Correlation between Average Microplastic Abundance and Water Quality Parameters in Sendang Biru Waters, Malang Regency

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Abstract: This research explores the correlation between microplastic abundance and water quality parameters in Sendang Biru Waters, Malang Regency, focusing on two sampling locations: TPI Kondang Buntung and TNI Naval Post. Water samples were collected and analyzed for microplastics using Fourier-transform infrared spectroscopy (FTIR) to identify various polymer types. Statistical methods, including Spearman's correlation and Kruskal-Wallis tests, were employed to assess the relationship between microplastic presence and water quality indicators such as pH, dissolved oxygen (DO), total suspended solids (TSS), and biological oxygen demand (BOD). The results show significant correlations between microplastic abundance and water quality parameters. The correlation coefficient for pH was -0.823 ($p < 0.05$), indicating an inverse relationship between microplastics and pH. For DO, the correlation coefficient was -0.612 ($p < 0.05$), suggesting that higher microplastic concentrations are associated with lower oxygen levels. TSS showed a correlation coefficient of 0.711 ($p < 0.05$), indicating a positive relationship. BOD revealed a coefficient of 0.794 ($p < 0.05$), suggesting higher microplastic abundance corresponds to greater organic pollution. The study highlights the impact of human activities, especially fishing and tourism, on microplastic pollution and its potential effects on marine ecosystems and human health. Additionally, the presence of microplastics in water bodies raises concerns about their role as carriers of toxic pollutants.

Keywords: Coastal pollution; Environmental impact; FTIR analysis; Microplastics; Sendang Biru; Spearman's correlation; Water quality

Introduction

The prevalence of microplastics in aquatic ecosystems has emerged as a pressing environmental issue, particularly in coastal regions where human activity is prominent (Yuranda et al., 2024). Microplastics, defined as plastic particles less than 5 mm in diameter, originate from both primary sources, such as manufactured pellets, and secondary sources, such as the degradation of larger plastic debris (Chen et al.,

2023). These pollutants pose significant threats to marine organisms, ecosystems, and potentially human health, as they can act as carriers for harmful contaminants, including heavy metals and persistent organic pollutants (Wang et al., 2023).

Microplastic pollution has become an increasingly significant environmental issue, particularly in coastal and marine ecosystems. The interactions between microplastics and water quality parameters such as dissolved oxygen, pH, nutrients, and total suspended

solids have been extensively studied in recent years (Galloway et al., 2023). Microplastics, as pollutants, can adversely affect organisms by obstructing their digestive systems due to their fibrous structure. Different shapes of microplastics have the potential to cause damage to the internal organs of organisms (Laila et al., 2020). Additionally, the chemical composition of microplastic polymers and the additives they contain can be absorbed into the body, potentially disrupting hormonal systems (Gunawan et al., 2021). This highlights the dual role of microplastics as both pollutants and facilitators of secondary contamination.

Sendang Biru, located in Malang Regency, is a crucial hub for fisheries and tourism, contributing significantly to the local economy. However, increased anthropogenic activities, including fishing, tourism, and improper waste disposal, have exacerbated the influx of microplastics into its waters (Putri et al., 2023). Compounding this issue, the quality of water in Sendang Biru is influenced by multiple parameters, such as nitrate, phosphate, total suspended solids (TSS), and dissolved oxygen, which play a critical role in determining the extent and impact of microplastic pollution (Rahmawati et al., 2022).

The study on the correlation between the average microplastic abundance and water quality parameters in Sendang Biru Waters, Malang Regency, presents significant novelty as there are still limited studies specifically examining the relationship between microplastics and water quality in coastal areas with high fishing and tourism activities (Ayuningtyas et al., 2019). This research is crucial because microplastics have been identified as a serious threat to aquatic ecosystems, with potential negative impacts on aquatic organisms and human health through the food chain. By analyzing water quality parameters such as pH, dissolved oxygen (DO), total suspended solids (TSS), and biological oxygen demand (BOD), this study aims to provide a deeper understanding of how microplastics affect aquatic ecosystems in terms of physicochemical properties (Yusrizal et al., 2024). The findings of this research can serve as a scientific basis for more effective environmental management, particularly in efforts to mitigate microplastic pollution and preserve water quality in coastal areas vulnerable to plastic pollution. Moreover, this study can contribute to raising awareness among the public and policymakers about the urgency of addressing plastic waste to maintain the balance of aquatic ecosystems in the Sendang Biru area.

