

# Spatial variation of microplastic abundance and types in Bitung coastal waters, North Sulawesi: influence of fishing, residential, and port activities

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**ABSTRACT:** Microplastic contamination in coastal waters is shaped by local human activities and hydrodynamic transport, yet spatially explicit evidence from many Indonesian coastal cities remains limited. This study assessed the spatial variation of microplastic abundance and morphological types in Bitung coastal waters, North Sulawesi, across three stations representing contrasting coastal activity zones: fishing area (Station 1), residential area (Station 2), and port area (Station 3). Surface-water samples were collected in July 2025 using horizontal plankton-net tows over a 10 m transect, with three replicates per station. Laboratory processing included sequential sieving (0.4 mm and 5 mm), oven drying (90°C, 24 h), wet peroxide oxidation (WPO) with fenton reagent, NaCl density separation, and filtration (Whatman 100–250 µm), followed by microscopic classification into fiber, fragment, pellet, film, and foam types. A total of 488 microplastic particles were recorded across all samples. The port station showed the highest abundance (320 particles, mean  $106.7 \pm 10.2$  particles per tow), substantially exceeding fishing (92 particles,  $30.7 \pm 6.4$ ) and residential (76 particles,  $25.3 \pm 9.5$ ) stations. Overall composition was dominated by fragments (41.8%) and fibers (35.7%). Type composition differed significantly among stations, with fragments strongly dominating the port station, whereas fibers dominated the fishing and residential stations. These patterns indicate distinct local sources (e.g., shipping/port operations and packaging debris vs. textiles and fishing gear), highlighting the need for targeted waste control and monitoring in Bitung's coastal zones.

Keywords: microplastics, wet peroxide oxidation, density separation, port pollution, bitung

## INTRODUCTION

Microplastics (plastic particles < 5 mm) are pervasive pollutants in marine environments and are increasingly recognized for ecological risks and potential human exposure through food webs. Microplastic loads in coastal waters reflect a combination of local inputs (urban runoff, domestic wastewater, fisheries, tourism, and port operations) and transport processes (currents and wind-driven mixing) (Hidalgo-Ruz, 2012; GESAMP, 2019; Arat, 2025; Zhao et al., 2025). Among microplastic forms, fibers are often linked to synthetic textiles and rope/line abrasion, while fragments and films indicate breakdown of larger packaging materials and consumer plastics. Port and shipping activities can elevate microplastic loads through maritime traffic, cargo handling, and dense coastal infrastructure.

Bitung (North Sulawesi) is a strategically important coastal city with diverse coastal activities including fishing communities, residential areas, and port operations. However, station-resolved evidence comparing microplastic abundance and type composition across these activity zones remains limited. This study aimed to (i) quantify microplastic

abundance and (ii) characterize microplastic morphological types (fiber, fragment, pellet, film, foam) across three representative stations in Bitung waters, and (iii) evaluate spatial variation attributable to differences in anthropogenic activity.

## MATERIALS AND METHODS

### Study area and station definition

Sampling was conducted in Bitung coastal waters at three stations representing distinct coastal activity contexts: Station 1 (fishing area), Station 2 (residential area), and Station 3 (port area), GPS coordinates: 1°27'00.7"LU-125°13'44.6"BT (fishing area); 1°26'27.5"LU-125°13'15.6"BT (residential area); 1°26'39.2"LU-125°12'27.7"BT (port area), (Figure 1).

### Sampling design and field collection

Sampling was conducted in July 2025. At each station, surface-water samples were collected using a horizontal plankton-net tow along a 10 m transect, with three replicates per station (n = 9 tows total). Samples retained in the cod-end

