven environmental stewardship initiatives along the Kaliotik river.

2. METHODS

2.1 Research Location

The research was carried out along the Kaliotik river (Figure 1) with the river pollution areas determined at five stations. The abundance of organisms and the level of river water pollution were carried out using the biotylical index. In this way, it will be known which stations have experienced light, medium or heavy pollution in accordance with water self-purification (Hendrasarie & Cahyarani, 2010).

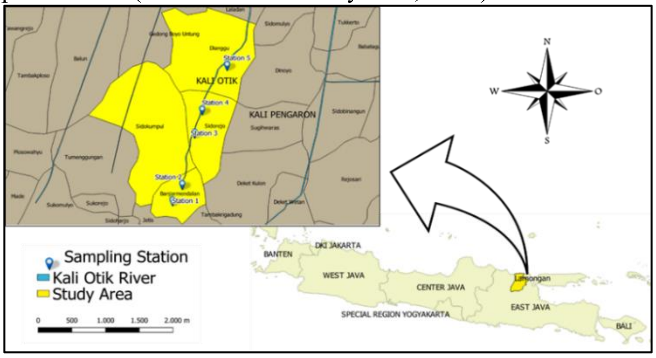


Figure 1. Research Location

2.2 Sampling Procedure

Identification of river pollution zones along the Kaliotik river is based on four criteria such as clean-zone, decomposition zone, septic zone and recovery zone. The contamination zone was identified by the content of BOD, COD, DO also microscopic and biometric tests of the water biota diversity. This identification was carried out at five stations along the Kaliotik river. At each station, the water quality is analyzed by measuring the oxygen levels of the water and the abundance of organisms. Oxygen levels are measured by measuring DO, BOD5, and COD levels (Islami & Jolodar, 2023). The abundance of organisms is observed both microscopically and macroscopically. The abundance of aquatic organisms was taken at the surface and sediment of the waters using an Ekman grab tool. The observation of macroinvertebrates was conducted by collecting sediment samples from the aquatic environment at each observation station. The collected sediment was then sieved using graded mesh sieves until macroinvertebrate organisms were retained on the sieve surface. The retained organisms were subsequently separated and identified for the purpose of community analysis. Observation of micro invertebrates was carried out by collecting water samples using sterile vial bottles. These water samples were then examined in the laboratory under a light microscope to identify and quantify the presence of micro invertebrates. The data obtained from these observations were used as the basis for assessing the biological condition of the water body and determining the biotilic index.

2.3 Sampling Techniques

Sampling starts from the downstream station for 10 minutes from 20 meters/sampling station, then continues to the station leading upstream of the river. Take samples using a combination of kicking and jabbing techniques on parts of the river bank that are not too fast, not deep, and overgrown with water plants. Measurements have been carried out with one repetition at each station. Lift the net above the surface of the water and dip the net bag several times into the water until the water that comes out of the net bag is clear and not muddy. Macroinvertebrate sampling is stopped if 100 individual types have been found no new types have been found at the next station or 10% of new individuals have not been found at the previous station. Identify macroinvertebrates. River water quality assessment using biotilic index is carried out by calculating the diversity of family types, diversity of EPT types, the percentage of EPT abundance, and the biotilic index, which is given an assessment score using the following formula: EPT Index (Travin et al., 2019):

EPT = (n EPT / N) x 100% .... (i)

Biotilic index = (X/N) n .... (ii)

Where:

EPT : Number of individual members of the EPT

X : The tolerance value or biotic score assigned to each taxon, representing the level of tolerance of the organism to pollution.

N : The total number of individual organisms found in the sample.

n : The number of individuals of each observed taxon or species.

3. RESLUTS AND DISCUSSION

The results of testing BOD, COD, and DO levels at the five sample stations are presented in Table and graph 2 below:

Table 1. BOD, COD, DO levels at five sample stations

No	Concentration (mg/L)	Regulation threshold (mg/L)*	Station I (mg/L)	Station II (mg/L)	Station III (mg/L)	Station IV (mg/L)	Station V (mg/L)
1	BOD_5	60	435 ± 0,58	252 ± 0,58	161 ± 0,00	236 ± 0,58	247 ± 0,58
2	COD	150	593 ± 0,58	571 ± 0,01	402 ± 0,58	246 ± 0,00	128 ± 1,53
3	DO	> 5	0,3 ± 0,10	0,6 ± 0,06	0,7 ± 0,06	0,9 ± 0,00	1,7 ± 0,25

