SURFACE WATER POLLUTION ASSESSMENT AND PROPOSED SUSTAINABLE TECHNOLOGY INNOVATION FOR RIVER RESTORATION IN THE KLAWING WATERSHED, PURBALINGGA REGENCY, INDONESIA

Isrofah[1], Arianti Mutia Ningrum[1], Afifaturrifani[1], Gangsar Edi Laksono[2], Aulia Firda Alfiana[2]
Universitas Islam Negeri Prof. K.H. Saifuddin Zuhri Purwokerto, Indonesia

Email: isrofahtul@gmail.com

Abstract

Surface water quality continues to decline due to pressures from domestic, agricultural, and industrial activities, including along the Klawing River in Purbalingga Regency, which is essential for community needs and the Serayu watershed ecosystem. This study aimed to assess the water quality of the Klawing River and formulate a river restoration perspective grounded in environmental technology. A quantitative descriptive approach was applied through field surveys and laboratory analysis at three sampling points representing the upstream, middle, and downstream sections. The measured parameters included temperature, TDS, pH, BOD, COD, and DO, which were then compared with the water quality standards set forth in Government Regulation No. 22 of 2021 and evaluated using the STORET method. The results showed that temperature, TDS, and pH still met the standards, while COD was 70 mg/L at point 1, 28.8 mg/L at point 2, and 47 mg/L at point 3, and DO was only 2.85 mg/L at point 1, 5 mg/L at point 2, and 2.25 mg/L at point 3. STORET scores indicated that sampling points 1 and 3 were moderately polluted with scores of -16, whereas point 2 was slightly polluted with a score of -4. These findings confirm that organic pollution remains the main pressure on the river. Therefore, river management should focus on adaptive restoration strategies based on environmental technology, such as IoT, AI, GIS, and digital monitoring, to support pollution control and watershed sustainability.

Keywords: *River water quality; STORET method; Sustainable river restoration; Environmental technology*

Abstrak

Kualitas air permukaan semakin menurun akibat tekanan aktivitas domestik, pertanian, dan industri, termasuk di Sungai Klawing di Kabupaten Purbalingga yang berperan penting bagi kebutuhan masyarakat dan ekosistem DAS Serayu. Penelitian ini bertujuan untuk menganalisis status mutu air Sungai Klawing serta merumuskan perspektif restorasi sungai berbasis teknologi lingkungan. Penelitian ini menggunakan pendekatan deskriptif kuantitatif melalui survei lapangan dan analisis laboratorium pada tiga titik pengamatan yang mewakili bagian hulu, tengah, dan hilir. Parameter yang diamati meliputi suhu, TDS, pH, BOD, COD, dan DO, kemudian dibandingkan dengan baku mutu Peraturan Pemerintah Nomor 22 Tahun 2021 serta dianalisis menggunakan metode STORET. Hasil penelitian menunjukkan bahwa suhu, TDS, dan pH masih memenuhi baku mutu, sedangkan COD mencapai 70 mg/L di titik 1, 28,8 mg/L di titik 2, dan 47 mg/L di titik 3, serta DO hanya 2,85 mg/L di titik 1, 5 mg/L di titik 2, dan 2,25 mg/L di titik 3. Nilai STORET menunjukkan bahwa titik 1 dan titik 3 tergolong tercemar sedang dengan skor -16, sedangkan titik 2 tergolong tercemar ringan dengan skor -4. Temuan ini *menegaskan bahwa pencemaran organik masih menjadi tekanan utama pada sungai. Oleh karena itu, pengelolaan sungai perlu diarahkan pada strategi restorasi adaptif berbasis teknologi, seperti IoT, AI, GIS, dan pemantauan digital, untuk mendukung pengendalian pencemaran serta keberlanjutan.*

Kata Kunci: *Kualitas air sungai; Metode STORET; Restorasi sungai berkelanjutan; Teknologi lingkungan*

1. INTRODUCTION

Surface water quality has become a global environmental issue that has garnered increasing attention in recent decades. This situation is attributed to rising urbanization, industrialization, population growth, and changes in land use within river basins (Nastiti, Asih, and Hermawan 2024)(Elza 2025; Niandyti, Sufyandi, and Utami 2019; Pangesti et al. 2023; Saputra et al. 2024; Satria 2019). Rivers, as the primary water resource, play a vital role in supporting domestic, agricultural, fisheries, and industrial needs, as well as maintaining the balance of aquatic ecosystems (Sutrisno and Hamdani 2020; Ujianti, Agung, and Kurniawan 2021). However, various anthropogenic activities have led to a decline in river water quality in many developing countries, including Indonesia (UNEP 2024).

