Indonesian Journal of Limnology
Vol. 05 No. 01, 2024 (11–23)
E-ISSN :2774-2571

Analysis of Microplastic Contamination in Teluk Kombal Estuary: Impact and Sources as the Reference for Further and Mitigation Strategies

Maya Aprilia[a], Moh. Awaludin Adam[b]*, Nurul Izzati[a], Nadda Khalila Chairunnisa[c], Husna Shofi Talbia[a], Tuti Mutia[d], Heni Masruroh[d]

[a] Department of Biotechnology, Faculty of Life Sciences and Technology, Universitas Teknologi Sumbawa, Sumbawa, 84371, Indonesia
[b] Research Center for Marine and Land Bioindustry, National Research and Innovation Agency, Lombok, West Nusa Tenggara, 83352, Indonesia
[c] Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Mataram, Mataram, 83115, Indonesia
[d] Department Geography, State University of Malang, Malang, 65145, Indonesia

* Corresponding author: moha04@brin.go.id

Received 7 May 2024 Accepted 5 June 2024 Published 29 August 2024

DOI: 10.51264/inajl.v5i1.65

Abstract

Microplastics (MPs) refer to plastic waste particles that measure less than 5 millimeters in size. Their presence is widespread in the environment, particularly in aquatic ecosystems, posing significant risks to coastal organisms and human health. This study aims to assess microplastic contamination in the Kombal bay estuary by conducting identification, abundance analysis, and characterization of microplastics. The method used was to characterize the area, sample extraction, observation and calculation of microplastic abundance, FTIR analysis, water quality testing, and data analysis. Originating from the Teluk Kombal river, this estuary is subjected to various human activities such as fishing, agriculture, and household waste disposal. Sampling was conducted at three representative locations: the estuary, agricultural areas, and residential areas within Teluk Kombal, North Lombok, West Nusa Tenggara, Indonesia. Samples were collected and filtered for identification using a microscope Olympus Culture Inverted, 4×100 magnification. The results revealed microplastic abundances ranging from 19.5±14.71 to 25±14.54 particles per liter in water, 9.25±8.54 to 10.75 ±9.53 particles per kilogram in sediment, and 10.25±13.28 to 10.5±10.28 particles per individual in *Padina* sp. across the three locations. Various types of microplastics, including fragments, films, pellets, and fibers, were identified, with dominant colors of yellow, blue, red, black, and green. The presence of microplastics in the Teluk Kombal estuary and river indicates that they have been contaminated with microplastics, which can cause serious problems for organisms inhabiting them. Therefore, further research is needed to investigate the impact of microplastics on organisms and ecosystems in the estuary.

Keywords: Aquatic environment, Kombal Bay Lombok, Microplastics, Pollutant.

1. Introduction

Marine debris encompasses solid materials accumulated from various sources, whether intentionally or inadvertently, persisting in marine ecosystems for extended periods (Mulu *et al.*, 2020). Among the most alarming components of marine debris is plastic, notorious for its slow degradation process spanning hundreds of years. Indonesia, as a maritime nation, ranks second globally in terms of plastic waste inundating its oceans (Ayuningtyas, 2019). According to Suryono (2019), an array of plastic debris types of infiltrate oceans, including Styrofoam, Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC or Vinyl), among others. Plastic debris not only jeopardizes human health through contaminated water sources and marine food products but also despoils marine aesthetics, disrupts ecosystems, and imperils biodiversity (Rahmad *et al.*, 2019; Nugroho *et al.*, 2018). Additionally, microplastics (MPs), formed from the degradation of larger plastic materials into particles smaller than 5 mm, present a significant threat to marine ecosystems (Ayuningtyas, 2019). These minute plastic particles, varying in size, shape, color, composition, and density, can disrupt the marine food chain when accumulated in biotic environments (Nugroho *et al.*, 2018). Due to their diminutive size, MPs are sometimes ingested by marine organisms, posing ecological and physiological risks to biodiversity (Lestari *et al.*, 2021). Kombal Bay, situated in West Pemenang village, North Lombok, West Nusa Tenggara, stands out as a critical marine area susceptible to MPs pollution. This bay, sprawling across coastal regions and opening into the sea, harbors significant human activities like fisheries and agriculture along its shores (Adam *et al.*, 2018, Adam *et al.*, 2022), escalating the potential for waste accumulation (Ondara & Dhiauddin, 2021). As emphasized by Lestari *et al.* (2021), heightened local activities correlate with increased marine debris potency, thereby compromising water quality, including MPs pollution. The accumulation of MPs in oceanic environments raises concerns regarding its potential to disrupt food chains and habitat stability (Hanif *et al.*, 2021). Given these considerations, it is imperative to assess and analyze the abundance and type of MPs in Kombal Bay as a crucial step towards formulating effective mitigation strategies.

2. Methods

2.1. Sampling Site, Sample Collection, and Research Time

The coordinates of Kombal Bay are 8°24’8,92073 south latitude and 116°5’25,70093”E east longitude. The sampling sites, denoted as Site S1 (Teluk Kombal estuary), Site S2 (Teluk Kombal river proximal to agricultural and fisheries activities), and Site S3 (Teluk Kombal river adjacent to residential and dumping areas), were selected for their representative characteristics.