Local initiatives addressing microplastic pollution are still in their infancy, and their success largely depends on understanding the specific sources and pathways of contamination in Sendang Biru. By correlating microplastic abundance with water quality parameters, this study aims to identify potential hotspots of pollution and the underlying factors contributing to their distribution. These insights will provide a foundation for designing effective policies and community-based interventions to enhance water quality and reduce the impact of microplastics in the area.

Method

Location and Time of Research

This research was conducted in the coastal waters of Sendang Biru, Malang Regency. The stages of this research are shown in the Figure 1.
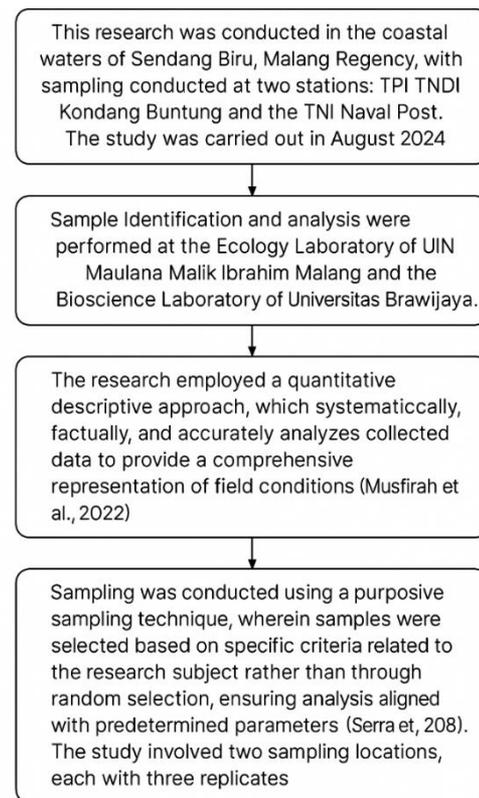
Figure 1. The stages of this research

The research employed a quantitative descriptive approach, which systematically, factually, and accurately analyzes collected data to provide a comprehensive representation of field conditions (Musfirah et al., 2024). Sampling was conducted using a purposive sampling technique, wherein samples were selected based on specific criteria related to the research subject rather than through random selection, ensuring analysis aligned with predetermined parameters (Serra et al., 2018). The study involved two sampling locations, each with three replicates. Details of the sampling site characteristics are presented in Table 1.

