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Assessment of Water Quality Based on Land Use in an Upper Watershed Using the STORET Method

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ABSTRACT

Land use change significantly affects water quality, particularly in watersheds. This study assessed the water quality of the Upper Welang Watershed, East Java, using the STORET method in relation to land use types. Water quality assessment involves comparing measured data with the National Water Quality Standard (Government Regulation No. 22 of 2021). Water samples were collected during the dry season (March to July 2023) from forest, plantation, rice field, dry field, settlement, and industrial areas. Parameters analyzed included pH, DO, BOD, COD, NO_3, TDS, Pb, Cd, and coliforms. Results showed that water quality declined in areas with high anthropogenic activity, particularly in industrial and settlement zones, with COD and NO_3 levels exceeding national standards. Rivers with stable substrates and sufficient habitats exhibit better water quality. The findings highlight the importance of land use management in watershed conservation.

1. INTRODUCTION

The increasing global population drives higher demand for essential resources, necessitating land use changes to meet human needs. Land, as a fundamental natural resource, plays a crucial role in sustaining life (Pahleviannur, 2019). However, development often leads to land conversion, such as transforming areas into rice fields and settlements (Elisabeth *et al*., 2016). These changes impact watershed hydrology by reducing soil infiltration, increasing runoff (Nilda *et al*., 2015), and ultimately affecting water quality, volume, and flow velocity (Setyowati, 2015). Such degradation disrupts ecosystems by exceeding their carrying capacities (Lapatandau *et al*., 2017), a phenomenon also observed in the upstream Welang River Watershed.

The increase in population and land conversion has disrupted watershed hydrology and water quality globally. Similar conditions are found in the Welang Watershed, which serves as a vital water source in East Java. The Welang watershed serves as a critical water source for Malang Regency, Pasuruan Regency, and Pasuruan City, but increasing population pressures contribute to land scarcity, potentially threatening its ecological balance (Prameswari *et al*., 2023). Covering 526.04 km², with the Welang River extending 40.09 km (Irawanto, 2021; Oktoprianica *et al*., 2020), its upper reaches support human activities, while downstream areas facilitate fishing (Khusnah, 2021). The diverse land use includes forests, settlements, agriculture, industry, and plantations, significantly influencing watershed function and water quality dynamics (Ningsih, 2015; Shrestha *et al*., 2018).

Non-conservative land use, including agriculture, livestock, fisheries, infrastructure, settlements, and industry, degrades watersheds by increasing erosion, runoff, sedimentation, and pollution (Alwi & Sitti, 2015). In the upper

Welang watershed, diverse land uses contribute to pollution, reducing water quality and usability. Poor environmental management, such as improper waste disposal and direct wastewater discharge, worsens this issue (Yogafanny, 2015). In 2020, pollution in the Welang River was reported, with foam linked to upstream factory activities (Hartono, 2020), underscoring the urgency of pollution control. Water quality assessment uses methods like STORET, comparing parameter values to national standards (Menteri Negara Lingkungan Hidup, 2003; Presiden Republik Indonesia 2021). The STORET method excels in terms of simplicity, legality, and compatibility with Indonesia's water quality management system. For regulatory research or baseline monitoring, STORET is very appropriate. Past studies indicate pollution from agriculture and industry, but limited research links these changes explicitly with land use patterns. This study aims to assess water quality across different land uses and identify the impact of anthropogenic activities using the STORET method. By identifying key pollutants, it aims to guide policymakers in implementing sustainable land use strategies to protect water resources.

2. MATERIALS AND METHODS

The research was carried out within the Upper Welang watershed, encompassing six distinct land use categories, with two replicates each in Lawang, Purwodadi, and Pasuruan (Figure 1). Water sampling locations were strategically selected across various land use types, including forests, plantations, rice fields, dry fields, settlements, and industrial zones. The use of the STORET method for water quality assessment is intended for regular monitoring with the use of multiparameters. Detailed coordinate points for these sampling locations are provided in Table 1.