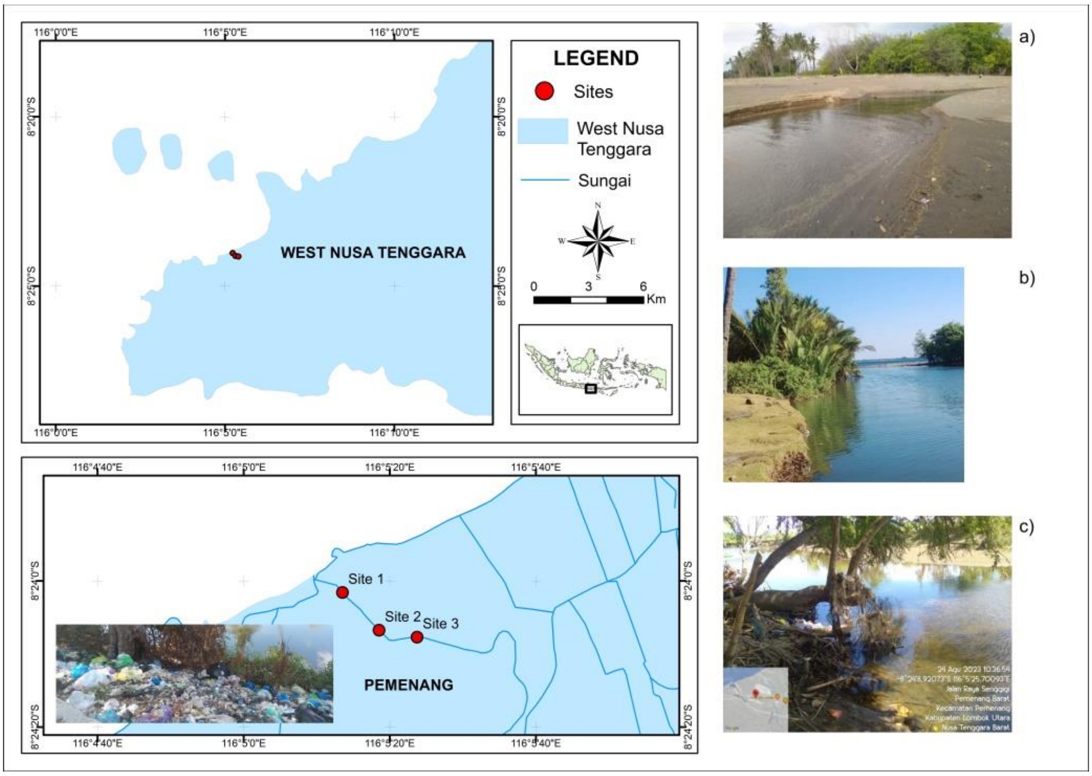


Figure 1. Sampling site of MPs surveillance, a) estuary, b) river that close to agricultural area, c) river that close to residences

Water, sediment, and algae (*Padina* sp) samples were collected in triplicate from each site. Water samples were collected in sample bottles and filtered through a 0.3 nm plankton net. Sediment samples, weighing approximately 300 g, were collected from the river and estuary surfaces using sample bottles, while *Padina* sp was preserved in plastic clips. All samples were stored in cool boxes during transportation to the laboratory.

2.2. Sample Extraction and Microplastic Quantification

Extraction organic compounds from sediment and *Padina* sp samples, the following procedure was followed: The samples were dried in an oven at 70°C for 3 days in a beaker glass. Once dried, the samples were treated with 10 mL of Fe(II) and 10 mL of 30% H_2O_2. For *Padina* sp samples only, 10 mL of NaOH 30% was added. The mixtures were homogenized and allowed to stand for 5 minutes. Subsequently, the samples were heated on a hot plate at 75°C for 15 minutes or until the first bubble burst. After cooling for 5 minutes, they were heated again for 30 minutes. Then, 6 grams of NaCl/20 mL sample was added to the mixtures and heated until dissolved. The mixtures were left to cool for 24 hours and then filtered using a 0.3 nm plankton net equipped with Whatman paper. The filtrates, along with water samples, were observed under a microscope (Olympus Culture Inverted, 4×100 magnification) to identify MPs based on their form, abundance, and color.

2.3. FT-IR Analysis

Following microscopic observation, MPs debris were analyzed using FTIR BRUKER Alpha II version 8.2 to identify the type of plastics based on their functional groups and polymers (Pungut *et al*., 2021).

2.4. Water Quality Analysis

Chemical and physical properties of water were tested, including ammonia, phosphate, nitrate, nitrite, and Dissolved Oxygen (DO) analysis was performed using the Salifert Freshwater Test Kit and total dissolved solids (TDS) analysis was conducted using a TDS Meter.

2.5. Data Analysis

Data were tabulated using Microsoft Excel 2013, and statistical analysis was performed using IBM SPSS 25. ANOVA was utilized to analyze differences in sampling sites and MPs forms with a 95% confidence level. The difference in abundance was assessed using T-Test Variance.

3. Results and Discussion

3.1. Result

3.1.1. The Abundance of Microplastics

Table 1 displays the abundance of MPs at the three sampling areas in Kombal Bay, representing the initial step of this study.

Table 1. The Abundance of the Microplastics

Type of Sample	The abundance of MPs at three sampling spots		
	Estuary	**River**	**River nearby residence area**
Water (particle/L)			
Mean±SD	19.5 ±14.71	25±14.54	21.5±14.62
Sediment (particle/kg dw)			
Mean±SD	10.75±9.53	9.25±8.53	9.75±6.31
***Padina sp* (particle/individual)**			
Mean±SD	15.25±9.53	10.25±13.3	10.5±10.27

Table 1 illustrates the average abundance of microplastics (MPs) in water samples collected from the estuary point, revealing the lowest concentration compared to the other two sampling sites, at 19.5 ±14.71 particles/L. Conversely, sediment samples obtained from the estuary point exhibit the highest average MPs abundance, measuring 10.75±9.53 particles/kg dw. Notably, the abundance of MPs in *Padina* sp. specimens collected from the estuary surpasses that of the other two sampling areas, reaching 15.25±9.53 particles/individual. This disparity suggests a potential accumulation of plastic debris at the estuary, likely attributable to its position at the terminus of the river (Riandi *et al*., 2018). Following the determination of MPs abundance, their forms were identified, as depicted in Figure 2.

