Detection of microplastic pollutants in marine sediment, seawater and rivers in Central Tapanuli Regency, west coast of North Sumatra Province, Indonesia

[1]Rahmatsyah Rahmatsyah, [1]Rita Juliani, [2]Syarifuddin Syarifuddin, [1]Rini Juliani, [1]Khairanum Andini, [3]Riri Syavira, [2]Agung Setia Batubara

[1] Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Medan, Indonesia; [2] Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Medan, Indonesia; [3] Graduate Studies of Chemistry, Universitas Gadjah Mada, Yogyakarta, Indonesia. Corresponding author: R. Rahmatsyah, rahmatunimed@gmail.com

Abstract. This study aims to detect microplastic pollutants in marine sediment, seawater and river water samples. The study was conducted in Central Tapanuli Regency from May to October 2024. Determination of sampling locations was conducted positively by dividing three stations/locations. Analysis of microplastic samples was carried out at the Physics Laboratory, State University of Medan, Indonesia. Research parameters include analysis of particles number of microplastics based on type, color, and research location. Analysis of microplastic polymer types was carried out using Fourier Transform Infra-Red Spectroscopy (FTIR). The results of the analysis showed 5 types of microplastics from marine sediment, seawater and river water samples including fiber, film, foam, fragments, and pellets. A total of 687 microplastic particles were detected in marine sediments, dominated by pellets (290 particles), followed by fibers (225 particles), films (104 particles), and fragments and foam (34 particles each). In contrast, seawater samples contained a lower abundance with 162 particles, where fibers were the most prevalent (88 particles), followed by fragments (39 particles), pellets (26 particles), and films (9 particles). Meanwhile, a total of 272 particles were found in river water, consisting of 147 fibers, 83 fragments, 28 pellets, and 13 films. The results of the FTIR test showed several types of chemical compound polymers, namely polyethylene terephthalate (PET), polypropylene (PP), low density polyethylene (LDPE), and polystyrene (PS). This study successfully revealed the types, colors, and polymers of microplastics that pollute marine sediments, seawater, and rivers in Central Tapanuli Regency, North Sumatra, Indonesia.

Keywords: foam, FTIR, polyethylene, polystyrene.

Introduction. Marine pollution is defined as an event where objects enter the marine environment intentionally or unintentionally. Common pollution components found are plastic waste (A'yun 2019). Plastic waste that enters the water can decompose within a certain period of time through chemical, physical, or biological processes which can then change the plastic waste into micro-sized plastic particles, so they are called microplastics. Around 80% of plastic waste comes from land, especially from residential areas, public places, trade, industry, or agriculture (Sen & Raut 2015), while the remaining 20% comes from the sea (Anggiani 2020).

The process of microplastic entry into waters is categorized into two categories, namely primary microplastics and secondary microplastics. Primary microplastics are types of microplastics that enter the marine environment directly in micro sizes, while secondary microplastics are microplastics that come from the fragmentation of larger pieces of plastic (Harpah et al 2020). Microplastics distributed in the water column can accumulate in sediments (Lim 2016), because microplastic transport tends to be slower in sediments than in water columns (Mardiyana & Kristiningsih 2020). If sedimentation occurs continuously, it will result in the accumulation of microplastics in deeper sediment layers (Azizah et al 2020). Factors that cause the accumulation of microplastics in sediments are hydro-oceanographic factors, fishing activities carried out by fishermen (Dewi et al 2015), microplastic density, gravity (Azizah et al 2020), and the role of biota (Sen & Raut 2015).

Microplastics have a size ranging from <5 mm, with a weight ranging from 0.1 to 8.8 mg (Layn & Emiyarti 2020). Several types of microplastics can be categorized based on their shape, including fragments, filaments, films, foams, pellets, and granules (Lusher et al 2015; Wu et al 2022). Fragments, fibers, and films are types of microplastics that are commonly found in water and sediment (Layn & Emiyarti 2020). Based on the polymers they consist of, microplastics can be categorized into several types such as PE (polyethylene), PP (polypropylene), PVC (polyvinylidene chloride), PS (polystyrene), PET, and PA (polyamide) (Mardiyana & Kristiningsih 2020).

Microplastics are classified as hazardous waste materials due to their potential environmental risks (Sianturi et al 2021). Based on several studies on microplastics that have been conducted, the results obtained state that the presence of microplastics in the environment can be a problem if it causes microplastic contamination in waters in the future, so it is feared that it can become a global threat with various implications for social and environmental conditions. This is because microplastics are persistent, contain toxic chemical compounds, and are carcinogenic. Plastic waste management can be carried out chemically, physically, or biologically (Rahmatsyah et al 2024).

Currently, there have been no reports of microplastic pollution on marine sediments, seawater, and rivers in Central Tapanuli Regency, North Sumatra, Indonesia. This has to do with the extensive industrial operations that take place in this region, which is part of the Minapolitan area. Minapolitan is a concept for regional-based marine and fisheries economic development, which aims to create balanced inter-regional development, especially by increasing interest in urban-rural development. Furthermore, it is predicted that household trash has an impact on the degree of water contamination. In order to identify microplastic pollution in marine sediments, seawater, and rivers in Central Tapanuli Regency, North Sumatra, Indonesia, this study was conducted. Based on the types of microplastics and the polymers that make them, this investigation should identify the primary sources of microplastic contamination.

Material and Method. This research was conducted from May-October 2024 in Central Tapanuli Regency (Figure 1, Table 1). The collected samples were then further analyzed at the Physics Laboratory, Universitas Negeri Medan.