Water quality and quantity have become increasingly critical global environmental issues due to rising population growth, urbanization, industrialization, and climate change, all of which affect the availability and condition of water resources. Water is a basic necessity for human life, ecosystems, agriculture, and industry; therefore, the sustainability of its quality and quantity must be managed in an integrated manner. However, various international reports indicate that the world is currently facing a water crisis characterized by increasing water pollution, declining clean water quality, and limited access to safe water in many regions. The United Nations Environment Program (UNEP) states that pollution from domestic, industrial, and agricultural waste, as well as microplastics, is the primary cause of global degradation water quality (UNEP 2024). Additionally, the World Meteorological Organization (WMO) explains that climate change is causing an increase in droughts, floods, and imbalances in the hydrological cycle, leading to a decline in the quantity of clean water in various countries(WMO 2025). Other studies also indicate that more than half of the world's population faces water scarcity pressures due to a combination of declining water quality and limited water resources (Fransiska, Sari, and Yolanda 2024). These conditions underscore the critical urgency of sustainable management of water quality, and quantity to support public health, food security, and environmental sustainability. Deteriorating water quality not only impacts the ecological functions of rivers but also threatens public health, the sustainability of water resources, and long-term environmental resilience (Plessis 2022).

In Indonesia, the decline in river water quality is generally influenced by domestic waste, industrial activities, agriculture, livestock farming, and changes in land use around river basins. Nevertheless, Indonesia's environmental quality has shown an upward trend nationally in recent years. Data from the Central Statistics Agency (BPS) indicates that the national Environmental Quality Index (IKLH) has continued to rise year over year and has consistently exceeded the government's targets. In 2020, the EQI stood at 70.27, then rose to 71.45 in 2021, increased further to 72.42 in 2022, and reached 75.53 in 2024. This increase indicates increasingly integrated environmental management efforts to maintain environmental quality in Indonesia. However, the Water Quality Index (IKA), which is part of the IKLH, remains below the national target despite an increase in its value. The AQI in 2024 was 54.78, while the national target was 55.5. This situation indicates that water quality remains a primary challenge in environmental management in Indonesia, particularly due to high pollution pressures from human activities on surface water bodies (Yonatan 2025).

One region in Indonesia that is vulnerable to river water pollution is Purbalingga Regency, Central Java. High levels of human activity around the river basin, particularly domestic activities, are among the main factors affecting water quality in the region (Indriyani, Sudarti, and Yushardi n.d.). A previous study on the Pundul River in Purbalingga Regency showed that the pH and total coliform parameters exceeded Class III water quality standards, with the river's quality classified as moderately polluted based on the STORET method due to domestic activities and the direct discharge of industrial waste from vermicelli production into the river (Afifah et al. 2025). Additionally, research on the Serayu River indicates that sand mining activities and human pressure along the watershed have the potential to degrade water quality and disrupt the sustainability of the river's ecosystem functions(Triwuri, Handayani, and Dwityaningsih 2024). Research on the analysis of surface water quality in the Klawing River area around industrial and residential areas using the STORET method and environmental restoration technologies has been limited in Purbalingga Regency.

Although various studies on river water quality have been conducted, most still focus on conventional analyses of physical and chemical parameters using the STORET method or pollution indices, without integrating a more comprehensive environmental technology approach (Ramadhawati, Wahyono, and Santoso 2021). Furthermore, studies on technology-based river restoration in local watersheds in Indonesia remain relatively limited, particularly those linking water quality evaluation results to the concepts of environmental monitoring technology, spatial analysis, and sustainable restoration strategies based on ecosystem resilience and adaptive environmental management (Wiandari, Maroeto, and Mindari 2024).

The Klawing River is an important part of the Serayu watershed system that the community relies on for various activities, such as domestic needs, agriculture, fisheries, and other economic activities. The high level of community activity around the watershed has the potential to increase pollution pressure on the river, particularly due to the influx of domestic wastewater, surface runoff, and economic activities in the surrounding water areas (Lestari, Sukamata, and Sari 2023). If not managed sustainably, these conditions can lead to a decline in environmental carrying capacity, threats to clean water availability, disruption of aquatic ecosystems, and reduced environmental resilience within the watershed. Without effective monitoring and restoration strategies, river water quality degradation is likely to continue to worsen and threaten the sustainability of water resources in the future.