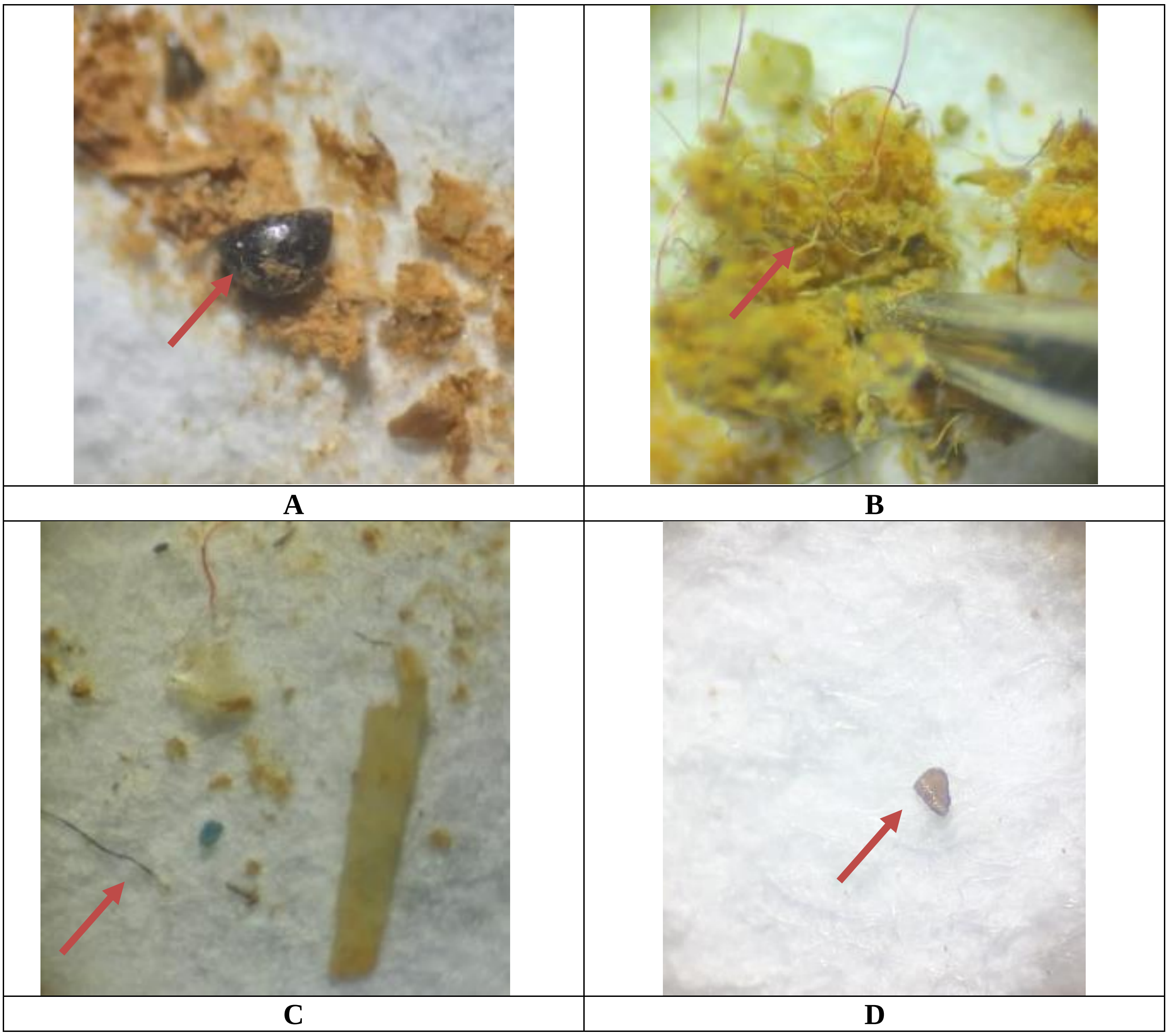


Figure 2. Form of Microplastics (a) Fragments, (b) Film, (c) Fibers, (d) Pellets

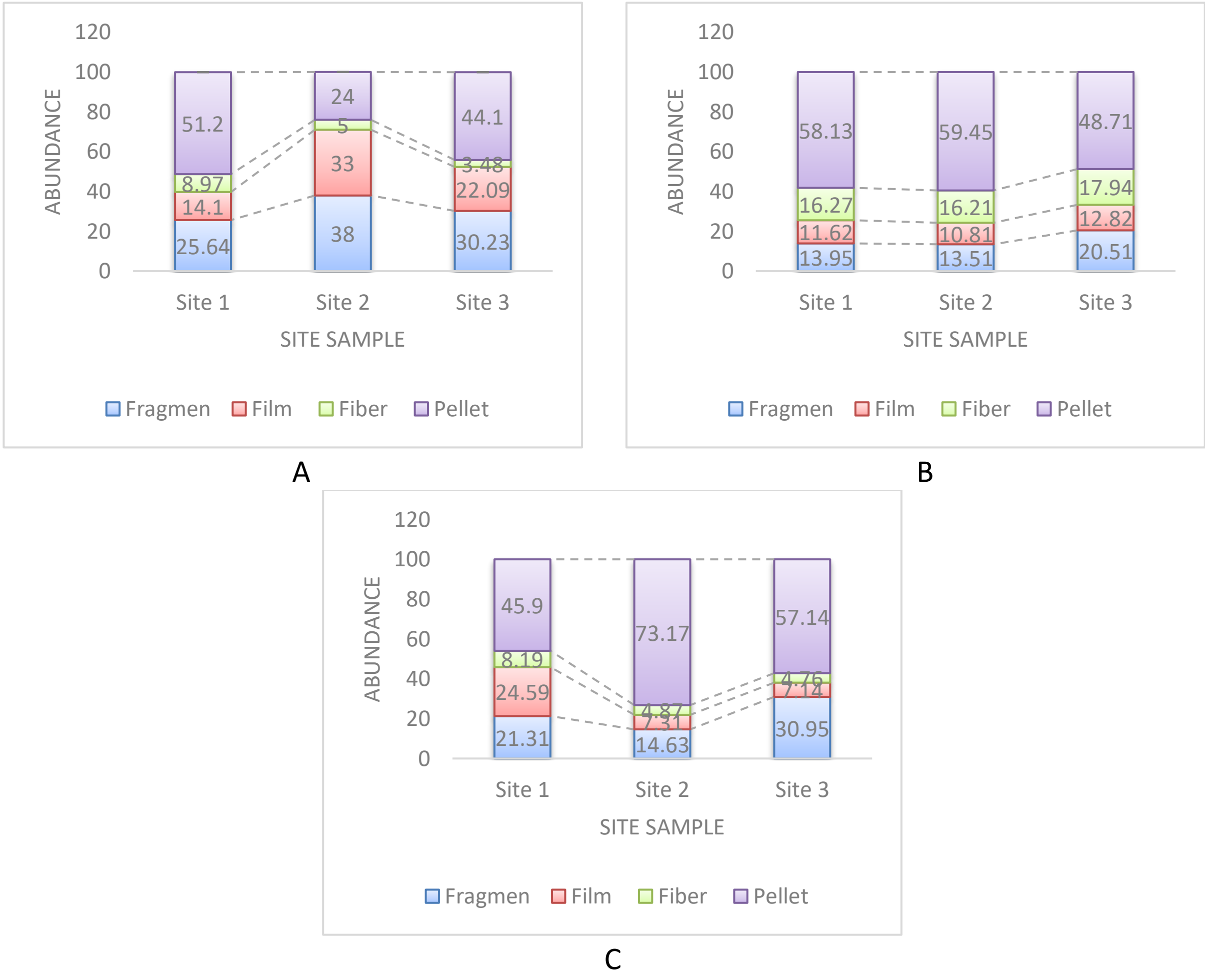
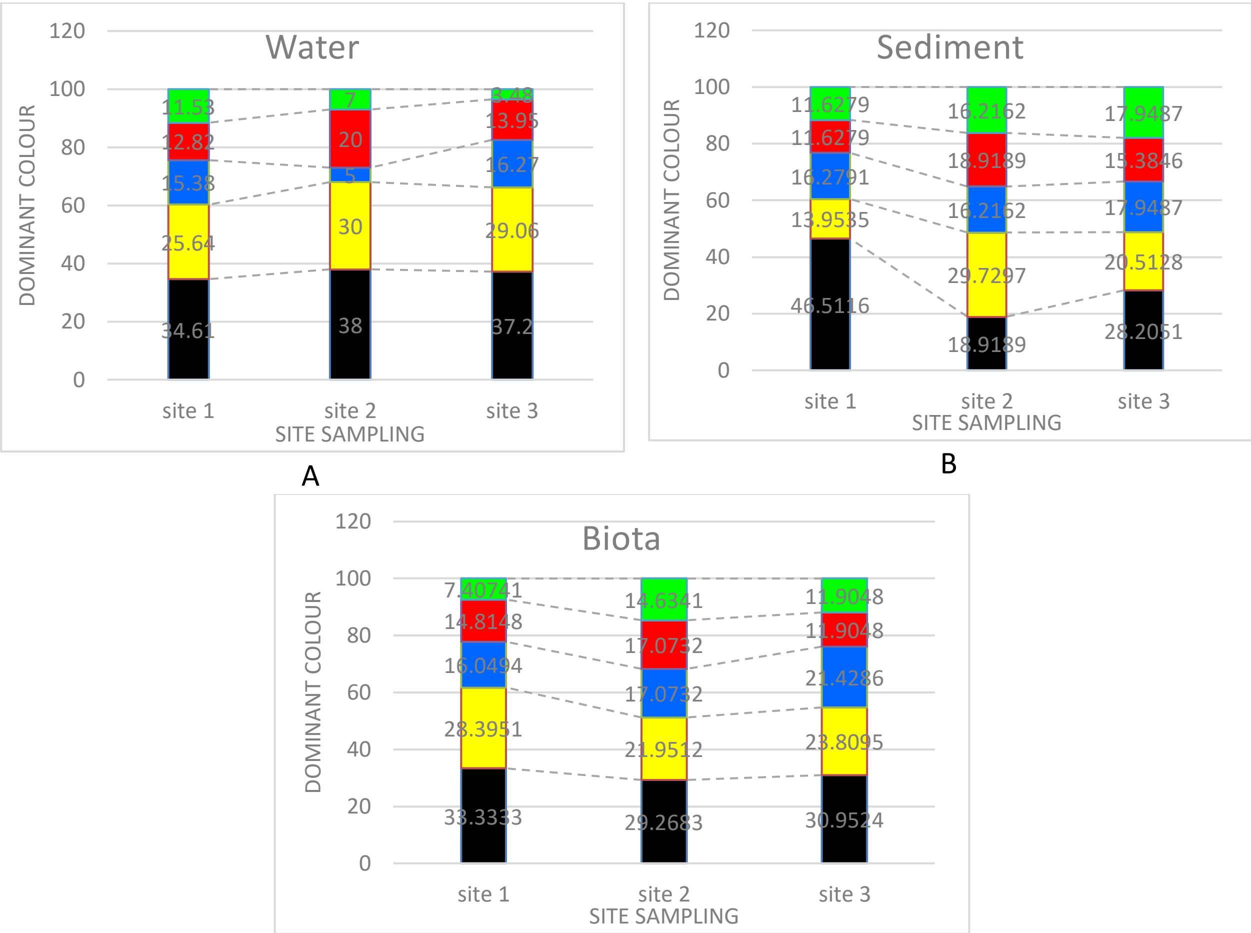


Figure 3. The Percentage (%) of MPs Abundance were Collected from (a) Water, (b) Sediment, (c) and *Padina* sp

Using a microscope inverter, we identified four forms of microplastics (MPs) present in water, sediment, and *Padina* sp. samples: fragments, film, fibers, and pellets. Fibers are categorized as solid-like threads with colors such as black, yellow, red, white, and blue, potentially originating from clothing residues or fishing gear (Sawalman *et al.*, 2021), as illustrated in Figure 4. Film-form MPs appear transparent, often yellow or brown, possibly stemming from domestic utensils (Labibah & Triajie, 2020). Conversely, fragment MPs are opaque, typically in black, yellow, green, or blue hues, originating from plastic containers, bags, or toys; Ridlo *et al.* (2020) note that these fragments are usually thick. Pellet-shaped MPs are circular, black, and may derive from materials like Styrofoam (Sandra & Radityaningrum, 2021). The distribution of these plastic forms across the sampling areas is presented in Figure 3.