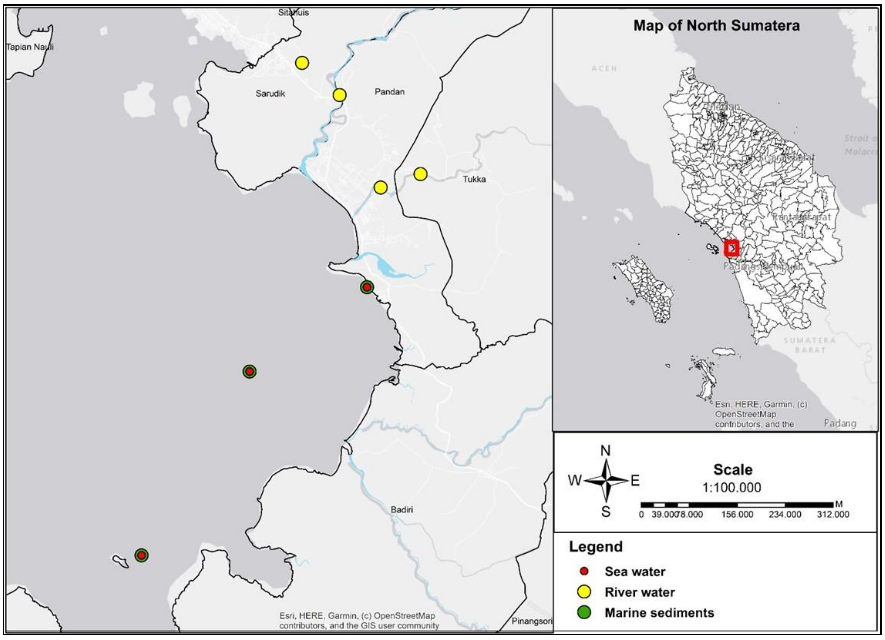

Figure 1. Map of research locations in Central Tapanuli Regency, North Sumatra, Indonesia (map generated using ArcGIS 10.3).

Table 1

Sample types and locations of microplastic data collection

Samples	*Coordinates*
Marine sediments	1.630966° Lat; 98.796645° Long 1.576837° Lat: 98.76493° Long 1.655777° Lat; 98.831151° Long
Sea water	1.630966° Lat; 98.796645° Long 1.576837° Lat: 98.76493° Long 1.655777° Lat; 98.831151° Long
River water	1.688771° Lat; 98.846672° Long 1.685043° Lat; 98.83520° Long 1.712212° Lat; 98.82337° Long 1.721666° Lat; 98.81209° Long

Marine sediment sampling was carried out using a sediment trap placed at the bottom of the waters in the coastal area of Central Tapanuli, North Sumatra. The sediment trap is made of PVC pipes with a diameter of 8 cm and a height of 27 cm, at the top of the pipe there are cover partitions, the sediment trap tube is installed on an iron pole with a height of 52 cm from the base with a weight using a cement mixture.

Seawater and river water samples were preserved by taking water at each research location using 500 ml sample bottles (Figure 2). Seawater samples were taken at a distance of 1-2 miles from the coastline towards the Ocean, while river samples were taken on the riverbank towards the upstream. The water samples were then transported to the Physics Laboratory, State University of Medan, Indonesia for further analysis.

Potassium hydroxide (KOH) solution was put into seawater and river sample bottles with a concentration of ± 10%. This was done to degrade organic/non-plastic materials, thus facilitating the process of identifying microplastics. The sample bottles were then incubated at 60°C for 24 hours so that all organic materials were evenly dissolved. The samples were then filtered using Whatman no. 42 filter paper and then incubated until dry (Figure 2). The dried Whatman paper was then placed on a Petri dish. Microplastic observations were carried out using binocular and stereo microscopes (Rahmatsyah et al 2024).

Marine sediment samples were removed from the PVC pipe, then put into a bucket and filled with water and salt (Figure 2). The stirring process was carried out so that the microplastics floated to the surface due to the increased water density determined by increased salinity. Surface water was then taken and filtered using Whatman filter paper no. 42. The identification process is carried out the same as before using a microscope. Several samples of marine sediment were taken, then dried in an oven at a temperature of 90°C for 24 hours. The microplastic polymer is analyzed using the FTIR tool.

Microplastic data analysis was measured including the value of the number of particles based on the type, color and polymer forming microplastics in each type of research sample based on Kasmini & Batubara (2023). The results of the analysis were then explained descriptively.

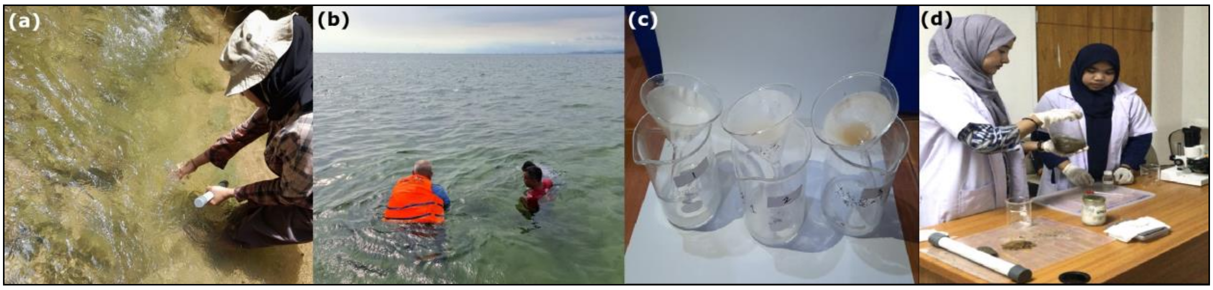

Figure 2. The process of sampling at the research location and laboratory analysis, where (a) river water samples were taken, (b) sea water samples were taken, (c) water sample filtration with Whatman paper no. 42, and (d) analysis of marine sediment samples.