Notes: Sign (*) were according to Permen Kes RI, no. 32 Tahun 2017

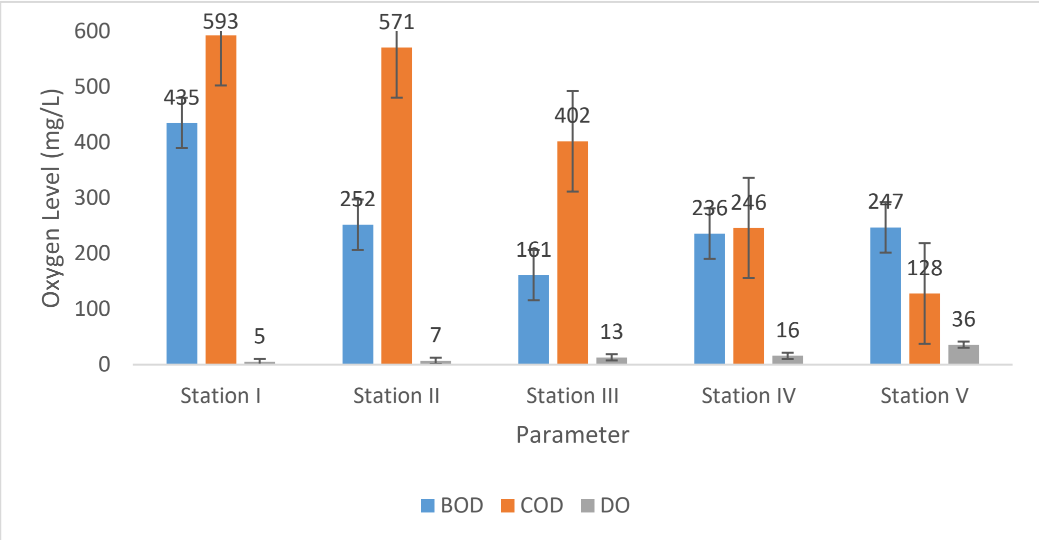


Figure 1. BOD, COD, DO levels at five sample stations

Based on the results presented in Table 1, the concentrations of BOD, COD, and DO at all sampling stations exceeded the established quality thresholds. These findings indicate that the water quality of the Kaliotik river is generally poor and that pollution is present across all monitoring stations. The highest concentrations of BOD and COD were recorded at Station I, which is influenced by waste discharge from the nearby fish market, suggesting a strong contribution of organic pollution in this area. In contrast, dissolved oxygen (DO) levels tended to decrease at stations located further away from the fish market, reflecting an increasing level of degradation along the river. Overall, the measured parameters did not comply with the applicable water quality standards in several zones of the Kaliotik river research stations. Consequently, the river water is considered unsuitable for various uses. The elevated levels of BOD and COD, coupled with the reduced levels of DO, are attributable to the excessive input of organic waste into the river. The decomposition of abundant organic matter and complex protein compounds by microorganisms increases oxygen consumption, resulting in decreased dissolved oxygen concentrations. Furthermore, graphical analysis of BOD and DO concentrations demonstrates an inverse relationship, where an increase in BOD corresponds to a decrease in DO levels.

As the BOD concentration decreases at the sampling stations, the DO concentration tends to increase, indicating a reciprocal relationship between these two parameters. The variations in BOD and DO concentrations across Stations 1–5 are associated with oxidation processes occurring within the flowing water, which are characterized by fluctuations in dissolved oxygen levels and a gradual natural reduction in BOD concentrations. However, under the observed conditions, the river ecosystem has not yet been capable of effectively purifying the water from continuous BOD inputs. This situation is presumed to result from the inability of the dissolved oxygen concentration to recover to its optimal level, particularly in river segments that remain heavily affected by prolonged waste contamination, leading to suboptimal aerobic conditions (Nugraha et al., 2020). Similar findings have been reported in previous studies, which demonstrated that BOD and COD concentrations decreased concomitantly with increasing DO levels in the Surabaya River (Rosli et al., 2020). Furthermore, correlation analysis revealed that COD and BOD exhibited a strong linear relationship (Figure 2), while both parameters showed an inverse relationship with DO concentrations (Deswati et al., 2022). These results reinforce the notion that elevated organic pollution intensifies oxygen consumption through microbial degradation processes, thereby reducing the availability of dissolved oxygen in the aquatic environment.