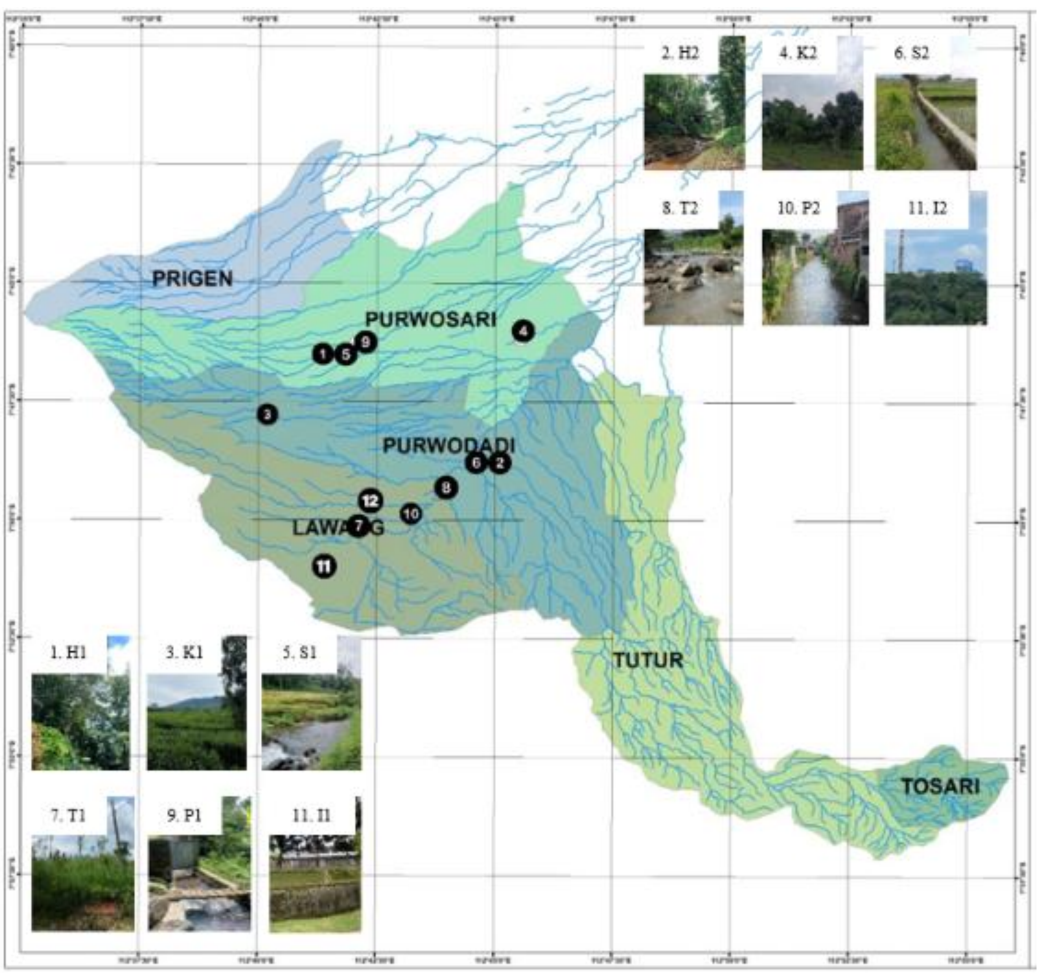

Figure 1. Map of land use and water sampling locations in the Upper Welang Watershed

Table 1. Water sample locations

Land use		Location X	Location Y
Western Forest	H1	7°77’21.40”S	112°69’42.10”E
Eastern Forest	H2	7°81’33.98”S	112°75’47.50”E
Western Plantation	K1	7°77’75.47”S	112°74’99.60”E
Eastern Plantation	K2	7°80’88.27”S	112°64’50.85”E
Western Rice Field	S1	7°77’16.88”S	112°70’33.11”E
Eastern Rice Field	S2	7°48’26.62”S	112°43’19.11”E
Western Dry Field	T1	7°82’44.41”S	112°73’01.02”E
Eastern Dry Field	T2	7°83’29.45”S	112°68’70.67”E
Western Settlement	P1	7°76’74.36”S	112°71’14.69”E
Eastern Settlement	P2	7°81’41.79”S	112°74’46.48”E
Western Industry	I1	7°83’24.84”S	112°70’52.50”E
Eastern Industry	I2	7°85’22.11”S	112°69’23.14”E

2.1. Tools and materials

The tools in research are a pH meter for acidity and alkalinity levels of water, a thermometer for water temperature, a water quality tester for TDS, spectrophotometry for COD and NO_3, Atomic Absorption Spectrophotometry (AAS) for metal contents and portable DO meter for DO (dissolved oxygen) and BOD (Biochemical Oxygen Demand), a millipore membrane filter for total coliforms, a Sechi disc for water clarity, meters, stationery, bottles, and a camera.

The material used is water from the upstream Welang River at the sampling site location. The investigation was carried out using a targeted random sampling method and descriptive analysis. Implementation phases include preparation, field survey, water sampling (Figure 2), laboratory analysis, and data analysis.

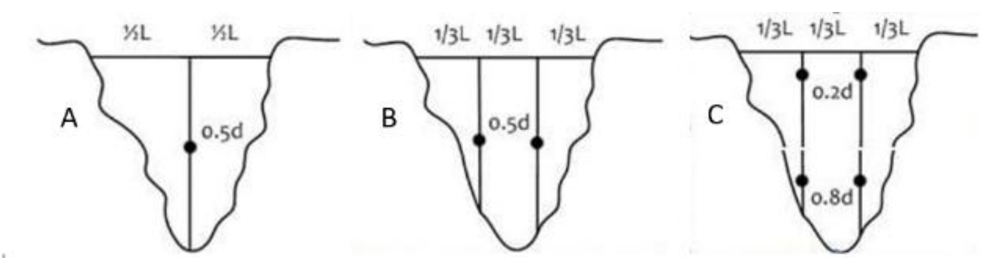

Figure 2. Sampling points for: (A). Very small river, (B). Small river, and (C). Medium river