Results and Discussion. As shown in Figure 3, a total of 687 microplastic particles were detected in marine sediments. Pellets were the most abundant type found (290 particles), followed by fibers (225 particles) and films (104 particles), while fragments and foam contributed the lowest amount with 34 particles each (Figure 3).

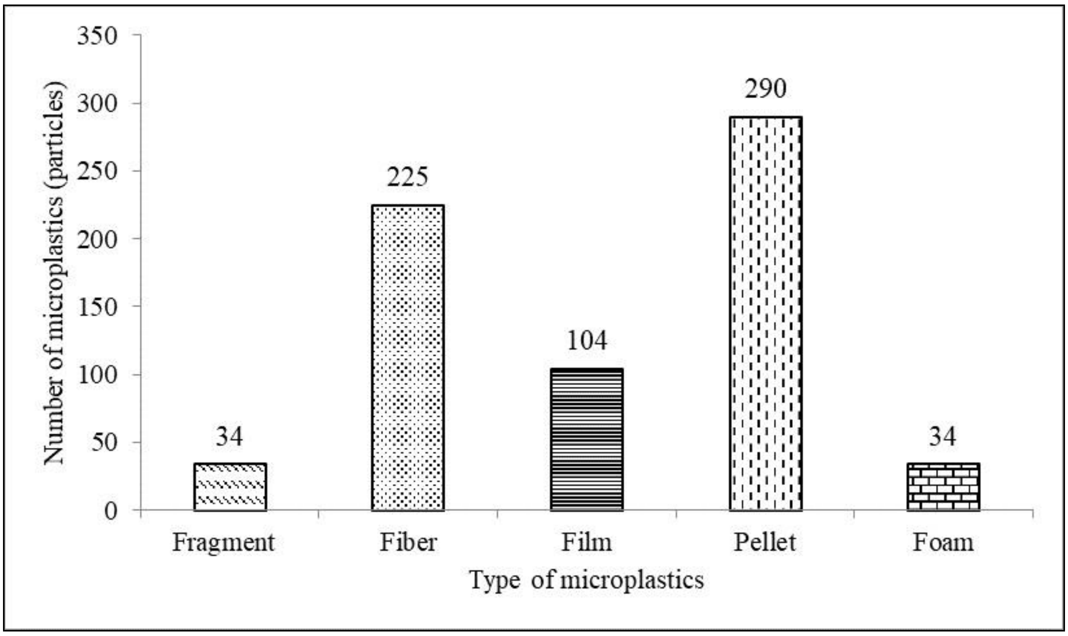

Figure 3. Microplastics based on type in marine sediments in Central Tapanuli Regency.

Of the 290 particles, pellets were divided into 183 yellow particles, 68 red particles, 39 transparent particles. Fiber in marine sediments consist of 4 colors including black with the highest number of 163 particles, 28 red particles, 22 blue particles, and 11 transparent particles. Film has 5 colors including 82 black particles, 16 yellow particles, 4 transparent particles, and 1 red and brown particle each. Fragments consist of 5 colors including black which is the most dominant with a total of 26 particles, followed by transparent color with 3 particles, 1 brown particle, and 2 yellow and green particles each. Foam has 2 colors, including transparent with 33 particles and black with 1 particle (Figure 4).

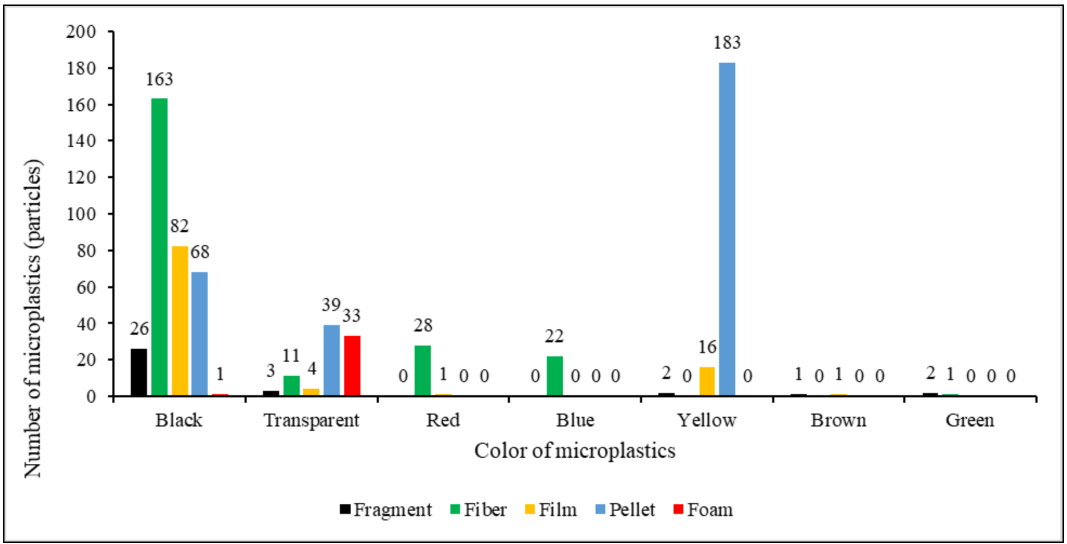

Figure 4. Microplastics based on color in marine sediments in Central Tapanuli Regency.

The total microplastics contained in seawater amounted to 162 particles consisting of fragments, fibers, films, and pellets. Fibers showed the highest value which reached 88 particles, followed by 39 fragments, 26 pellet particles, and 9 film particles (Figure 5).