Given these issues, this study aims to analyze the water quality of the Klawing River using the STORET method and to develop a river restoration perspective grounded in environmental technology as part of planetary restoration efforts. This study integrates water quality analysis with environmental monitoring technologies, including digital monitoring concepts, watershed-based spatial analysis, and sustainable restoration strategies, to support more adaptive, effective, and sustainable river management. The main contribution of this research lies in integrating STORET-based water-quality evaluation with environmental technology approaches and the concept of adaptive river restoration to support sustainable watershed management in developing regions, particularly at the local watershed scale in Indonesia.

2. RESEARCH METHOD

a. Research Appoarch

This study employs a quantitative, descriptive approach, combined with field surveys and laboratory analyses to evaluate river water quality. A literature review was also conducted to identify relevant references for developing an environmental technology-based river restoration strategy.

b. Research Location and Time

This study was conducted on the Klawing River, which is part of the Serayu River Basin (DAS), Purbalingga Regency, Central Java, Indonesia (Figure 1). The study was carried out from April to May 2026 for data collection and analysis. The determination of water sampling locations was based on the environmental characteristics at each point, which represent the surrounding anthropogenic activities. The upstream sampling point was used as a control point with relatively low human activity, the midstream sampling point represents residential areas and industrial activities, while the downstream sampling point represents an area dominated by industrial activities.

Picture 1. *Map of Sampling Locations*

Table 2. *Water Sampling Locations*

Point	Dessription	Coordinate		Sampling Method	Reference Standars
		LU/LS	BT		
1	Upper	7923'0.58"S	109°20'59.45"E	Grab sampling	SNI 8995:2021
2	Central	7°23'33.09"S	109°21'43.54"E	Grab sampling	SNI 8995:2021
3	Downstream	724'26.68"S	109°22'12.67"E	Grab sampling	SNI 8995:2021

c. *Data Analysis*

Table 2. *Measured water quality parameters*

Parameter	Instrument/Method	Observation location
Physical parameters		
Temperature(°C)	Termometer HANNA HI98509	In situ
Parameter kimia		
pH	pH meter	In situ
DO	DO meter HANNA HI9142	Laboratory
COD	Titrasi	Laboratory
BOD	Inkubator, Metode BUD 5 hari	Laboratory
TDS	TDS meter	Laboratory

Table 3. *Water Quality Standards Based on Government Regulation No. 22 of 2021 and WHO*

Parameter	Quality standard				
	PP Nomor 22 Tahun 2021				WHO
	1	2	3	4	
Temperature (°C)	Dev 3				10-22
pH	6-9				6,5–8,5
DO (mg/L)	6	4	3	1	-
COD (mg/L)	10	25	40	80	-
BOD (mg/L)	2	3	6	12	-
TDS (ppm)	1000	1000	1000	2000	-

d. *Storet Method and Pollutant Index*

In the analysis using the STORET method, water quality data are compared with quality standards appropriate for its intended use to determine water quality status. The results of the analysis for each water sample are then compared with quality standards appropriate for water use (Anwar et al. 2018). Determining water quality status using the STORET method is carried out through the following steps:

1. Collecting water quality data

2. Compare the measurement/test results for each water parameter with the quality standards corresponding to the water class.
3. If the measurement/test meets the water quality standard (the measurement result is lower than the standard), a score of 0 is assigned.
4. If the measurement/test results do not meet the water quality standards (measurement results exceed the standards), a score is assigned according to the table.
5. Calculate the total negative score for all parameters and determine the water quality status based on the total score obtained using the United States Environmental Protection Agency (US-EPA) scoring system, which classifies water quality into four classes, namely:
   - Class A: excellent, score 0, meets quality standards
   - Class B: good, score -1 to -10, slightly polluted
   - Class C: moderate, score -11 to -30, moderately polluted
   - Class D: poor, score < -31, heavily polluted.