2.2. Data analysis

The study analyzed water temperature, pH, TDS, DO, BOD, COD, NO_3, Pb, Cd, and total coliform using the STORET method, and comparing results with water quality standards (Presiden Republik Indonesia, 2021). The STORET classification categorizes water quality into four classes: A (very good, score = 0), B (good, -1 to -10, lightly polluted), C (moderate, -11 to -30), and D (poor, < -30, heavily polluted). River physical quality was assessed using six parameters of riverbed substrate: 1) Substrate cover in the literal zone (riverbank), 2) Riverbank substrate buried in mud, 3) Sediment deposition, 4) Substrate in the deep part of the river, 5) Shade of small river vegetation (width < 5 m), and 6) River water clarity), as well as 12 parameters of disturbance factors: 1) River flow modification, 2) Flow changes due to dredging or river straightening, 3) Stability of the left river bank, 4) Stability of the right river bank, 5) Condition of bank protection by left riverbank vegetation, 6) Condition of bank protection by right riverbank vegetation, 7) Width of left riverbank vegetation, 8) Width of right riverbank vegetation, 9) Large fluctuations in water level, 10) Human activities around the river and how big the impact, 11) Human activities within a radius of 2 km upstream of the observation location, 12) Human activities within a radius of 2-10 km in the upstream part (Trisnaini *et al*., 2018). River habitat conditions were classified as good (a), fair (b), or poor (c) based on Rini (2011). Kruskal-Wallis test at 5% level was used to analyze the relationship between land use and water quality parameters.

3. RESULTS AND DISCUSSION

3.1. Characteristics of tributaries in the upper Welang watershed

The Welang watershed is sourced from the Mount Arjuna and Mount Bromo areas, giving rise to two primary tributaries: the western tributary (1) and the eastern tributary (2) of the Welang River. For water sampling purposes, twelve locations were identified, with six points allocated to each tributary, enabling the assessment of water quality differences across various land uses within the upper Welang watershed. The measurement results for each parameter are presented in Table 2.

Table 2. Results obtained for each parameter analyzed

Location	**Water Temperature (°C)**	**TDS (mg/L)**	**pH**	**DO**	**BOD**	**COD**	**Pb**	**Cd**	NO_3	**Total *Coliform* (MPN.100/mL)**
				(mg/L)						
H1	27.80	146.50	7.31	8.56	5.12	22.68	0	< 0.0018	4.52	1350
H2	25.85	125	7.36	8.12	4.68	37.26	0	< 0.0018	16.98	1650
K1	23.68	91.50	7.54	8.12	4.60	24.74	0	< 0.0018	6.29	1600
K2	30.70	162.50	7.54	7.29	4.57	33.84	0	< 0.0018	7.09	3150
S1	28.13	158.50	7.96	7.88	5.23	28.31	0	< 0.0018	5.99	1700
S2	30.60	135	7.86	7.24	5.04	28.94	0	< 0.0018	3.72	2600
T1	26.88	194	7.60	7.19	4.24	24.14	0	< 0.0018	3.61	2300
T2	26.23	164.50	7.16	7.48	4.70	41.12	0	< 0.0018	16.83	2850
P1	28.50	159.50	7.59	7.19	5.58	29.71	0	< 0.0018	5.31	1900
P2	26.30	187.50	7.69	7.20	4.86	25.51	0	< 0.0018	3.22	3150
I1	28.13	190.50	7.83	7.08	4.84	45.44	0	< 0.0018	24.73	4100
I2	26.08	220	7.41	7.02	4.77	29.75	0	< 0.0018	11.25	2950

Note: H1 (Western forest), H2 (Eastern forest), K1 (Western plantation), K2 (Eastern plantation), S1 (Western rice field.), S2 (Eastern rice field.), T1 (Western Dry field), T2 (Eastern dry field), P1 (Western settlement), P2 (Eastern settlement), I1 (Western Industry) and I2 (Eastern Industry).

The western forest site shows annual plants, indicating community intervention, with concrete structures altering river boundaries. In contrast, the eastern forest retains its natural cover with rock boundaries. Vegetation influences dissolved oxygen (DO) through photosynthesis, and low DO levels are linked to garbage accumulation and sparse vegetation (Althaaf *et al*., 2025). DO levels inversely correlate with human activities, decreasing with intensified land use (dos Reis Oliveira *et al*., 2019). Vegetation has an influence on DO through its photosynthesis process which produces oxygen in the process. Low and high DO is inversely proportional to the human activities carried out on the land use. Fertilizers and pesticides from agriculture enter rivers via runoff, impacting ecosystems (Hu, 2018). Eastern forest land had high nitrate levels due to low temperatures, aligning with climate change studies (Patricia *et al*., 2018).