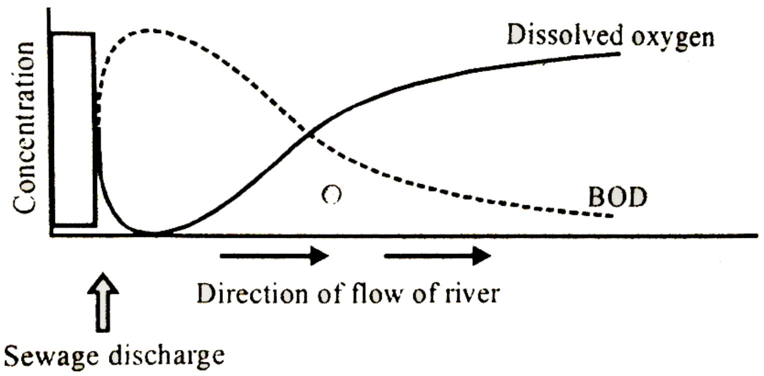
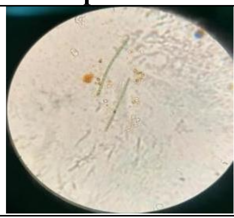


Figure 2. Inverse relationship between BOD and DO in river waterflow
Source: (Ghosh et al., 2018)

The examination of water biota along five sampling stations of the Kaliotik river involved both microscopic and biotic analyses. Microscopic analysis entailed detailed observation through microscopes, as documented in table 2 shows results of microscopic biota diversity using microscope using magnification 400X, to identify and quantify the diverse microorganisms present in the water samples. The biotic assessment was complemented by additional analysis by evaluating the broader ecological impact of these organisms on the river's ecosystem health and water quality dynamics.

Table 2. Results of microscopic biota diversity using microscope magnification 400X

Station	Microscopic Test Results	Information
1		No biota was found, and only debris (trash) was found
2		No biota was found, and only debris (trash) was found
3		No biota was found, and only debris (trash) was found
4		A type of *Cyanophyta* was found *Oscilatoria sp.*

Station	Microscopic Test Results	Information
5		Found *Cyanophyta* and *Protozoa*

Based on this table 2, it can be seen that at stations I, II, and III there were no organisms found. At station IV *Cyanophyta* group organisms were found. At station V, a variety of *protozoa* and *Cyanophyta* organisms were found. The self-purifying ability of river water was understood as a series of processes hydrodynamic, physical, biological, and chemical which aims to restore its original properties and composition. The results of the microscopic test using a microscope showed that no biota was found at Stations 1-3. However, what was found at this station was only debris (garbage). Meanwhile, at Stations 4 and 5, biota was found with the form of *Cyanophyta*, *Oscillatoria* type. This was the microalgae which is the water pollution indicator by Fukuyo's theory, which shows that the water quality in the area was polluted. This is possible because there was a lot of organic waste scattered around. Apart from that, this microalgae was able to protect itself from toxic substances in the waters. Therefore, this genus can live in polluted waters (Nugraha et al., 2020). According to (Hendrasarie & Cahyarani, 2010) the self-purification mechanism process consists of several zones, namely the clean water zone, decomposition zone, biodegradation zone, and recovery zone.

The highest BOD levels were found at station I, and was likely to have been included in the decomposition zone. This zone was found in the source area of pollution, the flowing waste would undergo decomposition/oxidation or the process of breaking down organic material by bacteria and microorganisms. At stations II and III, laboratory test results showed that the BOD concentration began to decrease and the DO concentration began to increase. The observed decline in BOD values across the stations is associated with the increasing distance from the pollution source and the progressive oxidation and redistribution of organic matter within the aquatic system. This shows that the longer the distance traveled, the organic compounds would naturally experience a decrease in concentration values and this had been followed by a decrease in the number of microorganisms in the water. However, because the DO values at this station was still below II, no biota was found in the microscopic test, but only aquatic waste. At stations 4 and 5, DO values began to increase and BOD concentrations decreased. At station 4 and 5, began to entered the oxygen recovery zone which came from air captured by air, aeration and watered plants. Apart from that, organic matter decreases after decomposition so that BOD decreases and bacterial populations decrease. In this zone, dissolved oxygen values began to return to normal. Likewise, microscopic air life was starting to become visible, however, test results at stations IV and V found blue algae biota such as oscillatoria which was a bioindicator that the waters had been polluted. This was possible because there was a lot of organic waste scattered around. Apart from that, this microalgae was able to protect itself from toxic substances in the waters. Therefore, this genus was able to live in waters that experience pollution (Nugraha et al., 2020). Apart from oscillatoria, at station 5, biota in the form of protozoa was also found which could be used as a bioindicator for water. The course and rate of the purification process depend on several conditions: the nature of the incoming chemical pollutants, the volume and rate of contamination, the hydrodynamic conditions of the aquatic environment, the chemical composition, and the biological state (Travin et al., 2019). EPT abundance test results and biotylics are presented in Table 3 below:

Table 3. Biotilic index test results

No.	Station	EPT/ Non EPT	Family Name	Biotilic Score (Ti)	Amount Individual (Ni)	Ti x Ni	Aboundance EPT (%)	Biotilic Index	Information
1	I	EPT	*Prosopistomatidae*	4	5	20	0.22	2.45	Polluted
			Subtotal EPT (n EPT)	5	20				
		nonEPT	*Nepidae*	2	8	16			
			Thiaridae -B	2	9	18			
			Subtotal Non-EPT	22	34				
			Total (N)	22					
2	II	EPT	*Prosopistomatidae*	4	5	20	0.33	2.66	Polluted
			Subtotal EPT (n EPT)	5	20				
		nonEPT	*Nepidae*	2	4	8			
			Thiaridae -B	2	6	12			
			Subtotal Non-EPT	10	20				
			Total (N)	15					
3	III	EPT	*Prosopistomatidae*	4	6	24	0.27	2.82	Polluted
			Subtotal EPT (n EPT)	6	24				

No.	Station	EPT/ Non EPT	Family Name	Biotilic Score (Ti)	Amount Individual (Ni)	Ti x Ni	Aboundance EPT (%)	Biotilic Index	Information
			Nepidae	2	7	14			
			Thiaridae -B	2	4	8			
		nonEPT	*Gyrinidae*	3	11	33			
			Subtotal Non-EPT	22	20				
			Total (N)	28					
		EPT	*Prosopistomatidae*	4	6	24			
			Subtotal EPT (n EPT)		6	24			
			Nepidae	2	7	14			
4	IV		*Thiaridae -B*	2	4	8	0.27	2.82	Polluted
		nonEPT	*Gyrinidae*	3	11	33			
			Subtotal Non-EPT		22	20			
			Jumlah total (N)		28				
			Prosopistomatidae	4	9	36			
		EPT	*Psychomyiidae*	4	7	28			
			Subtotal EPT (n EPT)		16	64			
			Libellulidae	3	4	12			
			Vellidae	3	6	18			
5	V		*Nepidae*	2	6	12	0.37	2.97	Polluted
		nonEPT	*Thiaridae -B*	2	8	16			
			Viviparidae	2	3	6			
			Subtotal Non-EPT		27	64			
			Total (N)		43				

In Station I of the Kaliotik river, the assessment revealed a notable presence of EPT taxa such as *Prosopistomatidae*, alongside Non-EPT taxa including *Nepidae* and *Thiaridae* – B. The indicator values indicated an EPT abundance percentage of 0.22 and a biotilic index of 2.45, categorizing the station as experiencing heavy contamination. Similarly, Station II exhibited a comparable composition with EPT represented by *Prosopistomatidae* and Non-EPT taxa like *Nepidae* and *Thiaridae* – B, yielding an EPT abundance percentage of 0.33 and a biotilic index of 2.66, also indicating heavy contamination.