Table 4. *Determination of Values to Determine Water Quality Status Using the Storet Method*

Number of Samples	**Value**	**Parameter**		
		Physical	**Chemical**	**Biology**
< 10	Maxsimum	-1	-2	-3
	Minimum	-1	-2	-3
	Average	-3	-6	-9
≥ 10	Maxsimum	-2	-4	-6
	Minimum	-2	-4	-6
	Average	-6	-12	-18

e. **Pollutant Index (PI) Method**

Based on the ministry of Environment Decree No. 115 of 2003. The water quality status of the Klawing River is calculated using the PI method with the following equation:

$$PIj = \sqrt{\frac{(\frac{Ci}{Lij})^2_{max} + (\frac{Ci}{Lij})^2_{avg}}{2}}$$

Notes:

Pij : Pollutant Index for the designated use (j)

Ci : Measured concentration of water quality parameters

Lij: Concentration of water quality parameters specified in the water quality standards for specific uses (j)

(Cij/Lij) max: Maximum Cij/Lij value

(Cij/Lij) avg: MaximumCij/Lij value

This formula calculates the pollution index based on the maximum and average values of all analyzed parameters. The use of these two values aims to better describe pollution conditions. The results of the Pollutant Index calculation are then interpreted to determine the water body's water quality status. Based on the guidelines set forth in the Decree of Keputusan Menteri Negara Lingkungan Hidup Nomor 115 Tahun 2003, the classification of water quality status based on the Pollutant Index value is as follows:

***Table 5**. Classification of Class Criteria Using the Pollutant Index Method*

Pollutant Index Value	Water Quality Status
Meets	Meets quality standards (good condition)
$1 < IP \leq 5$	Slightly polluted
$5 < IP \leq 10$	Moderately polluted
$IP > 10$	Heavily contaminated

3. RESULT AND DISCUSSION

Results of Water Quality Analysis of the Klawing River Based on Government Regulation No. 22 of 2021

The results of water quality measurements in the Klawing River show variations in water quality parameters at each observation point, influenced by environmental activities and anthropogenic pressures along the river's course. The parameters analyzed include temperature, total dissolved solids (TDS), pH, biological oxygen demand (BOD), chemical oxygen demand (COD), and dissolved oxygen (DO). The measurement results were then compared with water quality standards for Classes I–IV as outlined in Government Regulation No. 22 of 2021.

Table 6. *Klawing River Water Quality Measurement Results*

No	Parameter	Unity Quality	Baku mutu (PP Nomor 22 Tahun 2021)				WHO	Test Result			Reference standard
			1	2	3	4		Titik 1	Titik 2	Titik 3	
1.	Temperature	°C	Dev 3				10-22	29,3	28,9	28,5	SNI 06-6989.23-2005
2.	TDS	ppm	1000	1000	1000	2000	-	118	111	132	SNI 06-6989.27-2005
3.	PH	Skala 0-14	6-9				6,5–8,5	7	7,3	7	SNI 06-6989.11-2004
4.	BOD	mg/L	2	3	6	12	-	1,3	2,4	1,75	SNI 6989.72-2009
5.	COD	mg/L	10	25	40	80	-	70	28,8	47	SNI 06-6989.2-2009
6.	DO	mg/L	6	4	3	1	-	2,85	5	2,25	SNI 60-6989.72-2009

Based on the measurement results, the temperature, TDS, and pH parameters at all observation points remain within the quality standards for all water quality classes as stipulated in Government Regulation No. 22 of 2021 on the Implementation of Environmental Protection and Management, where TDS ≤ 1,000 mg/L and pH 6–9 apply to Classes I, II, and III. The relatively low TDS values indicate that the dissolved solids content in the river body is still considered safe and does not yet show significant accumulation of dissolved materials, as also reported in several river water quality studies in Indonesia, indicating that TDS and pH values still meet the quality standards for Classes I–III (Denny et al. 2025).

The DO parameter indicates relatively low levels at Point 1 and Point 3, at 2.85 mg/L and 2.25 mg/L, respectively. These values fall below the quality standards for Classes I, II, and III, indicating a decrease in dissolved oxygen levels due to high organic pollutant loads in the river. Low DO levels can disrupt the respiration of aquatic organisms, degrade the quality of aquatic habitats, and reduce the river's natural capacity for self-purification. This condition can also increase ecological pressure on the river ecosystem and disrupt the balance of aquatic biota (Revansyah et al. 2023).