Western settlement tributaries have concrete borders with vegetation, while eastern ones lack plants. The western industrial zone houses a textile factory, while the eastern zone contains a fertilizer and isotonic drink factory, with boundaries altered by municipal interventions. Settlement and industrial tributaries have higher coliform bacteria due to human activities (Widiyanto *et al*., 2015). Eastern industrial inflows also show high COD, reducing oxygen and harming aquatic life (Mulyaningsih *et al*., 2013). Especially in industrial areas (I1), the addition of organic waste materials causes COD concentrations to increase because it is a chemically degradable waste that can be carried out by anaerobic microorganisms (Yuniarti & Biyatmoko, 2019). On the other hand, residential and industrial activities in both rivers do not cause heavy metals in the form of Pb and Cd, as evidenced by the very low test values.

3.2. Diversity of Water Quality Parameters

Water quality parameters include physical, chemical and biological aspects. DO, TDS, and BOD indicators showed significant differences with land use variation (based on Kruskal-Wallis test at 5% level). Meanwhile, other parameters including temperature, pH, COD (Chemical Oxygen Demand), NO_3^-, total Coliform, Pb, and Cd did not show significant variations between treatments. Figure 3 presents the results of the Kruskal-Wallis test at 5% level between water quality parameters and land use.

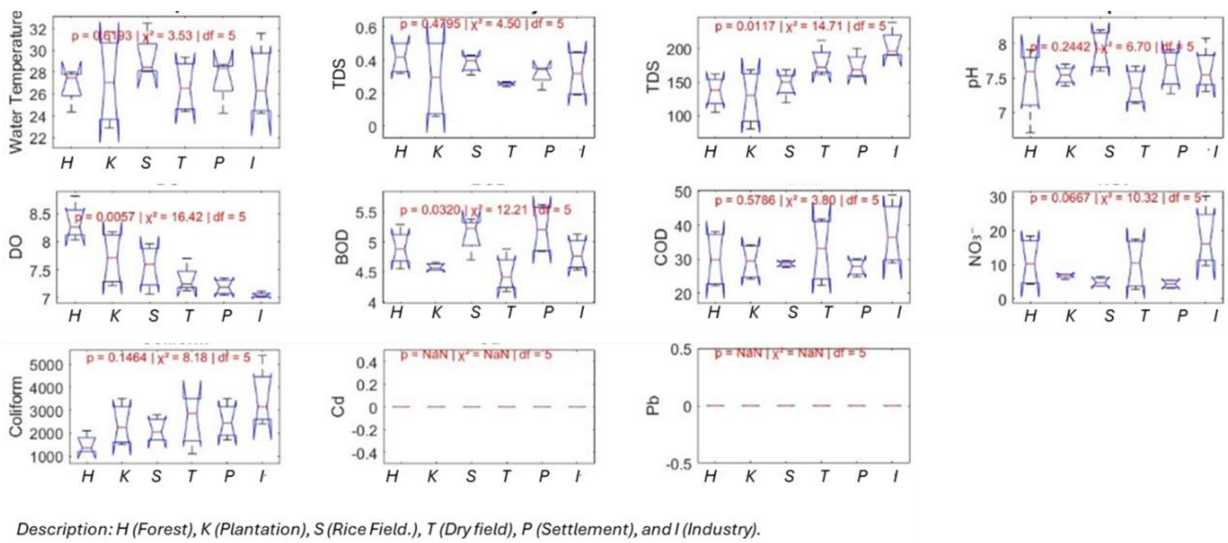

Figure 3. Relationship between water quality parameters and land use

The Kruskal–Wallis test, applied to eleven water quality parameters across six contrasting land use types, revealed that Dissolved Oxygen (DO) (χ^2 = 16.42, p = 0.0057), Total Dissolved Solids (TDS) (χ^2 = 14.71, p = 0.0117), and BOD (χ^2 = 12.21, p = 0.0320) varied significantly with land use, underscoring the measurable ecological footprint of anthropogenic activities. Forest-dominated catchments consistently maintained higher DO levels (median ~8.4 mg/L), reflecting superior ecological buffering, whereas residential and industrial zones exhibited elevated TDS and BOD, indicative of urban runoff and organic loading. Interestingly, nitrate (NO_3^-) approached significance (p = 0.0667), aligning with concerns over nutrient enrichment in agroecosystems. Other parameters such as pH, water clarity, and coliform counts showed no statistically significant differences, but their variability hinted at complex interactions among hydrology, land management, and pollutant sources. Heavy metals (Cd, Pb) remained uniformly undetectable, suggesting limited contamination or analytical constraints.