Stations III and IV displayed a diversity of EPT taxa including Prosopistomatidae, *Nepidae*, *Thiaridae* – B, and *Gyrinidae*, with EPT abundance percentages of 0.27 and biotic indices of 2.82, denoting heavy contamination levels. Station V exhibited the highest EPT diversity with *Prosopistomatidae* and Psychomyiidae, along with Non-EPT taxa such as *Libellulidae*, *Vellidae*, *Nepidae*, *Thiaridae* – B, and *Viviparidae*, resulting in an EPT abundance percentage of 0.37 and a biotilic index of 2.97. These findings collectively indicate severe pollution across all stations, rendering the water unsuitable for daily human needs. The variations in EPT taxa composition and abundance along the river suggest differing pollutant sources, with upstream locations generally showing lower diversity compared to downstream areas (Malvandi et al., 2021). The percentage of *Ephemeroptera* and EPT taxa composition, Tolerance metric consists of the tolerance taxa percentage. To calculate the tolerant taxa percentage, aquatic insect families are sorted based on their tolerance value families that have a tolerance value of less than 5 are considered taxa sensitive to pollution, and those that have a tolerance value of 5 or greater than 5 are categorized as tolerant organisms (Athulya, 2023). Their relationship to the physicochemical parameters of water also varies from one species to another. In addition, only a few arthropods showed a significant relationship with the type of water quality in the sampling area (Chatto Paylangco et al., 2021). This is also in accordance with (Odume, 2020), that urban pollution that urban pollution affects macroinvertebrate traits differently. Certain ecological traits and preferences were largely associated with impacted sites compared with control sites. Taxonomically, certain metrics such as EPT abundance, diversity, and richness have been established through years of research as being quite sensitive to environmental disturbances including urban pollution. Understanding these relationships is crucial for effective water quality management and conservation efforts in urban river ecosystems.

4. CONCLUSION

This results showed that The biotic index values recorded at each station varied, with Station I registering 2.45, Station II 2.66, Station III 2.82, Station IV 2.82, and Station V 2.97. These values consistently indicate a high level of ecological degradation. Based on this assessment, it can be concluded that the Kaliotik River is classified as heavily polluted and falls within the polluted zone, reflecting a severely compromised water quality status. The study highlights significant implications for environmental management and public health. It underscores the severity of water pollution in the Kaliotik river, exacerbated by organic waste from fish markets and urban runoff. The findings suggest that water quality across all five stations is severely compromised, as indicated by elevated levels of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), coupled with depleted Dissolved Oxygen (DO) levels. These conditions are detrimental to aquatic biota, as evidenced by the absence of macroinvertebrates and the presence of pollution-tolerant microorganisms like *Cyanophyta* and *Protozoa*.

REFERENCES

Aitken, J. A., Alaybek, B., Hartman, R., Mika, G., Broad Leib, E. M., Plekenpol, R., Branting, K., Rao, D., Leets, L., & Sprenger, A. (2024). Initial Assessment of The Efficacy of Food Recovery Policies in US States for Increasing Food Donations and Reducing Waste. *Waste Management*, *176*(1), 149–158. https://doi.org/10.1016/j.wasman.2023.12.051

Akamagwuna, F. C., Mensah, P. K., Nnadozie, C. F., & Odume, O. N. (2019). Trait-based responses of Ephemeroptera, Plecoptera, and Trichoptera to sediment stress in the Tsitsa River and its tributaries, Eastern Cape, South Africa. *River Research and Applications*, *35*(7), 999–1012. https://doi.org/10.1002/rra.3458

Alnoiji, E. M., Yazdi, F. T., & Safari, O. (2022). Morphological plasticity of Nemoura Cinerea (Arthropoda, Nemouridae) as a biological indicator for aquatic systems. *International Journal of Aquatic Biology*, *10*(6), 515–524. https://doi.org/10.22034/ijab.v10i6.1354

Anawar, H. M., & Chowdhury, R. (2020). Remediation of polluted riverwater by biological, chemical, ecological and engineering processes. *Sustainability (Switzerland)*, *12*(17), 1–18. https://doi.org/10.3390/su12177017

Andreano, S. (2020). Colonization Comparisons of Stream Macroinvertebrates in Introduced Logs at Various Placements of Water Velocity and Water Column Position. *Proceedings of The National Conference On Undergraduate Research (NCUR)*, 875–884.

Athulya, P. (2023). *Aquatic insects for monitoring the health status of riverine potholes : A case study in Chalakudy river*. *196*(108), 1–22. https://doi.org/10.1007/s10661-023-12254-x

BPS Lamongan. (2021). *Kabupaten Lamongan dalam Angka*.