Spatially, water quality degradation tends to occur at Points 1 and 3, which are suspected to be influenced by domestic activities and the accumulation of pollutants from the surrounding watershed. These conditions indicate varying pollution distributions across river segments, making watershed-based management and spatial analysis crucial for supporting sustainable river restoration. Water quality status analysis was conducted using the STORET method in accordance with the water quality standards of Government Regulation No. 22 of 2021, Classes I–IV. STORET scores were determined by comparing water-quality measurement results with the standard values for each water body class.

Analysis of the Water Quality Status of the Klawing River Using the STORET Method

Table 7. *STORET Calculation Results for the Klawing River*

Parameter	Titik 1	Titik 2	Titik 3	Keterangan
Suhu	0	0	0	Meets quality standards

TDS	0	0	0	Meets quality standards
PH	0	0	0	Meets quality standards
BOD	0	0	0	Meets Class II–IV quality standards
COD	-8	-4	-8	Exceeds quality standards
DO	-8	0	-8	Below quality standards
Total STORET score	**-16**	**-4**	**-16**	
Water quality status	Moderately polluted	Lightly polluted	Moderately polluted	

STORET analysis results indicate that Point 1 and Point 3 fall into the moderately polluted category with a total score of -16, while Point 2 is classified as slightly polluted with a score of -4. Pollution levels are primarily influenced by high COD parameters and low DO levels at several monitoring points. These conditions indicate that organic pollution pressure is the primary factor affecting the water quality of the Klawing River. High COD values indicate a large amount of organic matter and chemical compounds that require oxygen during decomposition, while low DO levels suggest that the water body's ability to support aquatic life is beginning to decline.

The findings of this study align with those of several previous Indonesian studies. Research on the Pundul River in Purbalingga Regency showed that river water quality has deteriorated due to domestic activities and household industrial waste. Another study on the Serayu River also indicated that human activity pressures and environmental changes in the watershed have the potential to degrade river water quality. Similar findings were also reported in studies of the Citarum and Code Rivers, where domestic discharges and anthropogenic activities significantly affected river water quality and aquatic ecosystem conditions (Revansyah et al. 2023).

Water quality analysis results indicate that the Klawing River requires additional adaptive environmental restoration and management efforts to prevent further water quality degradation. In the context of Technology for Planetary Restoration, river restoration focuses not only on reducing pollution sources but also on developing technology-based environmental management systems that support sustainable, efficient water quality monitoring.

Technology Recommendations for River Water Quality Monitoring and Restoration

1. *Internet of Things (IoT) dalam Pemantauan Kualitas Air*

The development of the Internet of Things (IoT) has been a key innovation in water quality monitoring systems, enabling real-time, continuous measurement of environmental parameters. These systems typically utilize integrated sensors to measure physical and chemical water parameters, such as temperature, pH, turbidity, dissolved oxygen (DO), and several other pollutant indicators, which are then transmitted via communication networks to a cloud-based data storage platform. The primary advantage of IoT is its ability to perform continuous monitoring, enabling the detection of changes in water quality more quickly than conventional methods based on periodic sampling. Additionally, integrating sensor data with digital systems enables multisite monitoring, enabling the simultaneous and efficient management of water quality across multiple river locations (Sains et al. 2025; Setiawan and Siswanto 2024).

2. *Artificial Intelligence (AI) dan Machine Learning untuk Prediksi Kualitas Air*

Artificial Intelligence (AI) and Machine Learning (ML) are increasingly used in water quality management to predict changes in environmental conditions by analyzing historical patterns and relationships among variables. These technologies leverage datasets on water quality, hydrology, climate, and land use to build predictive models that estimate changes in water conditions temporally and spatially. Some commonly used algorithms include Random Forest, Support Vector Machine (SVM), Artificial Neural Network (ANN), and Long Short-Term Memory (LSTM), which have demonstrated strong performance in water quality trend analysis. AI also enables the identification of pollution patterns influenced by season, rainfall, river flow, and other anthropogenic pressures (Sudasman and Gereuw 2025).

3. *Geographic Information System (GIS) in Spatial Analysis of Water Quality*

Geographic Information Systems (GIS) are widely used technologies for spatial analysis and for visualizing pollution distribution within a water body. GIS can integrate water-quality data with geographic information, such as topography, land use, population density, and watershed characteristics, to produce more comprehensive environmental risk mapping. In river management, GIS is useful for identifying pollution hotspots, land-use changes, and river segments most vulnerable to declining water quality. This technology also helps establish area-based intervention priorities, enabling more effective resource management (Das 2025).