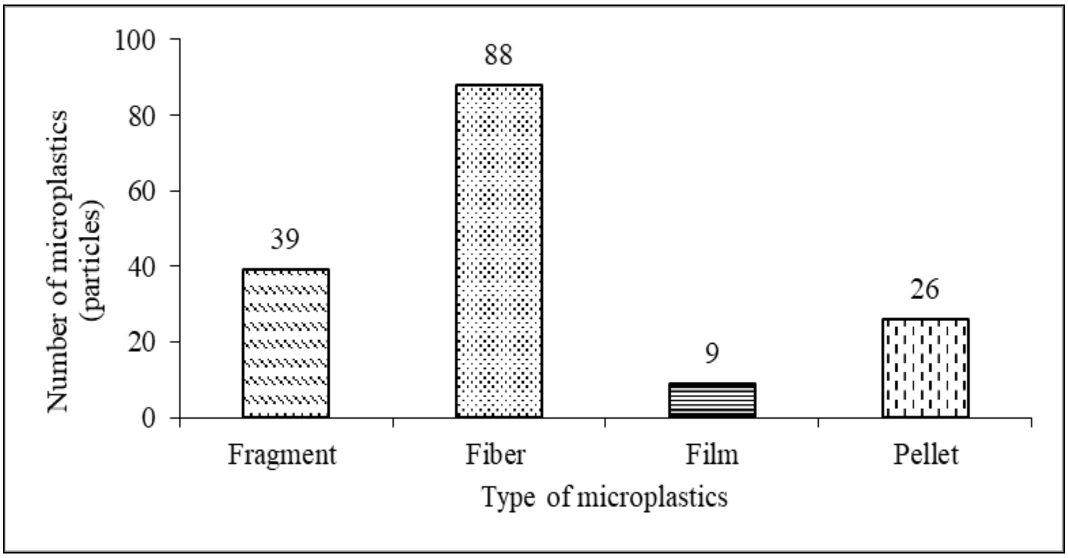

Figure 5. Microplastics based on type in seawater in Central Tapanuli Regency.

Of the total 88 fiber microplastic particles, black was found to reach 76 particles, followed by red with 5 particles, 3 blue particles and 2 each of yellow and transparent particles. Fragments are divided into 5 colors including 23 black particles, 10 yellow particles, 3 red particles, 2 green particles, and 1 blue particle. Pellet is divided into 2 colors including 19 black particles and 7 yellow particles (Figure 6).

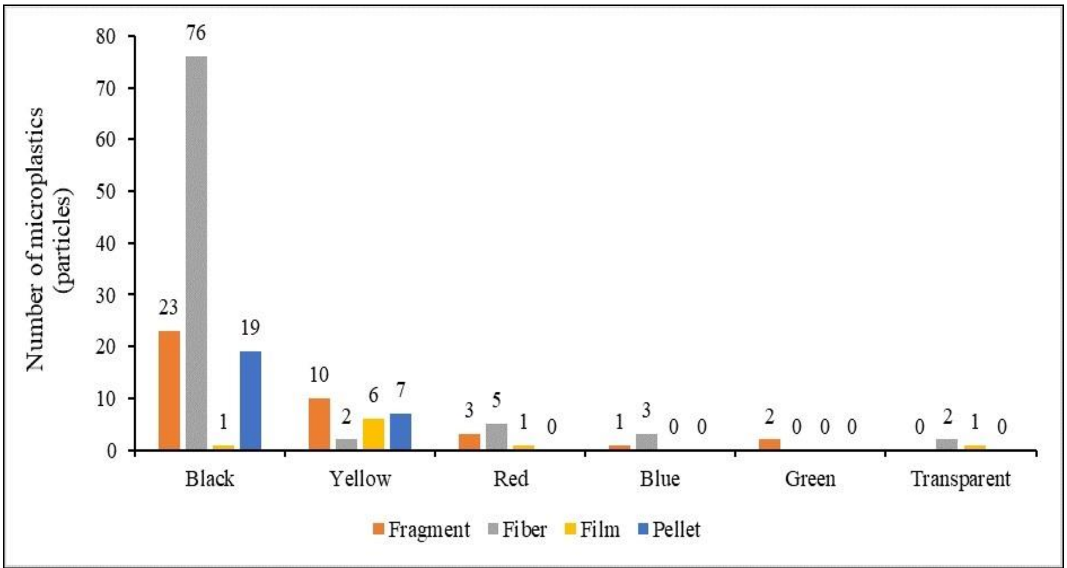

Figure 6. Microplastics based on color in seawater in Central Tapanuli Regency.

The total microplastics contained in river water amounted to 272 particles consisting of fragments, fibers, films, and pellets. The highest type of microplastics found was fibers with 147 particles, followed by fragments with 83 particles, pellets with 28 particles, and films with 13 particles (Figure 7).