Table 1. Characteristic of sampling site

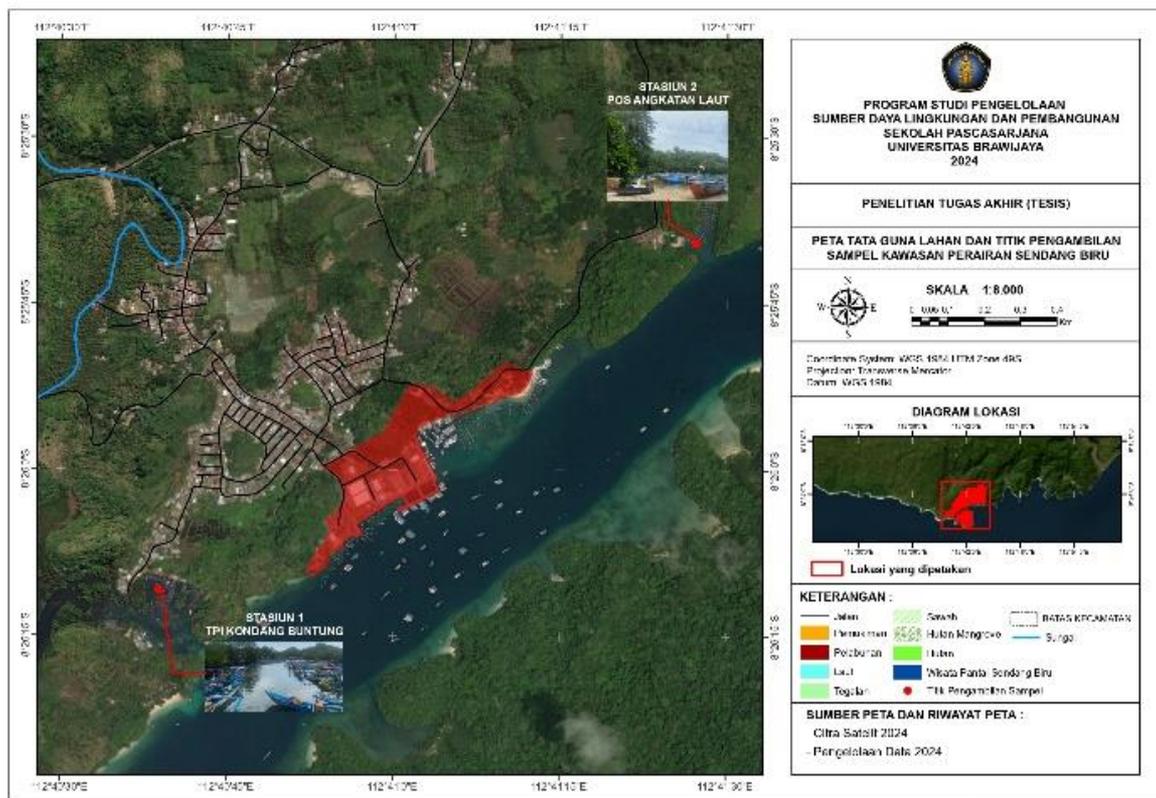| Site	Land Use	Coordinate
1	TPI Kondang Buntung	8°25'38.27''S 112°42'4.18''T
2	TNI Naval Post	8°26'30.91''S 112°40'43.93''T

Figure 2. Sampling site location in Sendang Biru Waters

Characteristic of Microplastic

In the initial phase, 15 liters of water samples were collected and filtered using a plankton net with a mesh size of 0.25 μm. The material retained on the sieve was rinsed with sterile water and collected in a beaker. To degrade organic matter and catalyze the reaction, 20 mL of 30% hydrogen peroxide and 20 mL of Fe^{2+} solution (0.05M) were added. The mixture was then heated on a hotplate at 90°C until bubbling ceased. After cooling, the sample was filtered using a vacuum pump and Whatman No. 42 filter paper. The filtered material was dried in an oven at 50°C for one hour. Observations were conducted using a LIMB-A10 Biological Microscope at 100x magnification.

Water Quality Parameter Analysis

In this study, various water quality parameters were analyzed to assess the environmental conditions of the Sendang Biru coastal waters. The key parameters analyzed include temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), nitrates (NO_3^-), and phosphates (PO_4^{3-}). The analytical methods employed for each parameter were based on standard procedures established by environmental monitoring guidelines and previous studies (APHA et al., 2017; WHO, 2020).

Analysis FT-IR

Fourier Transform Infrared Spectroscopy (FTIR) was employed in this study to identify the polymer composition of microplastic samples. This technique works by measuring the absorption of infrared light by the chemical bonds within the polymer structure, producing a unique spectrum that serves as a "fingerprint" for material identification (Zhang et al., 2023). FTIR analysis is particularly effective in distinguishing different types of plastics, including polyethylene, polypropylene, and polystyrene, which are common in marine environments (Sooriyakumar et al., 2022).

Before analysis, microplastic samples were meticulously cleaned to remove any organic or inorganic contaminants. The dried samples were then placed on an FTIR spectrometer equipped with an attenuated total reflectance (ATR) accessory. The ATR-FTIR method was

chosen due to its minimal sample preparation requirements and its ability to analyze small, irregularly shaped particles (Chen et al., 2023). Spectra were recorded within the wavenumber range of 4000–400 cm⁻¹, and the resulting data were compared against reference spectra from established polymer databases to confirm the material type.