3.2.1. Physical Parameters

a. Temperature

Temperature measurements were taken directly in the field in the first and third weeks and ranged from 23.68°C–30.70 °C in the western and eastern parts of the river. However, the test results showed insignificant differences. Existing land use differences have no effect on temperature in the Upper Welang watershed. One key factor influencing temperature differences is elevation. The western tributary, located in a tea plantation, reaches ±950 meters above sea level, whereas the eastern tributary is at ±300 meters. Elevation affects temperature through factors like seasonality, geographical location, and land cover. This happens because the average location of water sampling in western tributaries has a high altitude compared to eastern tributaries. These findings align with (Pingki, 2021), emphasizing the impact of seasonal changes, geographical attributes, and atmospheric processes on water temperature and quality. Elements such as cloud cover, wind direction, and air-water interactions further contribute to temperature variability in aquatic ecosystems. This highlights the need for comprehensive monitoring and analysis to understand these complex dynamics.

b. Total Dissolved Solid (TDS)

The additional Total Dissolved Solids (TDS) tests, highlight distinct trends across land use categories in western and eastern tributaries. In the western tributaries, the lowest TDS levels are observed under plantation land use, significantly differing (χ^2 = 14.71, p = 0.0117) from forests, rice fields, dry fields, settlements, and industrial areas. This suggests that plantations help mitigate TDS levels more effectively than other land uses. In contrast, in the eastern tributaries, forest land use records the lowest TDS levels, differing significantly from plantations, dry fields, settlements, and industrial areas. This can occur because the geographical location of the tea garden is higher than the forest, and has lower activity. However, TDS levels in forest and rice field land uses do not significantly differ, indicating that rice fields in the eastern tributaries may maintain TDS levels similar to forests. The condition of the channel in this rice field has been made permanent and is supported by adequate water resource management so as to minimize pollution entering the river. These results emphasize the role of land use practices in shaping TDS levels, reinforcing the need for effective land management to preserve water quality in aquatic ecosystems.

The elevated Total Dissolved Solids (TDS) values may indeed be attributed to intensified human activities, as highlighted by (Mahyudin *et al*., 2015). Anthropogenic inputs such as agricultural runoff, industrial discharges, and domestic wastewater can contribute to increased TDS levels in water bodies, reflecting the cumulative impacts of human development on aquatic ecosystems. Furthermore, variations in river depth between the eastern and western tributaries can also influence TDS levels. Deeper river channels in the eastern tributaries may facilitate greater TDS accumulation, as deeper water bodies have a larger volume and can dissolve and suspend more solids (Fahimah *et al*., 2021). In contrast, shallower river depths in the western tributaries may result in lower TDS concentrations due to reduced water volume and slower sedimentation rates. These insights underscore the multifaceted nature of TDS dynamics in river ecosystems, influenced by a combination of human activities, hydrological factors, and land use patterns. The high value of TDS can cause a decrease in sunlight absorbed into the water will be low due to the presence of excess solids. The low light entering the water can interfere with the photosynthesis of plants in the water. High TDS can cause pollution of water bodies if not managed, this is because it can interfere with aquatic life, and can interfere with human health if it contains high chemicals (Kustiyaningsih & Irawanto, 2020).

3.2.2. Chemical Parameters

a. pH value

The average pH in the western tributaries is 7.31–7.96, while the eastern tributaries have an average pH of 7.16–7.69. Factors that can affect water pH include the presence of vegetation around the quality of the water, such that the western tributary area has more vegetation than the eastern tributary area at the sampling location. Vegetation can affect pH because the trees produce it through respiration, and it can act as a buffer because it forms buffer ions, so it can keep pH stable (Rani & Afdal, 2020). However, the results of the measurements taken show that the pH value can still be considered normal. This is consistent with the statement Cardwell *et al*. (2018), that the normal pH of water is generally 6–8. Furthermore Lantang & Pakidi (2015), that pH can be influenced by biological activities such as temperature, photosynthesis, respiration of the organism, and the ions in these waters.

b. Dissolved oxygen (DO)

DO measurements conducted in the western and eastern tributary land uses can show that the west forest has the highest average DO in all measurements located in forest land uses at 8.56 $mg.l^{-1}$. Meanwhile, the lowest DO content is in the western industry, with a value of 7.02 $mg.l^{-1}$, which has industry land use. Land use shows a significant influence on DO values ((χ^2 = 16.42, p = 0.0057).The observed highest oxygen levels in forested areas within the western tributaries can be attributed to the relatively lower human activity levels, thereby minimizing the introduction of pollutants into the water. Adis & AR (2021) emphasize that oxygen levels may decrease due to inputs of pollutants, particularly from nearby industrial sources. Dissolved Oxygen (DO) is a critical component for the metabolic processes of aquatic organisms, as highlighted by Yuniarti & Biyatmoko (2019). Fluctuations in DO levels over time are influenced by various factors, including the uptake and utilization by organisms and microbial decay processes. Furthermore, environmental factors such as wind, temperature, pressure, and the concentration of dissolved ions can impact the diffusion of oxygen into water bodies, thus influencing DO levels, as noted by Puspitasari *et al*. (2017). These factors collectively contribute to the dynamic nature of oxygen levels in water quality, influencing both high and low DO concentrations. Overall, understanding the complex interplay of environmental variables and human activities is crucial for interpreting and managing dissolved oxygen levels in aquatic ecosystems effectively.