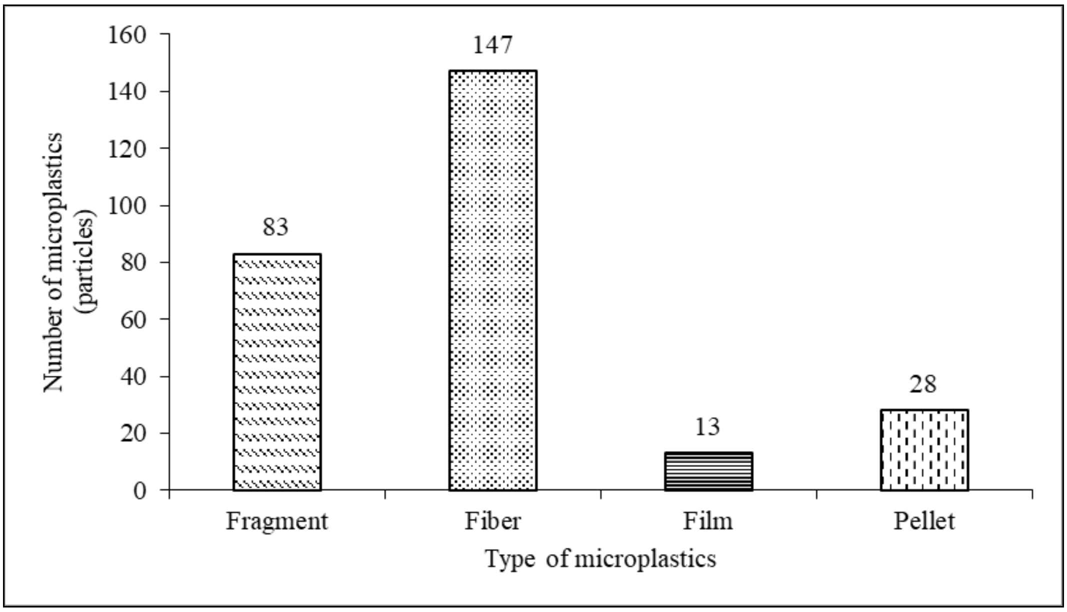

Figure 7. Microplastics based on type in river water in Central Tapanuli Regency.

Of the 147 fiber particles, there were 122 black particles, 12 red particles, 6 transparent particles, 1 green particle, and 3 particles each of yellow and blue. Fragment microplastics were divided into 5 colors including 45 black particles, 23 yellow particles, 12 blue particles, 2 red particles, and 1 green particle. Pellet microplastics consisted of 4 colors including 11 yellow particles, 10 blue particles, 6 black particles, and 1 transparent particle. Film microplastics were divided into 2 colors including 11 yellow particles and 2 black particles (Figure 8).

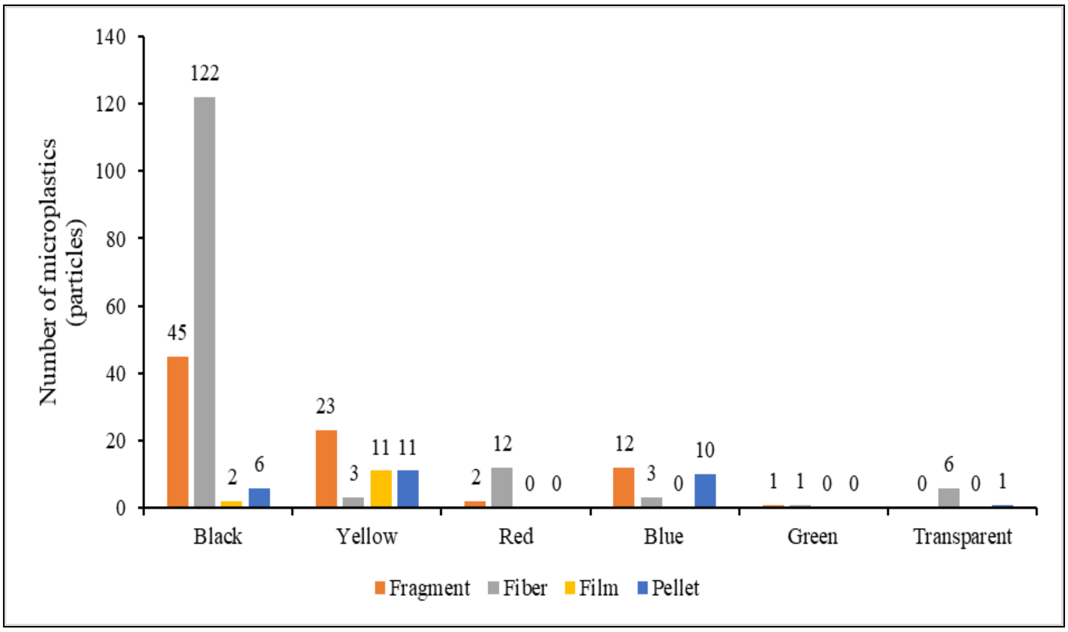

Figure 8. Microplastics based on color in river water in Central Tapanuli Regency.

The results of the FTIR analysis were confirmed with functional groups indicating that there were several types of microplastic polymers as shown in Figure 9. The results of the FTIR test showed several types of chemical compound polymers, namely polyethylene terephthalate (PET), polypropylene (PP), low density polyethylene (LDPE), and polystyrene (PS). PET polymers are characterized by the presence of an absorption peak at a wave number of 1084.71 cm^{-1} which is the C-O stretching vibrations. PP polymers are characterized by absorption at 798.67 cm^{-1} and are CH2 - rocking vibrations. PS polymers are characterized by absorption at 695.31cm^{-1}. LDPE polymers are characterized by the presence of an absorption peak at a wave number of 779.68 cm^{-1} (Table 2).