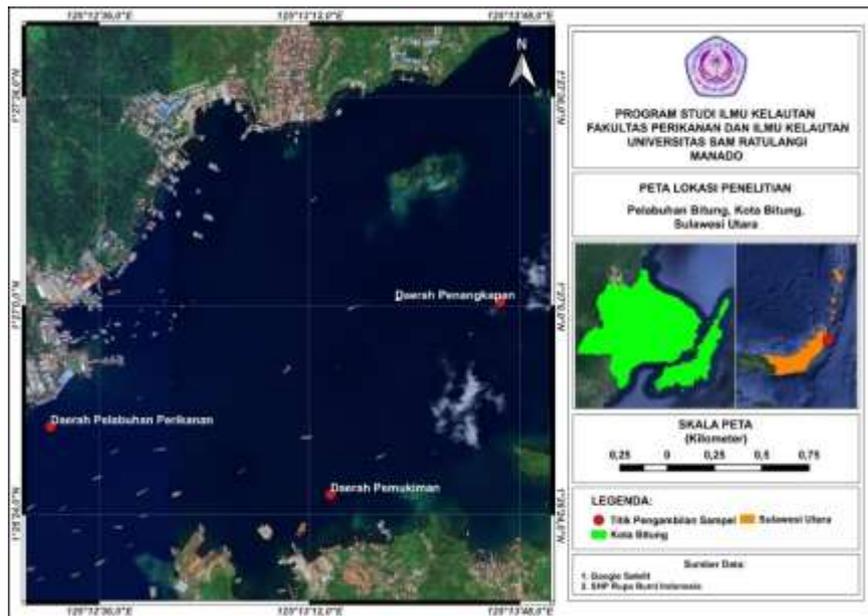


Figure 1. Location of study areas

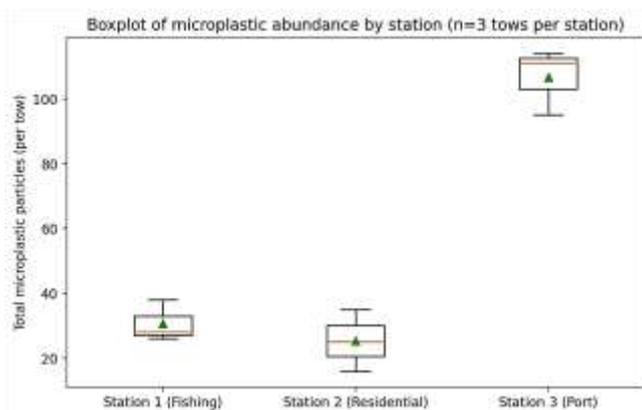


Figure 2. Boxplot of total microplastic particles per tow by station (n = 3 tows per station)

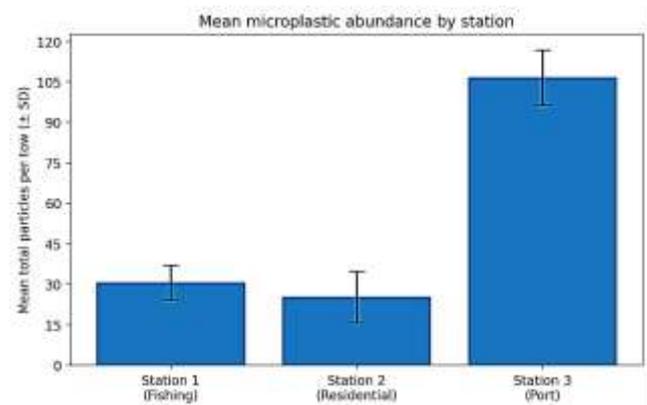


Figure 3. Mean ( $\pm$  SD) total microplastic particles per tow by station

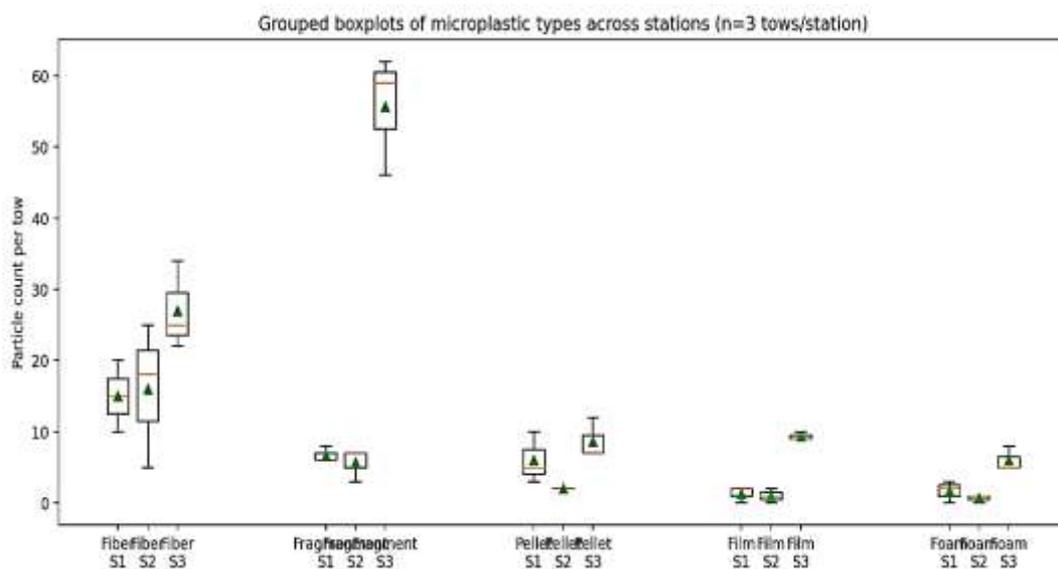


Figure 4. Grouped boxplots of microplastic types across stations

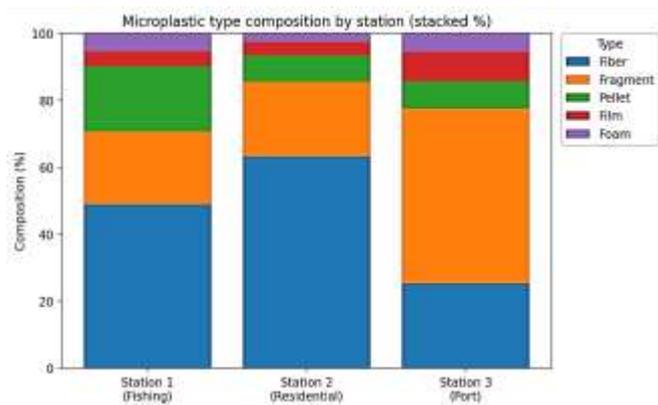


Figure 5. Microplastic type composition by station (stacked percentage)