C

Figure 4. The Dominant Colors of MPs Abundance were Collected from (a) Water, (b) Sediment, (c) and *Padina* sp

The average concentration of microplastics in surface water (Figure 3) is highest in S1 and S3 in the form of pellets and S2 in the form of fragments. The average number of microplastic concentrations in the sediment is highest in S1, S2, and S3 in the form of pellets, and the average number of microplastic concentrations in Padina sp is highest in S1, S2, and S3 in the form of pellets.

3.1.2. Identification of Microplastic Monomers Using Fourier Transform Infrared (FTIR) Spectroscopy

The abundance of microplastics was further analyzed to identify their monomers using FTIR, as detailed in Table 2. From the water samples collected at the estuary, the wave numbers of monomers indicated the presence of polystyrene (PS) at 3315.75 cm^{-1}, identified by hydroxyl (N-H), carbonyl (C-O), nitryl (C-N), and alkane (C-H) groups. Additionally, a spectrum at 2165.03 cm^{-1} specific for carbonyl (C≡C) and (C-O) groups was detected, indicative of Low-Density Polyethylene (LDPE) (Sugandi *et al.*, 2021). In sediment samples, three spectra were observed: one at 3340.19 cm^{-1}, specific for amine (N-H), carbonyl (C=O), and alkane (C-H) groups, suggesting polystyrene; another at 2165.03 cm^{-1}, indicating LDPE with specific C≡C and C-O groups; and finally, a spectrum at 2234.69 cm^{-1}, predicting polyethylene when the C≡N group appeared (Sugandi *et al.*, 2021). Detailed spectra are provided in Figure 5.

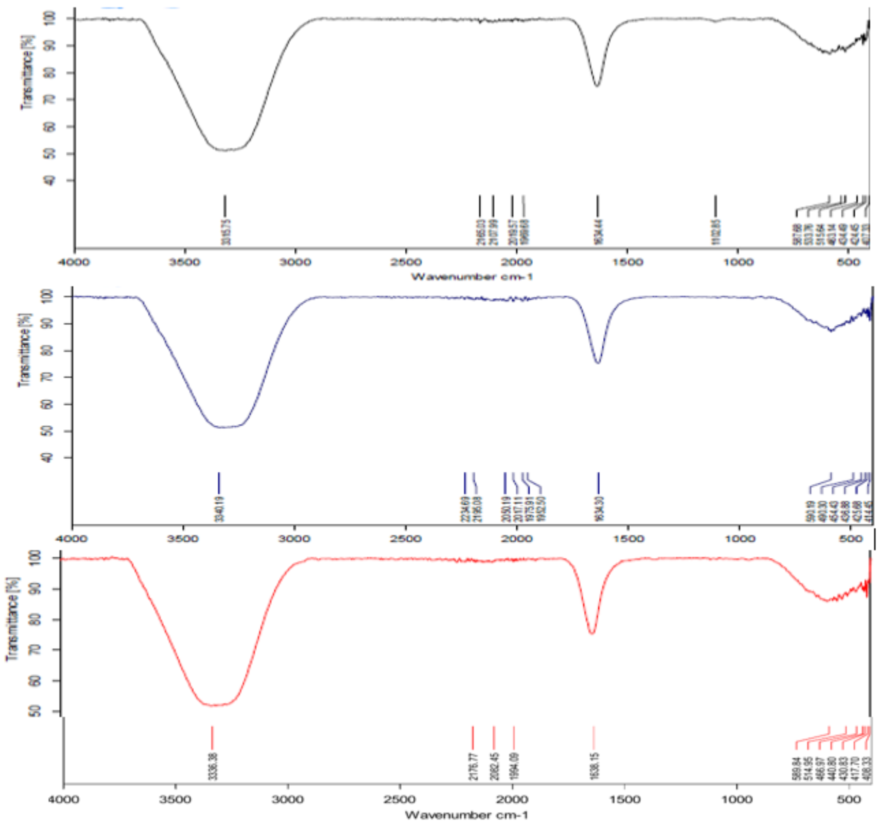


Figure 5. The FTIR Results of Water (black), Sediment (blue), and Biota at the Estuary (red) Samples.

Table 2. Analysis of Functional Group Based on FTIR Result, Samples (Water, Sediment and Padina sp.) were Collected from the Estuary.

Sampling site	Wavelength (cm^{-1})	Functional group	Polymer
Surface water	3315.75	N-H	PS (*polystyrene)*
	2107.99 - 2165.03	C≡C	LDPE (*Low Density Polyethylene)*
	1634.44 - 2019.57	C-O	LDPE (*Low Density Polyethylene)*
	1102.85	C-N	PS (*polystyrene)*
	407.33 - 587.68	C-H	PS (*polystyrene)*
Sediment	3340.19	N-H	PS (*polystyrene)*
	2234.69	C≡N	PE (*polyethylene)*
	2195.08 - 2017.11	C≡C	LDPE (*Low Density Polyethylene)*
	1975.91 - 1952.50	C−O	LDPE (*Low Density Polyethylene)*
	1634.30	C=O	PS (*polystyrene)*
	590.19 -414.45	C-H	PS (*polystyrene)*
Padina sp	3328.62	N-H	PS (*polystyrene)*
	2237.39	C≡N	PE (*polyethylene)*
	2198.33 - 2122.81	C≡C	LDPE (*Low Density Polyethylene)*
	1986.90 - 1634.27	C=C	LDPE (*Low Density Polyethylene)*
	594.23 - 407.35	C-H	PS (*polystyrene)*

Figure 5 presents the monomers of microplastics (MPs) identified from the peaks observed in the Fourier Transform Infrared (FTIR) results of samples collected from *Padina* sp. Polyethylene (PE) was detected at 2237.39 cm^{-1} wavelength, indicating a covalent bond, C≡N. Additionally, polystyrene was identified at 3328.62 cm^{-1} wavelength, specific to the amine group, N-H. Another peak observed at 2198.33 cm^{-1} suggests the presence of a carbonyl group, C≡C, and C=C, indicative of Low-Density Polyethylene (LDPE). These findings are consistent with local plastic usage patterns. Huo *et al.* (2023) suggests that fragments of MPs, such as those identified in this study, are commonly derived from polyethylene polymers found in plastic bags, while pellets may originate from microbeads used in the cosmetic industry (Sugandi *et al.*, 2021).