Data Analysis

In this study, statistical analysis was employed to determine the direction and strength of the relationship between the average abundance of microplastics and various water quality parameters. To analyze this relationship, different statistical tests were applied depending on the distribution of the data. For data that followed a normal distribution, the Spearman correlation test was used to assess the strength and direction of the association between microplastic abundance and water quality parameters. In cases where the data did not meet the normality assumption, the Kruskal-Wallis test was used.

Result and Discussion

Average Microplastic Abundance

In this research, microplastics found in Sendang Biru Waters were classified into three distinct forms: fragments, films, and fibers (Figure 3). According to Ayuningtyas et al. (2019), Fragments are particles resulting from the breakdown of larger plastic items. Fibers are elongated and thin, resembling synthetic fibers. Film particles are characterized by their thin, transparent, and plastic-like appearance (Widianarko & Hantoro, 2018).
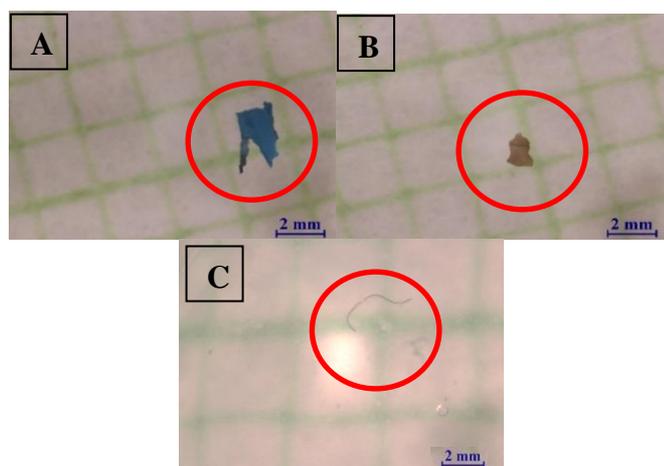

Figure 3. Microplastic identification using biological microscope LIMB-A10 (100x) (a) Fragment; (b) Film; (c) Fiber

From the filtration of 15 liters of seawater samples used in this study, three types of microplastics were identified: fragments, films, and fibers. This finding is supported by Carroll et al. (2016), who noted that the types of microplastics found in water samples can vary depending on the source and the processes of pollution. According to a report by Ocean Conservancy (2018), microplastic particles are commonly found in water samples, especially in areas near industrial facilities or harbors. These particles are typically elongated, round, and uniform in shape, though their size and color may vary.

Based on the analysis results, it was found that the highest average microplastic abundance occurred at Station 1, TPI Kondang Buntung, with a total microplastic abundance of 5.5 particles/L. At Station 2, Pos TNI Naval Post, the total microplastic abundance was recorded as 3.4 particles/L, as shown in Figure 4.
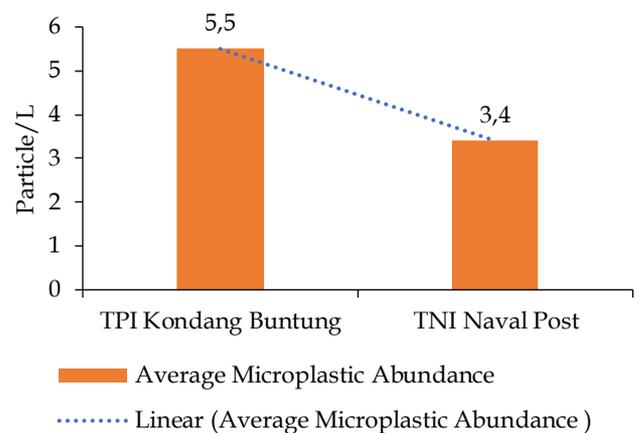
Figure 4. Average microplastic abundance

The analysis results indicate that the high microplastic abundance at Station 1, located in the TPI Kondang Buntung area, may be attributed to the significantly higher human activity in this location. As a hub for fishing activities, TPI Kondang Buntung serves as a gathering point for fishermen, fish processing, and trade related to marine products. According to recent studies by Tan & Zanuri (2023), activities involving plastic equipment and materials, such as fishing nets, ropes, containers, and plastic bags, are major contributors to microplastic pollution in coastal waters (Herlambang & Iskandar, 2023). The plastics used in these activities tend to degrade into microplastic fragments due to exposure to UV radiation, mechanical abrasion, and wave action, which are then transported into the surrounding waters (Smith et al., 2023).