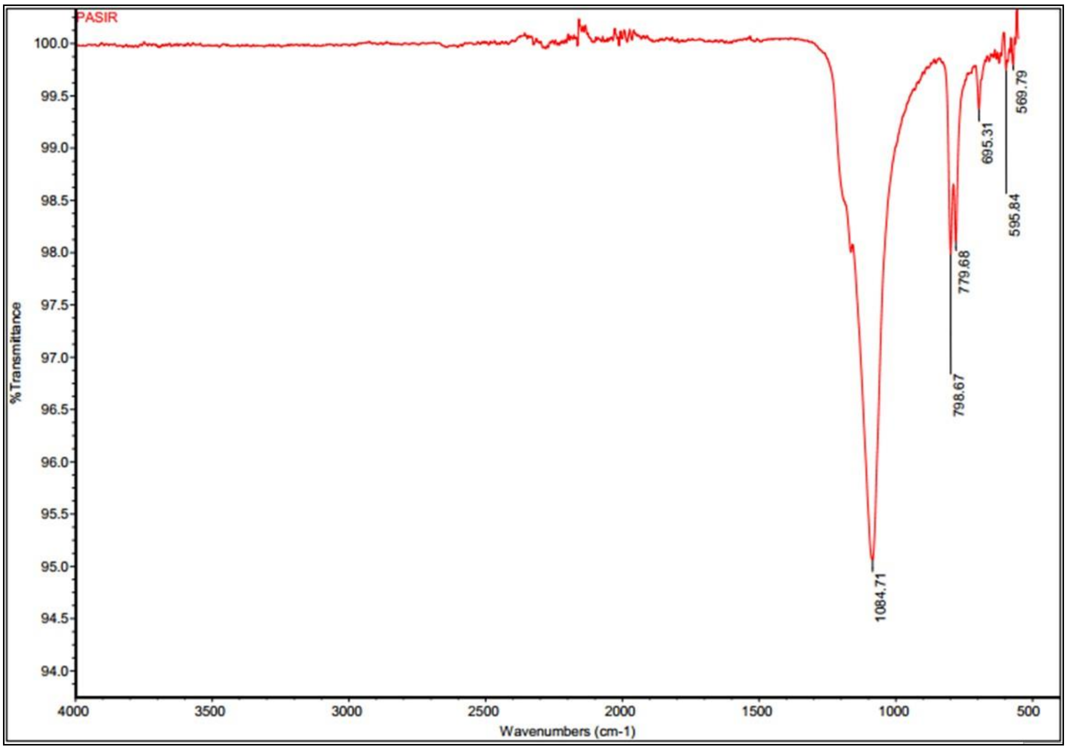

Figure 9. Graph of FTIR spectrometry results on microplastic samples.

Table 2
Absorption of microplastic waves based on the polymers that form them (Asensio et al 2009; Noda et al 2007)

No	*Wave absorption (cm^{-1})*	*Function group*	*Polymer type*
1	1084.71	C-O Stretching	PET
2	798.67	CH_2 Rocking	PP
3	779.68	CH_2 Rocking	LDPE
4	695.31	Aromatic CH out-of plane bend	PS

Microplastics contained in marine sediments have the highest value compared to microplastics in seawater and rivers. This is related to microplastics that continuously settle to the seabed so that it is positively correlated with the increasing content of microplastics in sediments (Zhang 2017), while microplastics in seawater and rivers tend to move due to currents and waves (Li et al 2020). In addition, the process of plastic waste degradation that occurs in sediments due to sedimentation is another factor that influences the high number of microplastics (Wu et al 2022).

Fiber microplastics dominate seawater and river samples, while in marine sediments are dominated by pellet microplastic (Figure 10). Furthermore, based on the color of microplastics, black dominates in seawater and river samples, while marine sediments are dominated by yellow. Although yellow microplastics (183 particles) in marine sediment samples are higher than black (163 particles), the values are relatively equivalent.

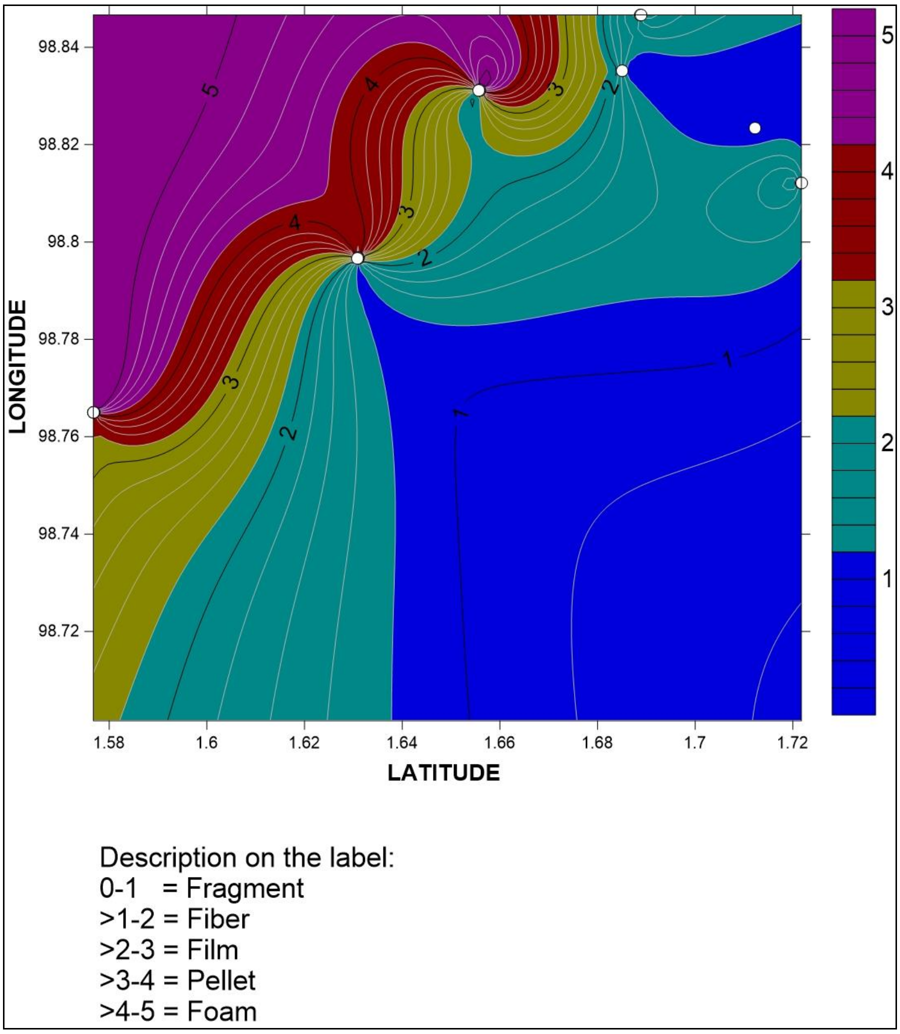

Figure 10. The distribution of microplastics is marked by colour, where the colour closest to the point indicates the type of microplastic that dominates.