4. *Cloud Computing and Monitoring Dashboards*

Cloud computing plays a crucial role in supporting modern water quality monitoring systems by enabling centralized data storage, processing, and access. Data from field sensors can be automatically processed and displayed on a monitoring dashboard to support rapid, systematic evaluation of environmental conditions. This technology facilitates integration across monitoring points, long-term data storage, and the issuance of early notifications when water quality parameters exceed safe limits. Thus, cloud-based monitoring can enhance the efficiency of environmental data management (Interface, Engine, and Measures 2024).

5. *Remote Sensing and Unmanned Aerial Vehicles (UAVs)*

Remote sensing and UAVs (drones) have been used in water quality management to monitor environmental changes through satellite imagery and high-resolution imagery. This technology enables observation of vast, hard-to-reach areas, particularly for analyzing sedimentation, changes in riparian vegetation, erosion, and land cover changes that affect water quality. Integrating remote sensing with GIS enhances spatial analysis capabilities, enabling the monitoring of environmental conditions in greater detail and regularly. This approach is particularly valuable at the watershed scale because land-use factors significantly influence river water quality. On the Klawing River, this technology can be used to observe changes in land cover and the potential for pollutant runoff from areas surrounding the river(Yang et al. 2023).

6. Wastewater Treatment Technologies at Pollution Sources

In addition to monitoring systems, improving water quality also requires a direct control approach at pollution sources. Various wastewater treatment technologies have been implemented to reduce pollutant loads before they enter water bodies. Some commonly used methods include aeration, filtration, biological treatment, reverse osmosis, and plasma-based treatment. Aeration increases dissolved oxygen levels, while filtration and biological treatment reduce organic matter and other pollutants. These technologies are generally applied to domestic, agro-industrial, and livestock waste, which are the primary sources of river pollution. In the context of the Klawing River watershed, this approach is crucial when the dominant sources of pollution stem from domestic and agricultural activities(Aji et al. 2024).

Given the characteristics of the Klawing River, which are influenced by domestic and agricultural activities, and the potential for increased organic load in the water body, the combination of IoT, AI, and GIS technologies is considered the most relevant for implementation. IoT functions as a real-time monitoring system to quickly detect changes in water quality parameters. GIS maps the distribution of pollution sources and hotspots in vulnerable areas, while AI predicts trends in water quality changes based on historical patterns and environmental factors.

However, if the research focuses on the high levels of DO and COD in the Purbalingga area, the most appropriate technology is the integration of IoT and AI. IoT is necessary for continuous monitoring of changes in water quality parameters, while AI supports predictive analysis and the identification of pollution patterns. GIS continues to function as a tool for spatial analysis, but is not the primary technology for controlling water quality parameters. Therefore, the IoT–AI combination can be considered the most effective approach for monitoring, evaluating, and mitigating water quality in the Klawing River basin, Purbalingga.

4. CONCLUSION

This study clearly answers the research questions by showing that the water quality status of the Klawing River varies across monitoring points, where points 1 and 3 are classified as moderately polluted. In contrast, point 2 is classified as slightly polluted based on the STORET analysis. The main findings indicate that high COD and low DO are the most influential parameters contributing to water quality deterioration, whereas temperature, TDS, and pH remain within acceptable standards. These results confirm that organic pollution remains the dominant pressure affecting the Klawing River. Theoretically, this study strengthens the assessment of river water quality by integrating the STORET method with an environmental technology-based restoration perspective. Practically, the findings provide a scientific basis for local authorities, watershed managers, and communities to implement pollution control through routine monitoring, domestic wastewater management, and the use of technologies such as IoT, AI, and GIS to support sustainable river restoration. Future research should expand the number of sampling locations, include different seasonal conditions, and integrate biological and spatial parameters to produce a more comprehensive evaluation of water quality.

REFERENCES

Afifah, Naufal, Eric Armando, Program Studi Akuakultur, Fakultas Pertanian, Universitas Tidar, Jl Barito, and Kota Magelang. 2025. "Status Mutu Sungai Sungai Pundul , Kutasari Kabupaten Purbalingga River Quality Status of the Pundul River , Kutasari , Purbalingga Regency." *Journal of Aquatic and Fisheries Sciences* 4(2):107–14.