c. Biologically Dissolved Oxygen (BOD)

The results of further BOD tests are shown in Figure 3, with the average BOD in all western tributaries having the highest BOD at 5.58 mg.l^{-1} in tributaries with settlement land use and the eastern tributaries having the highest average BOD of 5.04 mg.l^{-1} corroborated by the results of the Kruskal-Wallis test with a significant effect (χ^2 = 12.21, p = 0.0320). The elevated Biochemical Oxygen Demand (BOD) in western tributary settlements is linked to higher household waste discharge compared to the eastern tributary. Gupta *et al*. (2017) emphasize that household and industrial waste significantly increase BOD levels, deteriorating water quality. In contrast, the highest BOD levels in eastern tributaries occur under rice field land use, suggesting a different cause. This indicates that fertilizer and pesticide use in western rice fields may be lower, resulting in reduced BOD concentrations. Christiana *et al*. (2020) note that BOD pollutants stem from household waste and agricultural activities. The BOD discrepancy between the western and eastern tributaries highlights the varied impacts of human activities on water quality. Effective management strategies are needed to reduce pollutant inputs from household and agricultural sources, ensuring better water quality in both tributaries.

d. Chemically dissolved oxygen (COD)

The test results showed no interaction between land use and COD values. Bahagia *et al*. (2020) highlight that COD presence is influenced by various factors, including water volume, substrate characteristics, oxygen demand, sludge volume, as well as anthropogenic activities such as household, agricultural, and industrial practices. The elevated COD concentration serves as an indicator of increased pollution in water quality, as noted by Atima (2015). This pollution stems from the abundance of organic materials discharged into the water from industrial activities. Organic pollutants, such as those from industrial effluents, contribute to higher COD levels due to their high oxygen demand during decomposition processes. Overall, the higher COD levels in tributaries under western industrial land use underscore the significant impact of industrial activities on water quality deterioration. Implementing effective pollution control measures and regulatory interventions are essential for mitigating COD levels and safeguarding aquatic ecosystems from the adverse effects of industrial pollution.

e. Nitrate (NO_3)

NO_3 content of the water was not high in all areas, and it was proven that land use had no significant effect on NO_3 content. Factors such as human activities, agricultural fertilizer residues, animal feces, vehicle emissions, and industry and household waste can cause high levels of nitrates. Bahri (2016), nitrate concentrations can be influenced by the high activity of microorganisms in the water during oxidation. Microorganisms oxidize ammonium to nitrite, which is then converted into nitrate by bacteria (Patricia *et al*., 2018). High concentrations of nitrates in water can negatively impact aquatic ecosystems and human health. The adverse effects of high levels of nitrates in water quality lead to eutrophication, which can increase the growth of algae and aquatic plants, and drinking water with high levels of nitrates can lead to a reduction in blood capacity (Yogafanny, 2015).

f. Cadmium (Cd)

The detection of Cd (cadmium) levels below 0.0018 mg/l across all land uses, as indicated in Table 2, suggests a uniform absence or very low concentration of Cd in the water samples. However, even trace amounts of Cd can pose risks to aquatic ecosystems and human health due to its toxicity. The presence of Cd in water bodies across various land uses may be attributed to several anthropogenic activities. For instance, agricultural practices such as fertilization and pesticide usage in plantation management can introduce Cd into the environment. Additionally, household activities, as well as industrial operations, may contribute to Cd contamination through wastewater discharge or runoff. While the measured Cd levels may currently be below regulatory thresholds, continued vigilance and proactive measures are necessary to prevent Cd accumulation and mitigate potential environmental and health risks. Implementing best management practices, promoting sustainable agricultural methods, and enforcing stringent pollution control measures can help minimize Cd pollution and safeguard water quality in affected areas.

g. Lead (Pb)

The absence of Pb (lead) measurements in Table 2 over the three-week period suggests that Pb contamination was not detected during the monitoring period. However, it's important to recognize that heavy metal pollution, including Pb contamination, poses significant risks to aquatic ecosystems. Various human activities, including commercial operations, agriculture, urban settlements, transportation, and industrial processes, can contribute to Pb pollution in water bodies, as noted by Mahasri *et al*. (2014). These activities may involve the discharge of Pb-containing effluents, runoff from contaminated surfaces, or improper waste disposal practices, ultimately leading to Pb accumulation in aquatic environments.