The results of the FTIR analysis showed that the microplastic polymers that were successfully identified included polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), and low density polyethylene (LDPE). PET polymer microplastics are plastics made from smooth, transparent and thin materials (Tirkey & Upadhyay 2024). PET is commonly used in soft drink packaging and single-use water bottles (Asamoah et al 2020). PP polymer microplastics have stronger and lighter characteristics with low vapor permeability such as bottle caps, straws, and plastic toys (Ram 1997; Rahardiyan et al 2023). In addition, PP polymers are plastics used by the chemical industry in making laboratory equipment and automotive components (Hossain et al 2024). PP polymers have strong and stable resistance when faced with high temperatures (Galli et al 1984). PS polymer plastics are characterized by the presence of C-H phenyl, CH aliphatic, CH_2 aromatic and phenyl functional groups identified in IR with an absorption of 695 (Battulga et al 2022). Due to their complex chemical structure, PS polymers are highly resistant, causing them to persist in the environment for a long time. PS is one of the aromatic polymers and can release styrene into food (Ajaj et al 2021). PS is used for food and beverage packaging so this material should be avoided because it can interfere with estrogen hormones in women (Ong et al 2022). One of the most commonly found plastics in waters is LDPE (Sen & Raut 2015). LDPE plastic is a polyolefin that is most susceptible to degradation. LDPE has characteristics that are resistant to chemical compounds, is a flexible material, very tough, easy to process, and transparent (Szlachetka et al 2021; Saha et al 2022).

Conclusions. This study successfully revealed the types, colors, and polymers of microplastics that pollute marine sediments, seawater, and rivers in Central Tapanuli Regency, North Sumatra, Indonesia. The types of microplastics that were successfully identified included fiber, film, foam, fragments, and pellets. The colors of microplastics that were successfully identified included black, yellow, blue, brown, green, red, and transparent. The results of the FTIR test showed several types of chemical compound polymers, namely polyethylene terephthalate (PET), polypropylene (PP), low density polyethylene (LDPE), and polystyrene (PS).

Authors Contributions. Conceptualization: RR. Methodology: RJ, SS, ASB. Formal Analysis: RJu, RS, ASB. Investigation: RR, RJ, RS. Data Curation: RR, RJu, KA. Writing – Original Draft: RR, RJ, KA, RS, ASB. Writing – Review & Editing: RR, RS, ASB. Supervision: RR.

Conflict of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Funding. The authors would like to thank the Rector of the Universitas Negeri Medan, who funded this research through the "Penelitian Produk Terapan" scheme, with contract number 0100/UN33.8/PPKM/PPT/2024.

References

A'yun N. Q., 2019 [Analysis of microplastics using FT-IR in water, sediment, and mullet fish (*Mugil cephalus*) in the Bengawan Solo River segment that crosses Gresik Regency]. Universitas Islam Negeri Sunan Ampel Surabaya. Thesis. 60 pp. [in Indonesian]

Ajaj A., J'Bari S., Ononogbo A., Buonocore F., Bear J. C., Mayes A. G., Morgan H., 2021 An insight into the growing concerns of styrene monomer and poly (styrene) fragment migration into food and drink simulants from poly (styrene) packaging. Foods 10(5):1136.

Anggiani M., 2020 [Potential of microorganisms as bioremediation agents for marine microplastics]. Oseana 45(2):40–49. [in Indonesian]

Asamoah B. O., Roussey M., Peiponen K. E., 2020 On optical sensing of surface roughness of flat and curved microplastics in water. Chemosphere 254:126789.

Asensio R. C., San Andrés M., de la Roja J. M., Gómez M., 2009 Analytical characterization of polymers used in conservation and restoration by ATR-FTIR spectroscopy. Analytical and Bioanalytical Chemistry 395(7):2081–2096.

Azizah P., Ridlo A., Suryono C. A., 2020 [Microplastics in sediments at Kartini Beach, Jepara Regency, Central Java]. Journal of Marine Research 9(3):326–332. [in Indonesian]

Battulga B., Kawahigashi M., Oyuntsetseg B., 2022 Characterization of biofilms formed on polystyrene microplastics (PS-MPs) on the shore of the Tuul River, Mongolia. Environmental Research 212(B):113329.

Dewi I. S., Budiarsa A. A., Ritonga I. R., 2015 [Distribution of microplastics in sediments in Muara Badak, Kutai Kartanegara Regency]. Depik 4(3):121–131. [in Indonesian]

Galli P., Danesi S., Simonazzi T., 1984 Polypropylene based polymer blends: fields of application and new trends. Polymer Engineering & Science 24(8):544-554.