Aji, Bayu, Staniya Uswatun Khasanah, Riandra Restu Mahestra, Sita Alfia Kusprihatini, Program Studi, Teknik Industri, Fakultas Teknologi Industri, and Universitas Ahmad Dahlan. 2024. "I-Findi: Pengolahan Limbah Cair Sampah Organik (Leachate) Dengan Reverse Osmosis Terintegrasi Solar Cell System Dan IoT Berbasis Filtrasi Aerasi Bioremediasi." *Prosiding Nasional 2024 Universitas Abdurachman Saleh SItubondo* 54–61.

Anwar, Saiful, Budi Hariono, Michael Joko Wibowo, Merry Muspita, Dyah Utami, Kali Tlogo Ampel, Kali Curah Macan, Kali Baru, Kali Bomo, Kali Tambong, Kali Bajulmati, and Kali Curah. 2018. "Penentuan Status Mutu Air Metode Storet DAS Kali Curah Macan Determination of Water Quality Status of the Storet Method of Curah Macan River." *Jurnal Ilmiah INOVASI* 18(2):95–99.

Das, Abhijeet. 2025. *Water Quality Assessment and Geospatial Techniques for the Delineation of Surface Water Potential Zones : A Data-Driven Approach Using Machine Learning Models*. Vol. 324. Elsevier Inc.

Denny, Shalehudin, Wardatul Hidayah, Daru Kelvin, Argya Pradana, and Diepa Febriana. 2025. "Contamination Level Analysis of the Kelinjau River in Dun Village , Muara Ancalong District , East Kutai Regency , East Kalimantan Province." *Jurnal Agriment* 10:51–57.

Elza, Pelia. 2025. "Pengaruh Limbah Domestik Terhadap Pencemaran Air Sungai Di Kawasan Padat Penduduk." *Jurnal Riset Kesehatan Lingkungan Dan Sanitasi* 1(1):30–36.

Fransiska, Gadis, Apriliana Sari, and Devi Yolanda. 2024. "Krisi Air Menangani Penyediaan Air Bersih Di Dunia Yang Semakin Kekurangan Sumber Daya." 1(5):334–41.

Indriyani, Amalia Rosyida, Sudarti, and Yushardi. n.d. "Analisi Limbah Pencemaran Air Sungai Di Kota Dan Desa." *Jurnal Pendidikan Fisika* 8(1):29–35.

Interface, Dashboard, Alerting Engine, and Security Measures. 2024. "Cloud Monitoring Using Dashboard." *International Research Journal* 11(7):552–59.

Lestari, Devita Satya, Sukamata, and Yunitta Chandra Sari. 2023. "Status Kualitas Air DAS Sanggai Di Kabupaten Penajam Paser Utara Dan Perumusan Strategi Pencegahan Serta Pengendalian Pencemaran Air." *Jurnal Ilmu Lingkungan* 21:914–32.

Nastiti, Endah Ummi, Andrea Sumarah Asih, and Anggi Hermawan. 2024. "Pengaruh Perubahan Tata Guna Lahan Terhadap Debit Banjir Pada DAS Cibanten." 10–20.

Niandyti, Febsy, Yendi Sufyandi, and Westi Utami. 2019. "Dampak Pembangunan Industri Terhadap Perubahan Penggunaan Tanah Dan Kesesuainnya Dengan Tata Ruang." *Jurnal Tunas Agraria* 2(2).

Pangesti, Dinda Tri, Abdul Razak, Nurhasan Syah, and Skunda Diliarosta. 2023. "Hubungan Antara Pertumbuhan Populasi Dan Kerusakan Lingkungan: Kajian Literature." *Jurnal Kependudukan Dan Pembangunan Lingkungan* 4(3):123–29.

Plessis, Anja. 2022. "Commentary Persistent Degradation : Global Water Quality Challenges and Required Actions." *One Earth* 5(2):129–31. doi: 10.1016/j.oneear.2022.01.005.

Ramadhawati, Devi, Heru Dwi Wahyono, and Arif Dwi Santoso. 2021. "Pemantauan Kualitas Air Sungai Cisadane Secara Online Dan Analisis Status Mutu Air Menggunakan Metode Storet." *Jurnal Sains Dan Teknologi Lingkungan* 13(April):76–91.