3.1.3. The Water Quality of Kombal bay

Table 3. Comparison of Teluk Kombal River Water Quality Based on Chemical and Physical Parameters with River Water Quality Standards Based on Government Regulations No. 82, 2001

Parameters	River water quality standards	Sampling point		
		SI	S2	S3
TDS (ppm)	500	259	274	337
DO (mg/L)	3.00	6.00	5.00	4.00
Ammonia(mg/L)	<0.5	0.25	0.25	<0.15
Nitrate(mg/L)	1	0	0	0
Nitrite(mg/L)	1	0	0	0
Phosphate(mg/L)	0.5	0.1	0.25	0.25

notes:

S1: Estuary

S2: the river close to agricultural area

S3: the river close to residences

Table 3 provides an overview of the water quality in Teluk Kombal river across three sampling areas. Nitrate and nitrite were not detected at any of the sampling sites. Ammonia was observed at concentrations of 0.25 mg/L at both S1 and S2, while at S3, it was less than 0.5 mg/L. Dissolved oxygen concentrations ranged from 4 to 6 mg/L.

This shows that the water quality can be said to be good because the ammonia level at the three sampling points is still low, the phosphate level is also low, and the DO level is high. In general, the water quality of a surface water source can be seen or observed from its dissolved oxygen (DO) content, this can be a reference that the water quality is said to be good. This is also confirmed in several articles which state that the greater the DO content value, the better the water quality (Asrori, 2021).

3.2. Discussion

At site 1, downstream of Kombal bay, microplastic contaminants were detected, with the highest levels observed at this site (as shown in Table 1). This finding is likely attributed to the common use of fish nets in this area and the accumulation of microplastics transported downstream by the river. n addition, river water flowing into the estuary is thought to also influence MPs contamination which then settles in the estuary or even enters the sea. Microscopic analysis revealed four forms of microplastics: fragments, fibers, films, and pellets, which are often the result of the degradation of macroplastics into smaller particles (Hanif *et al.*, 2021).

Pellet-form microplastics were predominantly found at sites 1 and 2, potentially influenced by runoff flowing towards the estuary. This is in accordance with research conducted by (Shafani *et al.*, 2022) which states that the pellet form is the most common form of MPs found in the estuarine waters of the East Flood Canal, so that the total density is higher than other forms of MPs. The high density of pellet shape MPs in the estuarine waters of the East Flood Canal can be caused by run off towards the mouth of the East Flood Canal. The pellet shape is influenced by community activities that dispose of household waste in the form of used laundry water (Azizah *et al.*, 2020). Makrima *et al.* (2022) suggest that these pellets may originate from exfoliated particles from body scrubs or soaps, as well as domestic waste. Fragment-form microplastics were more prevalent at site 3, likely influenced by tourism activities and domestic waste. The most commonly found plastic waste includes beverage bottles made of polyethylene (PE) or polypropylene (PP) (Sugandi *et al.*, 2021).

The abundance of fiber-form microplastics is attributed to the high intensity of fish net usage (Helfira *et al.*, 2022). Film-form microplastics, identified as PE and PP, likely originate from plastic bags commonly used by local residents and are relatively easier to degrade compared to other plastic packaging (Susanti *et al.*, 2019). Films and fragments were the most abundant microplastics found at the sampling sites.

The predominant colors of the microplastics were black, yellow, blue, red, and green, reflecting the diversity of plastic sources. Fragment microplastics are often white and blue (Kapo et al., 2020), while film microplastics are mostly white, with red and blue hues possibly resulting from physical degradation, such as exposure to sunlight (Ningrum et al., 2022). The presence of black microplastics may indicate the abundance of organic particles (Hiwari et al., 2019).

3.2.1. FTIR Analysis

FTIR analysis revealed the presence of specific functional groups characteristic of various polymers. Polystyrene (PS) was identified by peaks representing N-H, C-O, C-N, and C-H bonds (Trivantira *et al.*, 2023). LDPE was identified by peaks indicating C≡C and C-O bonds (Gumulya *et al.*, 2020), while PE was characterized by the presence of C≡N functional groups.

This assumption is almost the same as the research of Sugandi et al., (2021) that polystyrene (PS) type plastics are characterized by the presence of C-H phenyl, CH aliphatic, CH2 aromatic and phenyl functional groups identified in IR with the presence of absorption at 3348 cm-1, 2917 cm-1 and 1397 cm-1.

3.2.2. Water Quality Analysis

Ammonium levels in Teluk Kombal river ranged from <0.15 to 0.25 mg/L, within class 1 standards set by Indonesia President Regulation No. 82, 2001. Phosphate concentrations ranged from 0.1 mg/L to 0.25 mg/L, also within acceptable limits (Government Regulations No. 82, 2001). Nitrate and nitrite were undetected, indicating good water quality (Hamuna *et al.*, 2018). Dissolved oxygen levels ranged from 4 to 6 mg/L, indicative of satisfactory water quality (Daroini & Arisandi, 2020). Total Dissolved Solids (TDS) fell within the classification range specified by Government Regulations No. 82, 2001.

4. Conclusion

Microplastics, primarily in pellet form, contaminate the estuary of Teluk Kombal river. Other forms include fragments, films, and fibers. Polymers identified include PS, LDPE, and PE. The presence of microplastics in the estuary of Kombal Bay is due to the input of waste from densely populated land or human activities in the estuary area such as fishing or household activities. These findings underscore the urgent need for disaster mitigation strategies to prevent further pollution in Teluk Kombal river.

5. Funding

Thus research was funded by National Research and Innovation Agency (BRIN) Lombok Utara, NTB, Indonesia.

6. Acknowledgments

The auhors would like to thank National Research and Innovation Agency (BRIN) with Elektronik Layanan Sains (ELSA) for funding this work at Lombok Utara, NTB, Indonesia.