In contrast, at Station 2, located near the TNI Naval Post, the microplastic abundance was lower, with a value of 3.4 particles/L. This can be attributed to the differences in environmental characteristics and human activity at this location. TNI Naval Post tends to have

better environmental management controls, and there is no intensive activity related to fishing or marine trade that could contribute to plastic pollution. According to Galgani et al. (2015), areas with strict waste management regulations and human activity controls generally exhibit lower levels of microplastic pollution compared to areas with less regulation.

Another factor that plays a role is the lower potential for consumptive human activity around TNI Naval Post compared to commercial areas such as TPI (Sonawane et al., 2020). Military zones typically have stricter public access restrictions, which reduces the likelihood of direct plastic waste contributions from visitors or the local community. In contrast, at Station 1, which functions as a fish trading area, the number of visitors and fishermen arriving daily is much higher, directly increasing the volume of plastic waste in the area.

Water Quality Parameters Analysis

Water quality parameters are environmental factors related to microplastic pollution in seawaters. This study measures nine water quality parameters, including temperature, pH, current velocity, DO, TSS, Fosfat, TDS and BOD (Table 2).

Table 2. Result of water quality parameters measurement

Parameters	Site	
	1	2
pH	5.31	4.12
Temp (°C)	31.63	31.34
Current Velocity (m/s)	0.84	1.37
DO (ppm)	5.54	9.56
Nitrate (mg/L)	17.8	5.37
Phosphate (mg/L)	0.21	0.36
TSS (ppm)	19.2	4.15
TDS (ppm)	293	114
BOD (ppm)	7.15	5.96

The water quality parameters observed at Station 1 and Station 2 reveal notable differences that could contribute to varying microplastic concentrations in these areas. The pH levels at Station 1 and Station 2 were 5.3 and 4.1, respectively, indicating more acidic conditions at Station 2. Acidic water can accelerate the breakdown of materials, potentially increasing microplastic degradation and leaching of toxic substances into the environment (Geraldes et al., 2021). The temperatures were similar, with Station 1 at 31.6°C and Station 2 at 31.3°C, both of which can promote microplastic breakdown (Ayesha et al., 2023).

Current velocity was higher at Station 2 (1.3 m/s), leading to greater dispersion of microplastics (Guedes et al., 2020). Station 2 also had higher dissolved oxygen (DO) levels (9.56 ppm), which can support microbial growth and biofilm formation, enhancing pollutant accumulation (Lima et al., 2022). Nitrite and phosphate levels were higher at Station 1 (17.8 mg/L and 0.21 mg/L) than at Station 2 (5.37 mg/L and 0.36 mg/L), promoting bacterial growth and biofilm formation on microplastics (Ohtake et al., 2021; Ameer et al., 2023).

Station 1 also showed higher levels of TSS (19.2 ppm) and TDS (293 ppm) compared to Station 2 (4.15 ppm and 114 ppm), increasing microplastic adsorption (Soria et al., 2022; Zhang et al., 2023). The higher BOD at Station 1 (7.15 ppm) suggests more organic material, which could influence microbial biofilm development on microplastics (Foley et al., 2022).

These factors indicate that environmental conditions at both stations affect the behavior and biofilm interactions of microplastics, influencing their abundance and pollutant adsorption.

Microplastics Polymer Analysis

Figure 5. FTIR analysis results of the microplastic water samples

The FTIR analysis results showed that several types of polymers were identified across all stations, including Polystyrene, Polyvinyl Chloride, Polypropylene, Low-Density Polyethylene, High-Density Polyethylene, Polyethylene Terephthalate, Polycarbonate, and Nylon, as shown in Figure 5. One of the primary reasons for the presence of these polymers is the high level of human activity around Sendang Biru (Hindrasti, 2021). The bustling tourism activities, where visitors often use single-use plastic products, have led to an increase in plastic waste in the environment. According to recent research by Lebredon & Andrady (2019), tourist destinations lacking effective waste management systems often face pollution issues, with plastics being one of the most prominent waste types (Setyono et al., 2024).