3.2.3. Parameter Biological: Total Coliform Bacteria

The total coliform bacteria was determined because the land used in the upper Welang watershed includes settlements. The total number of coliform bacteria present in any given land use is directly correlated with the level of human activity. Forested areas typically exhibit lower community engagement compared to other land uses. As elucidated by Widiyanto *et al*. (2015), the presence and abundance of coliform bacteria in water bodies serve as indicators of human activities. Elevated levels of coliform bacteria signify an imbalance in environmental hygiene practices, resulting in compromised water quality. Notably, the highest concentration of coliform bacteria is recorded in areas designated for industrial activities. Windusari & Sari (2015) elaborate on the sources of bacterial contamination, which encompass groundwater, settlement activities, industrial discharges, and atmospheric deposition. Furthermore, the presence of human or animal waste exacerbates coliform contamination in industrial settings. Coliform bacteria are often associated with fecal contamination, signaling environmental pollution in water bodies, as highlighted by Arsyina *et al*. (2019). Environmental factors, including sunlight exposure, oxygen levels, temperature, pH, and the presence of disinfectants, also influence total coliform counts, as elucidated by Sidabutar *et al*. (2013), these ecological parameters collectively shape the abundance and distribution of coliform bacteria, underscoring the intricate interplay between human activities and environmental factors in determining water quality.

3.3. Water quality and physical habitat

Water quality and physical habitat using streambed substrate properties indicators and river health disruptors. The results of the assessments are shown in Table 3 and Figure 3. Utilizing the STORET method in compliance with Government Regulation of the Republic of Indonesia Number 22 of 2021, the water quality assessment of the upper Welang Watershed revealed conformity with Class III quality standards, encompassing Categories A, C, and D.

The observed water conditions signify moderate to heavy pollution levels. These findings hold significance for various applications, including freshwater fish farming and crop irrigation, necessitating water of similar quality standards. However, areas categorized as moderately and heavily polluted fail to meet the standards for COD and NO_3. Moreover, assessment outcomes indicate unsuitability for potable water and recreational purposes due to inadequate

Table 3. Water quality status and physical river habitat

Location	Water Quality		Physical habitat			
			Substrate		Disturbance	
	score	Class	score	Class	score	Class
H1	0	A (good condition)	b	Enough	a	Good
H2	0	A (good condition)	a	Good	a	Good
K1	0	A (good condition)	a	Good	b	Enough
K2	0	A (good condition)	b	Enough	b	Enough
S1	0	A (good condition)	b	Enough	b	Enough
S2	0	A (good condition)	b	Enough	b	Enough
T1	0	A (good condition)	b	Enough	b	Enough
T2	-20	C (moderately polluted)	b	Enough	c	Bad
P1	0	A (good condition)	b	Enough	b	Enough
P2	0	A (good condition)	b	Enough	b	Enough
I1	-40	D (heavily polluted)	b	Enough	c	Bad
I2	0	A (good condition)	b	Enough	b	Enough

Note: H1 (Western forest), H2 (Eastern forest), K1 (Western plantation), K2 (Eastern plantation), S1 (Western rice field.), S2 (Eastern rice field.), T1 (Western Dry field), T2 (Eastern dry field), P1 (Western settlement), P2 (Eastern settlement), I1 (Western Industry) and I2 (Eastern Industry).