7. Author Contributions

Conceptualization, M. A. A. and N.I. ; methodology, M.A.A, M.A. and N.I. ; software, M.A, T.M., H.M..and H.S.T.; validation, N.I, M.A.A., N.K.C. and M.A.; formal analysis, N.I.; investigation, M.A.A., T.M. and H.M,; resources, M.A.A.; data curation, M.A.A and M.A.; writing—original draft preparation, M.A.A, N.I. and M.A; writing—review and editing, M.A.A, N.I. and M.A.; visualization, H.S.T, M.A., T.M and H.M..; supervision, M.A.A..; project administration, M.A.A. .; funding acquisition, M.A.A.

8. Conflict of Interest

The author declares no conflict of interest.

9. References

Adam, M. A., Maftuch, M., Kilawati, Y., & Tahirah, S. N. (2018). Analysis of Heavy Metal Pollutant in Wangi River Pasuruan and Its Impact on Gambusia affinis. *Jurnal Pembangunan Dan Alam Lestari*, *9*(2), 120–128. https://doi.org/10.21776/ub.jpal.2018.009.02.09

Adam, M. A., Widiastuti, I. M., Ernawati, Yayan, A. Y., Insivitawati, E., Yuliana, Pakaya, R. F., Soegianto, A., & Khumaidi, A. (2022). Analysis of White Feces Disease (WFD) caused by Vibrio sp. and Dinoflagellata in Vannamei Shrimp (Litopenaeus vannamei) in Brackishwater Culture Pond. *Jurnal Ilmiah Perikanan Dan Kelautan*, *14*(1), 160–166. https://doi.org/http://doi. org/10.20473/jipk.v14i1.26684

Asrori, M. K. (2021). Pemetaan Kualitas Air Sungai Di Surabaya. *Jurnal Envirotek*, *13*(2), 41–47. https://doi.org/10.33005/envirotek.v13i2.127

Ayuningtyas, W. C. (2019). Kelimpahan Mikroplastik Pada Perairan Di Banyuurip, Gresik, Jawa Timur. *JFMR-Journal of Fisheries and Marine Research*, *3*(1), 41–45. https://doi.org/10.21776/ub.jfmr.2019.003.01.5

Azizah, P., Ridlo, A., & Suryono, C. A. (2020). Mikroplastik pada Sedimen di Pantai Kartini Kabupaten Jepara Jawa Tengah. *Journal of Marine Research*, *9*(3), 326–332. https://doi.org/10.14710/jmr.v9i3.28197

Http://Www.Joi.Isoss.Net/PDFs/Vol-7-No-2-2021/03_J_ISOSS_7_2., *5*(1), 9–14.

Daroini, T. A., & Arisandi, A. (2020). Analisis Bod (Biological Oxygen Demand) Di Perairan Desa Prancak Kecamatan Sepulu, Bangkalan. *Juvenil*, *1*(4), 558–566.

Dewi, I.S, Aditya Budiarsa, A., & Ramadhan Ritonga, I. (2015). Distribusi mikroplastik pada sedimen di Muara Badak, Kabupaten Kutai Kartanegara. *Depik*, *4*(3), 121–131.

https://doi.org/10.13170/depik.4.3.2888

Faujiah, N., Ira Ryski Wahyuni, D., Kunci, K., Minum Kemasan, A., & Minum Isi Ulang, A. (2022). Kelimpahan dan Karakteristik Mikroplastik pada Air Minum serta Potensi Dampaknya terhadap Kesehatan Manusia. *Gunung Djati Conference Series*, *7*, 89–95.

Gumulya, D., Febriyanti, F., & Meilani, F. (2020). Mendaur ulang sampah kantong plastik Low Density Polyethylene menjadi produk fungsional. *Productum: Jurnal Desain Produk (Pengetahuan Dan Perancangan Produk)*, *3*(7), 255–264. https://doi.org/10.24821/productum.v3i7.3505

Hamuna, B., Tanjung, R. H. R., Suwito, S., Maury, H. K., & Alianto, A. (2018). Kajian Kualitas Air Laut dan Indeks Pencemaran Berdasarkan Parameter Fisika-Kimia di Perairan Distrik Depapre, Jayapura. *Jurnal Ilmu Lingkungan*, *16*(1), 35. https://doi.org/10.14710/jil.16.1.35-43

Hanif, K. H., Suprijanto, J., & Pratikto, I. (2021). Identifikasi Mikroplastik di Muara Sungai Kendal, Kabupaten Kendal. *Journal of Marine Research*, *10*(1), 1–6. https://doi.org/10.14710/jmr.v9i2.26832

Helfira, V., Fauzi, M., & Yuliati, Y. (2022). Abundance of microplastic in Water Column of Lubuk Siam Lake (Oxbow) Lubuk Siam Village Siak Hulu District Kampar Regency Riau Province. *Jurnal Perikanan Dan Kelautan*, *27*(3), 366. https://doi.org/10.31258/jpk.27.3.366-370

Hiwari, H., Purba, N. P., Ihsan, Y. N., Yuliadi, L. P. S., & Mulyani, P. G. (2019). *Kondisi sampah mikroplastik di permukaan air laut sekitar Kupang dan Rote , Provinsi Nusa Tenggara Timur Condition of microplastic garbage in sea surface water at around Kupang and Rote , East Nusa Tenggara Province*. *5*, 165–171. https://doi.org/10.13057/psnmbi/m050204

Huo, Y., Liu, T., Lu, D., Han, X., Sun, H., Huang, J., Ye, X., Zhang, C., Chen, Z., & Yang, Y. (2023). Dynamic tensile properties of steel fiber reinforced polyethylene fiber-engineered/strain-hardening cementitious composites (PE-ECC/SHCC) at high strain rate. *Cement and Concrete Composites*, *143*(2), 105234. https://doi.org/10.1016/j.cemconcomp.2023.105234

Kapo, A., Mujkic, A., Turulja, L., & Kovačević, J. (2020). Continuous e-learning at the workplace: the passport for the future of knowledge. *Information Technology and People*, *34*(5), 1462–1489. https://doi.org/10.1108/ITP-04-2020-0223

Labibah, W., & Triajie, H. (2020). Keberadaan Mikroplastik Pada Ikan Swanggi (Priacanthus tayenus), Sedimen dan Air Laut di Perairan Pesisir Brondong, Kabupaten lamongan.