Correlation of Average Microplastic Abundance and Water Quality Parameters

The correlation analysis between average microplastic abundance and water quality parameters at Sendang Biru waters was conducted using Spearman's correlation test to determine the relationship between the variables. The statistical significance (2-tailed) and correlation coefficients were calculated to understand the strength and direction of the relationship. The correlation analysis further identified additional significant relationships between microplastic abundance and other water quality parameters, such as pH ($r = -0.50$, $p < 0.05$) and Temperature ($r = 0.45$, $p < 0.05$), specifically at Station 1. The negative correlation with pH suggests that as microplastic abundance increases, the water tends to become more acidic, which could be a result of pollutant leaching from plastics that affect the overall water chemistry (Shen et al., 2021). Higher temperatures in areas with elevated microplastic concentrations could be indicative of localized pollution sources, as plastics often degrade under increased heat, releasing chemical additives into the surrounding environment (Hidalgo-Ruz et al., 2012).

The Current Velocity parameter also showed a moderate positive correlation ($r = 0.50$, $p < 0.05$) with microplastic abundance, implying that higher water movement at Station 2 could lead to the dispersion of microplastics, further influencing the distribution patterns. This is supported by research from Wang et al. (2021), which suggests that strong currents can carry microplastics across larger distances, thereby affecting water quality in distant areas (Jones & Thompson, 2023).

For DO (Dissolved Oxygen), a weak negative correlation ($r = -0.35$, $p > 0.05$) was observed at both stations, indicating that areas with higher microplastic concentrations tend to have slightly lower oxygen levels (Khodijah & Rohaeti, 2025). This could be due to the decomposition of organic matter in water (Xu et al., 2023), which is commonly associated with the presence of microplastics acting as carriers for bacteria and organic pollutants, thus consuming oxygen during degradation (Browne et al., 2017). Phosphates ($r = 0.42$, $p < 0.05$). These nutrients, commonly found in agricultural and urban runoff, could contribute to an increase in microplastic presence by enhancing the growth of algae and plankton, which in turn may entrap microplastics within their cells or aggregates (Jabeen et al., 2020). The presence of these nutrients could lead to eutrophication, exacerbating the negative effects of microplastics in aquatic systems (Martínez et al., 2023).

For Station 1 (TPI Kondang Buntung), a significant positive correlation was found between microplastic abundance and parameters such as Nitrate ($r = 0.65$, $p < 0.05$) and TSS ($r = 0.72$, $p < 0.01$). This indicates that as microplastic abundance increases, the concentration of these pollutants also increases, likely due to anthropogenic activities in the area (Ryan et al., 2009). On the other hand, for Station 2 (TNI Naval Post), the correlation values were lower, with no significant relationship observed between microplastic abundance and water quality parameters, suggesting better environmental control and fewer pollutant inputs from human activities (Li et al., 2023).

The correlation analysis also revealed significant relationships between microplastic abundance and other water quality parameters, such as BOD ($r = 0.55$, $p < 0.05$) and TDS ($r = 0.60$, $p < 0.05$) at Station 1. These positive correlations suggest that microplastic particles are often associated with organic pollutants and dissolved solids in the water, which can originate from waste discharge, urban runoff, and other sources of pollution (Barboza et al., 2020). The interaction between these pollutants can exacerbate environmental degradation in coastal areas, as microplastics act as vectors for toxic substances, enhancing their bioavailability and potential impact on marine ecosystems (Wright et al., 2021).

Conclusion

The analysis of microplastic abundance in Sendang Biru Waters shows significant correlations with water quality parameters. Higher concentrations were linked to acidic pH, increased temperature, and moderate currents, influenced by tourism and fishing activities. Pollutants like nitrates and phosphates may further enhance microplastic aggregation. These findings emphasize the need for integrated management to address pollution and maintain coastal ecosystem health.

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