Chan, A. P. C., Darko, A., Olanipekun, A. O., & Ameyaw, E. E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of Cleaner Production*, *172*, 1067–1079. https://doi.org/10.1016/j.jclepro.2017.10.235

Chatto Paylangco, J. C., Gamalinda, E. F., Seronay, R. A., & Jumawan, J. C. (2021). Assessment of Macroinvertebrates as Bioindicators of Water Quality in the Littoral Zone of Lake Mainit, Philippines. *Asian Journal of Biological and Life Sciences*, *9*(3), 371–378. https://doi.org/10.5530/ajbls.2020.9.56

Chiwaridzo, O. T. (2024). Unleashing tomorrow's energy for sustainable development: Pioneering green building technologies and green tourism supply chain management in Zimbabwe's tourism sector. *Energy for Sustainable Development*, *78*(September 2023), 101382. https://doi.org/10.1016/j.esd.2024.101382

Deswati, D., Safni, S., Khairiyah, K., Yani, E., Yusuf, Y., & Pardi, H. (2022). Biofloc technology: water quality (pH, temperature, DO, COD, BOD) in a flood & drain aquaponic system. *International Journal of Environmental Analytical Chemistry*, *102*(18), 6835–6844. https://doi.org/10.1080/03067319.2020.1817428

Erta, A., Merve, Y., & Rk, A. (2021). *Evaluation of the Water Quality of Karabal Stream (Gediz River, Turkey) and Comparative Performance of the Used Indices The Existence of a Sufficient Amount of Good Quality Water is an Essential Need for the Future of Humanity and Sustainable Developme*. *17*(3), 334–349. https://doi.org/10.22392/actaquatr.819579

Gamage, A., Basnayake, B., De Costa, J., & Merah, O. (2021). Effects of Rice Husk Biochar Coated Urea and Anaerobically Digested Rice Straw Compost on the Soil Fertility, and Cyclic Effect of Phosphorus. *Plants*, *11*(1), 75. https://doi.org/10.3390/plants11010075

Ghosh, S., Paul, M., Raha, A., Mukherjee, P., Bagchi, A., & Si, A. (2018). Statistical evaluation of biochemical oxygen demand of river water. *Advance Pharmaceutical Journal*, *3*(4), 118–120. https://doi.org/10.31024/apj.2018.3.4.2

Hendrasarie, N., & Cahyarani. (2010). Kemampuan Self Purification Kali Surabaya, Ditinjau dari Parameter Organik Berdasarkan Model Matematis Kualitas Air. *Jurnal Ilmiah Teknik Lingkungan*, *3*(1), 1–11.

Huh, M. K., & Lee, H. Y. (2023). Evaluation of Water Quality by Benthic Macroinvertebrate at the Jukjeon Stream in Korea. *European Journal of Environment and Earth Sciences*, *4*(1), 6–10. https://doi.org/10.24018/ejgeo.2023.4.1.370

Islami, R. H., & Jolodar, N. M. (2023). Water health quality assessment in the Little Zab River, Iran using physicochemical and macroinvertebrates indices. *International Journal of Aquatic Research and Environmental Studies*, *3*(2), 91–107.

Liu, G., Liu, X., Yang, Z., Chen, B., Su, M., & Zhang, Y. (2014). A predictive analysis of China's energy security based on supply chain theory. *Energy Procedia*, *61*, 184–189. https://doi.org/10.1016/j.egypro.2014.11.1054

Malvandi, H., Moghanizade, R., & Abdoli, A. (2021). The use of biological indices and diversity indices to evaluate water quality of rivers in Mashhad, Iran. *Biologia*, *76*(3), 959–971. https://doi.org/10.2478/s11756-020-00618-4

Manuel, R. P. (2022). *Diversity and Functions of Benthic Macroinvertebrates in Relation to Water and Riparian Conditions in Riverine Channels of Eden and Dibibi , Quirino , Philippines*. *13*(1), 47–65. https://doi.org/10.7828/ajob.v13i1.1493

Midyurova, B., Belovski, I., & Dimova-Todorova, M. (2021). Assessing the self-purification capacity of surface waters in Mladezhka river. *Journal of Environmental Protection and Ecology*, *22*(1), 1–7. https://doi.org/10.3390/w11071505

Nugraha, W. D., Sarminingsih, A., & Alfisya, B. (2020). The Study of Self Purification Capacity Based on Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO) Parameters. *IOP Conference Series: Earth and Environmental Science*, *448*(1), 1–10. https://doi.org/10.1088/1755-1315/448/1/012105