Juvenil:Jurnal Ilmiah Kelautan Dan Perikanan, *1*(3), 351–358. https://doi.org/10.21107/juvenil.v1i3.8563

Lestari, K., Haeruddin, H., & Jati, O. E. (2021). Karakterisasi Mikroplastik Dari Sedimen Padang Lamun, Pulau Panjang, Jepara, Dengan Ft-Ir Infra Red. *Jurnal Sains &Teknologi Lingkungan*, *13*(2), 135–154. https://doi.org/10.20885/jstl.vol13.iss2.art5

Makrima, D. B., Suprijanto, J., & Yulianto, B. (2022). Mikroplastik pada Tentakel dan Pencernaan Cumi – Cumi dari TPI Tambak Lorok. *Journal of Marine Research*, *11*(3), 467–474. https://doi.org/10.14710/jmr.v11i3.35081

Mulu, M., Wendelinus Dasor, Y., Hudin, R., & Tarsan, V. (2020). Marine Debris Dan Mikroplastik: Upaya Mencegah Bahaya Dan Dampaknya Di Tempode, Desa Salama, Kabupaten Manggarai, Ntt. *Randang Tana - Jurnal Pengabdian Masyarakat*, *3*(2), 79–84. https://doi.org/10.36928/jrt.v3i2.404

Ningrum, I. P., Sa'adah, N., & Mahmiah, M. (2022). Jenis dan Kelimpahan Mikroplastik Pada Sedimen di Gili Ketapang, Probolinggo. *Journal of Marine Research*, *11*(4), 785–793. https://doi.org/10.14710/jmr.v11i4.35467

Nugroho, D. H., Restu, I. W., & Ernawati, N. M. (2018). Kajian Kelimpahan Mikroplastik di Perairan Teluk Benoa Provinsi Bali. *Current Trends in Aquatic Science*, *1*(1), 80. https://doi.org/10.24843/ctas.2018.v01.i01.p11

Ondara, K., & Dhiauddin, R. (2021). Identification of Floating Marine Debris in The Banda Aceh Estuary. *Jurnal Segara*, *17*(2), 75. https://doi.org/10.15578/segara.v17i2.9822

Pungut, N. A. S., Heng, M. P., Saad, H. M., Sim, K. S., Lee, V. S., & Tan, K. W. (2021). From one to three, modifications of sensing behavior with solvent system: DFT calculations and real-life application in detection of multianalytes (Cu2+, Ni2+ and Co2+) based on a colorimetric Schiff base probe. *Journal of Molecular Structure*, *1238*, 130453. https://doi.org/10.1016/j.molstruc.2021.130453

Rahmad, S., Purba, N., Agung, M., & Yuliadi, L. (2019). Karakteristik sampah mikroplastik di Muara Sungai DKI Jakarta. *Depik*, *8*(1), 9–17. https://doi.org/10.13170/depik.8.1.12156

Riandi, I., Ikhsan, M., & Amir, A. (2018). Perencanaan Ulang Jetty Di Muara Batu Putih Meulaboh. *Jurnal Teknik Sipil Dan Teknologi Konstruksi*, *1*(1), 96–107. https://doi.org/10.35308/jts-utu.v1i1.725

Ridlo, A., Ario, R., Al Ayyub, A. M., Supriyantini, E., & Sedjati, S. (2020). Mikroplastik pada Kedalaman Sedimen yang Berbeda di Pantai Ayah Kebumen Jawa Tengah. *Jurnal Kelautan Tropis*, *23*(3), 325–332. https://doi.org/10.14710/jkt.v23i3.7424

Sandra, S. W., & Radityaningrum, A. D. (2021). Kajian Kelimpahan Mikroplastik di Biota

Perairan. *Jurnal Ilmu Lingkungan*, *19*(3), 638–648. https://doi.org/10.14710/jil.19.3.638-648

Sawalman, R., Zamani, N. P., Werorilangi, S., & Ismet, M. S. (2021). Akumulasi Mikroplastik Pada Spesies Ikan Ekonomis Penting Di Perairan Pulau Barranglompo, Makassar. *Jurnal Ilmu Dan Teknologi Kelautan Tropis*, *13*(2), 241–259. https://doi.org/10.29244/jitkt.v13i2.34587

Shafani, R. H., Nuraini, R. A. T., & Endrawati, H. (2022). Identifikasi Dan Kepadatan Mikroplastik Di Sekitar Muara Sungai Banjir Kanal Barat Dan Banjir Kanal Timur, Kota Semarang, Jawa Tengah. *Journal of Marine Research*, *11*(2), 245–254. https://doi.org/10.14710/jmr.v11i2.31885

Sugandi, D., Agustiawan, D., Febriyanti, S. V., Yudi, Y., & Wahyuni, N. (2021). Identifikasi Jenis Mikroplastik dan Logam Berat di Air Sungai Kapuas Kota Pontianak. *Positron*, *11*(2), 112. https://doi.org/10.26418/positron.v11i2.49355

Suryono, D. (2019). Sampah Plastik di Perairan Pesisir dan Laut : Implikasi Kepada Ekosistem Pesisir Dki Jakarta. *Jurnal Riset Jakarta*, *12*(1), 17–23. https://doi.org/10.37439/jurnaldrd.v12i1.2

Susanti, S., Pratiwi, F. D., & Nugraha, M. A. U. (2019). *Abstrak Sungai Baturusa adalah salah satu sungai yang berada di Kabupaten Bangka yang di Pangkalbalam Kota Pangkalpinang . Sungai ini memiliki area yang Baturusa serta Estuari Sungai Baturusa yaitu hulu sungai , pelabuhan penyeberangan serta pantai yang t*. *April 2022*.

Trivantira, N. S., Fitriyah, F., & Ahmad, M. (2023). Identifikasi Jenis Polimer Mikroplastik Pada Ikan Tongkol lisong (Auxis rochei) Di Pantai Damas Prigi Kabupaten Trenggalek jawa Timur. *Biology Natural Resources Journal*, *2*(1), 19–23. https://doi.org/10.55719/binar.2023.2.1.19-23