Harpah N., Suryati I., Leonardo R., Risky A., Ageng P., Addauwiyah R., 2020 [Analysis of the types, forms, and abundance of microplastics in the Sei Sikambing River, Medan]. Jurnal Sains dan Teknologi 20(2):108–115. [in Indonesian]

Hossain M. T., Shahid M. A., Mahmud N., Habib A., Rana M. M., Khan S. A., Hossain M. D., 2024 Research and application of polypropylene: a review. Discover Nano 19(1):2.

Kasmini L., Batubara A. S., 2023 Microplastic contamination and growth pattern of oyster; *Crassostrea gigas* in a coastline. Global Journal of Environmental Science and Management 9(4):753-764.
Layn A. A., Emiyarti I., 2020 [Distribution of microplastics in sediments in Kendari Bay waters]. Jurnal Sapa Laut 5(2):115–122. [in Indonesian]
Li Y., Zhang H., Tang C., 2020 A review of possible pathways of marine microplastics transport in the ocean. Anthropocene Coasts 3(1):6-13.
Lim V. S., 2016 Research highlights: Impacts of microplastics on plankton. Environmental Science: Processes & Impacts 18:160-163.
Lusher A. L., Tirelli V., O’Connor I., Officer R., 2015 Microplastics in Arctic polar water: the first reported values of particles in surface and sub-surface samples. Scientific Reports 5:14947.
Mardiyana, Kristiningsih A., 2020 [The impact of microplastic pollution in marine ecosystems on zooplankton: A review]. Jurnal Pengendalian Pencemaran Lingkungan (JPPL) 2(1):29-36. [in Indonesian]
Noda I., Dowrey A. E., Haynes J. L., Marcott C., 2007 Group frequency assignments for major infrared bands observed in common synthetic polymers. In J. E. Mark (Ed.), Physical Properties of Polymers Handbook 2nd ed. Springer. 395–406 pp.
Ong H. T., Samsudin H., Soto-Valdez H., 2022 Migration of endocrine-disrupting chemicals into food from plastic packaging materials: an overview of chemical risk assessment, techniques to monitor migration, and international regulations. Critical Reviews in Food Science and Nutrition 62(4):957-979.
Rahardiyan D., Moko E. M., Tan J. S., Lee C. K., 2023 Thermoplastic starch (TPS) bioplastic, the green solution for single-use petroleum plastic food packaging – A review. Enzyme and Microbial Technology 168:110260.
Rahmatsyah R., Juliani R., Syarifuddin S., Andini K., Purba R. Y., Batubara A. S., 2024 Growth pattern and microplastic accumulation of *Anadara* spp. harvested from the eastern waters of North Sumatra Province, Indonesia. AACL Bioflux 17(5):2139-2147.
Ram A., 1997 Description of major plastics: structure, properties and utilization. Fundamentals of Polymer Engineering. 148-215 pp.
Saha N. C., Ghosh A. K., Garg M., Sadhu S. D., 2022 Flexible packaging material manufacturing processes and its application. In Food Packaging: Materials, Techniques and Environmental Issues. Singapore: Springer Nature Singapore. 47-87 pp.
Sen S. K., Raut S., 2015 Microbial degradation of low density polyethylene (LDPE): A review. Journal of Environmental Chemical Engineering 3(1):462-473.
Sianturi K. P., Amin B., Galib M., 2021 [Microplastic distribution in sediments in coastal area of Pariaman City, West Sumatera Province]. Asian Journal of Aquatic Sciences 4(1):73-79. [in Indonesian]
Szlachetka O., Witkowska-Dobrev J., Baryła A., Dohojda M., 2021 Low-density polyethylene (LDPE) building films–Tensile properties and surface morphology. Journal of Building Engineering 44:103386.
Tirkey A., Upadhyay L. S. B., 2024 Discrete sensors to detect microplastics in environment. International Journal of Environmental Science and Technology 21(2):2357-2366.
Wu X., Liu P., Zhao X., Wang J., Teng M., Gao S., 2022 Critical effect of biodegradation on long-term microplastic weathering in sediment environments: A systematic review. Journal of Hazardous Materials 437:129287.
Zhang H., 2017 Transport of microplastics in coastal seas. Estuarine, Coastal and Shelf Science 199:74-86.

Received: 02 August 2025. Accepted: 11 December 2025. Published online: 11 June 2026.
Authors:
Rahmatsyah Rahmatsyah (RR), Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Street William Iskandar Ps. V, 20221 North Sumatra, Indonesia, e-mail: rahmatunimed@gmail.com
Rita Juliani (RJ), Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Street William Iskandar Ps. V, 20221 North Sumatra, Indonesia, e-mail: julianiunimed@gmail.com
Syarifuddin Syarifuddin (SS), Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Street William Iskandar Ps. V, 20221 North Sumatra, Indonesia, e-mail: syarif.ecol@yahoo.com
Rini Juliani (RJu), Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Street William Iskandar Ps. V, 20221 North Sumatra, Indonesia, e-mail: rinijuliani@mhs.unimed.ac.id
Khairanum Andini (KA), Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Street William Iskandar Ps. V, 20221 North Sumatra, Indonesia, e-mail: khairanumandini2@gmail.com
Riri Syavira (RS), Graduate Studies of Chemistry, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia, email: ririsyavira@mail.ugm.ac.id
Agung Setia Batubara (ASB), Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Street William Iskandar Ps. V, 20221 North Sumatra, Indonesia, e-mail: agungsbb@unimed.ac.id

How to cite this article:
Rahmatsyah R., Juliani R., Syarifuddin S., Juliani R., Andini K., Syavira R., Batubara A. S., 2026 Detection of microplastic pollutants in marine sediment, seawater and rivers in Central Tapanuli Regency, west coast of North Sumatra Province, Indonesia. AACL Bioflux 19(3):1231-1241.