Odume, O. N. (2020). Searching for urban pollution signature and sensitive macroinvertebrate traits and ecological preferences in a river in the Eastern Cape of South Africa. *Ecological Indicators*, *108*, 1–10. https://doi.org/10.1016/j.ecolind.2019.105759

Pamungkas, M. . O. A. (2016). Studi Pencemaran Limbah Cair dengan Parameter Bod5 dan pH di Pasar Ikan Tradisional dan Pasar Modern di Kota Semarang. *Jurnal Kesehatan Masyarakat*, *4*(2), 166–175.

https://doi.org/10.14710/jkm.v4i2.11942

Pozdnyakova, N., Dubrovskaya, E., Schlosser, D., Kuznetsova, S., Sigida, E., Grinev, V., Golubev, S., Kryuchkova, E., Varese, G. C., & Turkovskaya, O. (2022). Widespread Ability of Ligninolytic Fungi to Degrade Hazardous Organic Pollutants as the Basis for the Self-Purification Ability of Natural Ecosystems and for Mycoremediation Technologies. *Applied Sciences (Switzerland)*, *12*(4), 1–25. https://doi.org/10.3390/app12042164

Pratiwi, D., Sumiarsa, D., Oktavia, D., & Sunardi, S. (2023). Water Quality Influences Self-Purification in the Cihawuk and Majalaya Segments Upstream of the Citarum River, West Java, Indonesia. *Water (Switzerland)*, *15*(16), 2–17. https://doi.org/10.3390/w15162998

Rosli, R., Mohamed, I. S., Mohamed, N., Othman, R., & Rozzani, N. (2020). Development of Fraud Prevention (FP) Model Using the Theory of Planned Behavior. *Business and Economic Research*, *10*(3), 311. https://doi.org/10.5296/ber.v10i3.17313

Shaleh, F. R., Prihatini, E. S., & Masud, F. (2021). Analysis of Ater Pollution in Kaliotik River, Lamongan-West Java Analysis of Water Pollution in Kaliotik River, Lamongan-West Java. *IOP Conf. Series: Earth and Environmental Science*, *744*(012075), 1–6. https://doi.org/10.1088/1755-1315/744/1/012075

Sturiale, L., Scuderi, A., Timpanaro, G., & Matarazzo, B. (2020). Sustainable Use and Conservation of the Environmental Resources of the Etna Park (Unesco Heritage): Evaluation Model Supporting Sustainable Local Development Strategies. *Sustainability (Switzerland)*, *12*(4). https://doi.org/10.3390/su12041453

Travin, S., Duca, G., & Gladchi, V. (2019). Self-purification of aquatic media from hexachlorocyclohexane in a radical process. *Chemistry Journal of Moldova*, *14*(1), 47–53. https://doi.org/10.19261/cjm.2018.537

Unger, S., Benfield, S., Williams, L., Lawson, C., & Groves, J. (2021). Macroinvertebrate Communities and Body Condition of Larval Eastern Hellbender Salamanders (Cryptobranchus alleganiensis) in North Carolina. *Zoological Studies*, *30*, 1–9. https://doi.org/10.6620/ZS.2021.60-77

Wijaya, H., Arina, F., & Ferdinant, P. F. (2013). *Identifikasi Sumber Pencemaran Permukaan Air Sungai Cidurian Menggunakan Analisis Multivariat*. *1*(1), 23–28. https://doi.org/10.36055/jti.v1i1.113

Yogafanny, E. (2015). *Pengaruh Aktifitas Warga di Sempadan Sungai terhadap Kualitas Air Sungai Winongo*. *7*(1), 41–50. https://doi.org/10.20885/jstl.vol7.iss1.art3

Zhang, W., Fang, S., Li, Y., Dong, F., Zhang, C., Wang, C., Wang, P., Xiong, W., & Hou, X. (2019). Optimizing the integration of pollution control and water transfer for contaminated river remediation considering life-cycle concept. *Journal of Cleaner Production*, *236*, 1–10. https://doi.org/10.1016/j.jclepro.2019.117651

Zubaidah, T., Karnaningroem, N., & Slamet, A. (2019). The self-purification ability in the Rivers of Banjarmasin, Indonesia. *Journal of Ecological Engineering*, *20*(2), 177–182. https://doi.org/10.12911/22998993/97286