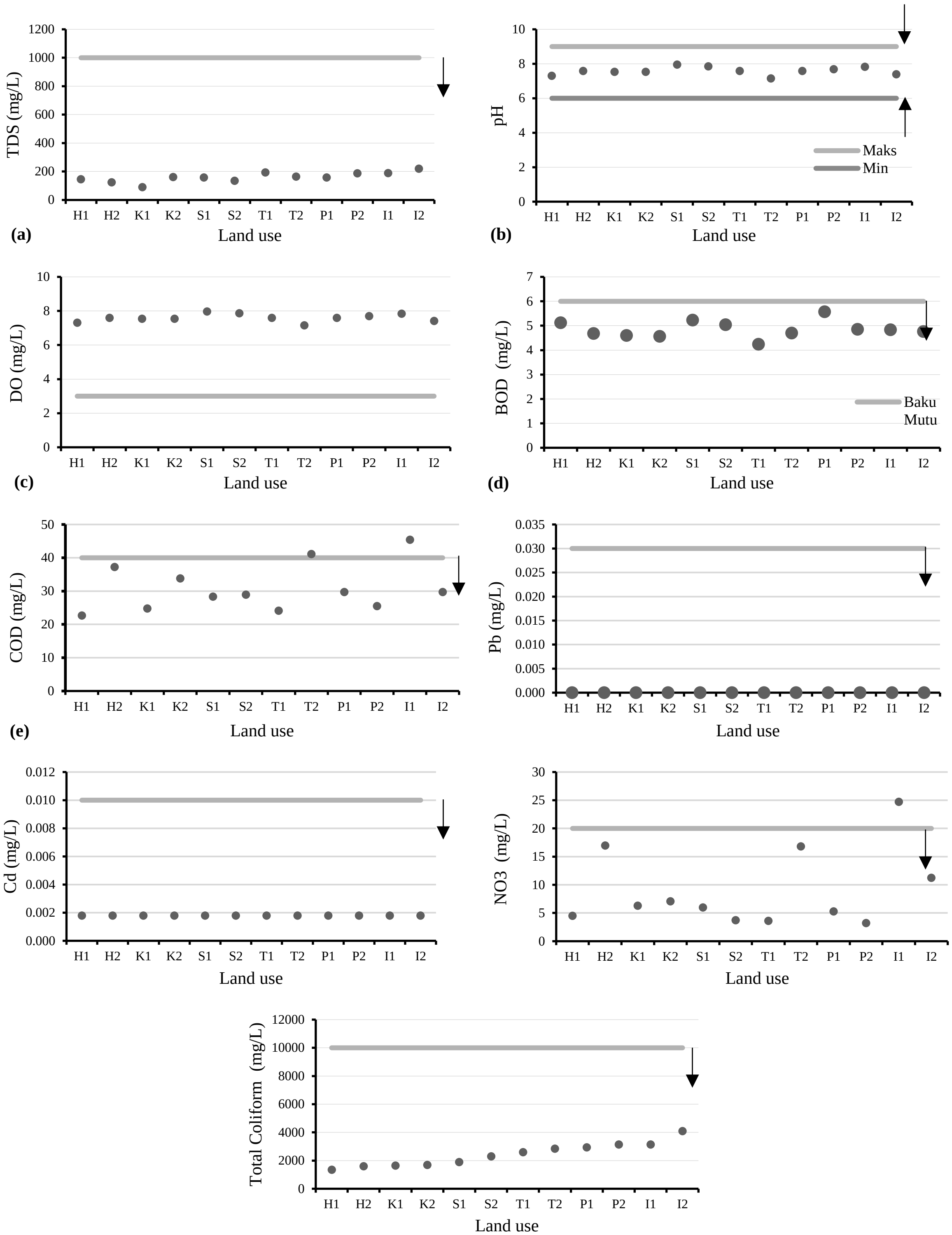

Figure 3. Comparison of Results of Each Parameter with Quality Standard. [Description: Parameter results: a. TDS; b. pH; c. DO; d. BOD; e. COD; f. Pb; g. Cd; h. NO_3; i. Total *Colifor*m; H1 (Western forest), H2 (Eastern forest), K1 (Western plantation), K2 (Eastern plantation), S1 (Western rice field.), S2 (Eastern rice field.), T1 (Western Dry field), T2 (Eastern dry field), P1 (Western settlement), P2 (Eastern settlement), I1 (Western Industry) and I2 (Eastern Industry)]

total coliform bacteria levels, which pose potential health risks. It is imperative for drinking water to be devoid of hazardous bacteria and chemicals to prevent health complications, as highlighted by Pulungan & Away (2019), Coliform bacteria, including *Escherichia coli* (E. *coli*), originate from diverse sources such as industrial raw materials, unsanitary environments, and human and animal waste. Notably, high levels of organic pollution are often characterized by elevated BOD values (Rompas *et al*., 2018).

This classification signifies moderate to heavy pollution levels, underscoring the importance of diligent monitoring and management strategies. While suitable for applications like freshwater fish farming and crop irrigation, areas categorized as moderately and heavily polluted failed to meet standards for parameters such as Chemical Oxygen Demand (COD) and nitrate (NO_3). Consequently, these areas are deemed unsuitable for potable water and recreational purposes due to inadequate levels of total coliform bacteria, which pose potential health risks. As emphasized by Pulungan & Away (2019), the absence of hazardous bacteria and chemicals is imperative in drinking water to safeguard public health. Coliform bacteria, including *Escherichia coli* (E. *coli*), originate from diverse sources, including industrial raw materials, unsanitary environments, and human and animal waste. Elevated Biological Oxygen Demand (BOD) values, as highlighted by Rompas *et al*. (2018), often indicate high levels of organic pollution, further emphasizing the need for comprehensive water quality management strategies.

The existing habitat disturbance factors remain relatively sufficient, albeit susceptible to alterations prompted by both environmental and human influences. Environmental dynamics, including natural calamities such as earthquakes, landslides, and floods, play a significant role in shaping these conditions. Concurrently, human activities, encompassing settlement expansion, agricultural practices, industrial operations, and mining activities, exert notable impacts on habitat integrity. As noted by Trisnaini *et al*. (2018), heightened population density along riverbanks intensifies anthropogenic pressures on water bodies, with household activities like bathing and washing, agricultural endeavors, sand mining, and industrial ventures contributing to water quality alterations. Furthermore, the composition and stability of substrate properties and habitat disturbance are influenced by various factors, including the indiscriminate disposal of both organic and inorganic waste materials directly into rivers. This practice is particularly prevalent in areas designated for dry fieldland use within settlement and industrial zones.

4. CONCLUSION

Water quality in the Upper Welang watershed is strongly influenced by land use through TDS, DO and BOD parameters. Industrial and residential areas show high levels of COD and NO_3 that exceed national standards, causing them to be classified in Class III. Forest and plantation areas have better water quality. These findings support the need for improved land management and pollution control policies, especially in high impact areas.

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