Revansyah, M. Arya, Puspaningrum W.M.S, Mita Putriyani, Nisrina Padma Ayu, Liu Kin Men, Setianto, Lusi Safriani, Fitrilawati, Norman Syakir, and Annisa Aprilia. 2023. "Analisis Tds, Ph, Dan Cod Untuk Mengetahui Kualitas Air Warga Desa Cilayung." *Jurnal Material Dan Energi Indonesia* 12(02):43–49.

Sains, Jurnal, Vol No, September Hal, and Miftah Alfidyah. 2025. "Pemanfaatan Internet Of Things (IOT) Untuk Monitoring Kualitas Air Sebagai Upaya Mendukung Smart City." *Jurnal Sains Dan Teknologi* 1(1):8–14.

Saputra, Harmedi Yulian, Nurhasan Syah, Indang Dewata, Abdul Razak, Skunda Diliarosta, and Aulia Azhar. 2024. "Urbanisasi Dan Dampaknya Terhadap Kualitas Lingkungan: Literature Review." *Gudang Jurnal Multidisipline Ilmu* 2:920–26.

Satria, Adhi Putra. 2019. "Environmental Quality Protection in the Period of Industrialization to Realize Environmental-Based Industry." *Jurnal Ilmu Hukum* 03(1):3–4.

Setiawan, Nuris Dwi, and Eko Siswanto. 2024. "Pemanfaatan Teknologi Internet of Things Untuk Monitoring Kualitas Air Sungai Di Wilayah Perkotaan Lebih Lanjut Terhadap Ekosistem Dan Kesehatan Masyarakat . Pendekatan Ini Melibatkan Dan Analisis Kualitas Air Secara Real-Time Di Sungai Perkotaan . Sistem." *Journal of New Trends in Sciences*.

Sudasman, Fuad Hilmi, and Gabriel Enjel Gereuw. 2025. "Integration of AI and GIS in Clean Water Quality Monitoring in Urban and Rural Communities : A Systematic Review." *Journal of Artificial Intelligence and Digital Business* 4(2):5338–44.

Sutrisno, Nuno, and Adang Hamdani. 2020. "Optimalisasi Pemanfaatan Sumber Daya Air Untuk Meningkatkan Produksi Pertanian." *Jurnal Sumberdaya Lahan* 73–88.

Triwuri, Nurlinda Ayu, Murni Handayani, and Rosita Dwityaningsih. 2024. "Kajian Status Mutu Peraian Sungai Serayu Dengan Menggunakan Pendekatan Metode Indeks Pencemaran (Pollution Index)." *Jurnal Akbar Juara* 9(115).

Ujianti, Rizky Muliani Dwi, Lukman Anugrah Agung, and Fathoni Tri Kurniawan. 2021. "Optimalisasi Hilir Daerah Aliran Sungai Sebagai Kawasan Pertanian Dan Budidaya Perikanan Berbasis Masyarakat." *Jurnal Inovasi Penelitian* 2(1):229–34.

UNEP. 2024. *Progress on Ambient Water Quality Mid-Term Status of SDG Indicator 6.3.2 and Acceleration Needs, with a Special Focus on Health*.

Wiandari, Nabila Putri, Maroeto, and Wanti Mindari. 2024. "Kajian Kualitas Air Pada Berbagai Penggunaan Lahan Di Sub DAS Jagir Kota Surabaya." *AGROTEKNIKA* 7(September):314–32.

WMO. 2025. *State of the Global Climate*.

Yang, Wenlan, Bolin Fu, Sunzhe Li, Zhinan Lao, Tengfang Deng, Wen He, Hongchang He, and Zhikun Chen. 2023. "Monitoring Multi-Water Quality of Internationally Important Karst Wetland through Deep Learning , Multi-Sensor and Multi-Platform Remote Sensing Images : A Case Study of Guilin , China." *Ecological Indicators* 154(March):110755. doi: 10.1016/j.ecolind.2023.110755.

Yonatan, Agnes Z. 2025. "Indeks Kualitas Lingkungan Hidup Indonesia Terus Meningkat Dalam 5 Tahun Terakhir." *GoodStats*. Retrieved (https://data.goodstats.id/statistic/lampaui-target-indeks-kualitas-lingkungan-hidup-ri-terus-naik-Uv22X).