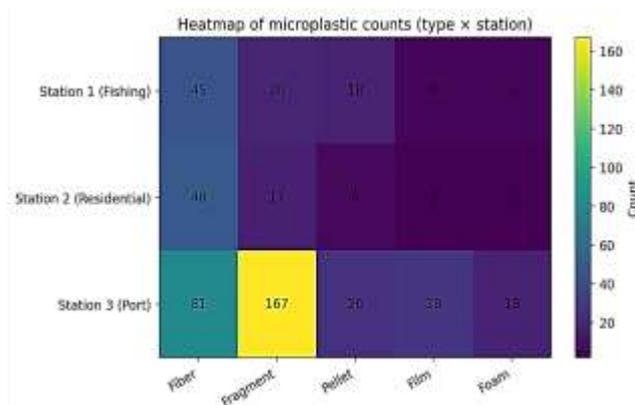


Figure 6. Heatmap of microplastic counts (type × station; counts summed across three tows per station)

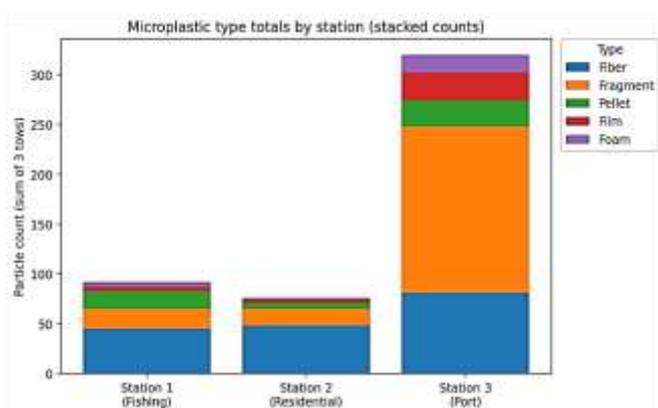


Figure 7. Microplastic type totals by station (stacked counts)

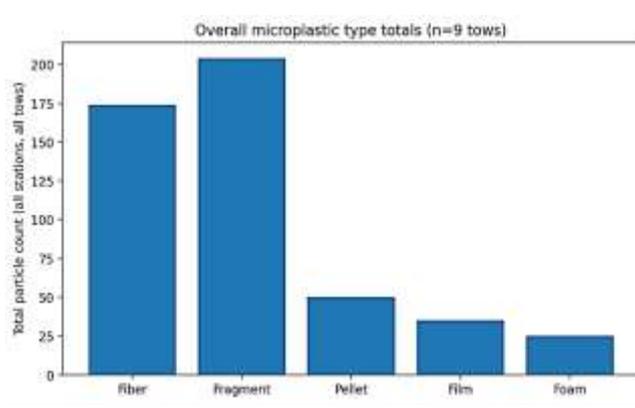


Figure 8. Overall microplastic type totals all stations, all tows)

were transferred to glass bottles and transported to the Bio-Ecology of Waters Laboratory (Faculty of Fisheries and Marine Science, Sam Ratulangi University) for processing and identification. Filtered volume can be estimated as  $V = p \times l \times a$ , where  $V$  is filtered volume (L),  $p$  is net mouth length (m),  $l$  is half net mouth width (m), and  $a$  is towing distance.

### Laboratory processing and identification

Samples were processed by sieving (0.4 mm and 5 mm), oven drying (90°C for 24 h), Wet Peroxide Oxidation (WPO) using Fenton reagent (20 mL H<sub>2</sub>O<sub>2</sub> 30% + 20 mL Fe(II)), NaCl density separation (6 g per 20 mL sample), and final filtration on Whatman paper (100–250 μm), (Masura et al., 2015; UNEP; 2021; KLHK, 2024). Particles were identified under a microscope and classified into five morphological types: fiber, fragment, pellet, film, and foam. Color and transparency attributes were also recorded.

### Data analysis

Microplastic abundance was summarized as raw counts per replicate and station and as mean ± SD per station (particles per tow). Type composition (%) was calculated by station and overall. Station differences in type composition can be evaluated using a chi-square test on the station × type contingency table. All data were analyzed using Python language program.

## RESULTS AND DISCUSSION

Microplastics were detected at all stations. The port station (Station 3) exhibited the highest abundance, totaling 320 particles across three tows (111, 95, 114 particles per tow), with a mean of  $106.7 \pm 10.2$  particles per tow. Station 1 (fishing area) totaled 92 particles (28, 38, 26; mean  $30.7 \pm 6.4$ ), and Station 2 (residential area) totaled 76 particles (25, 35, 16; mean  $25.3 \pm 9.5$ ) (Figure 2, 3, 4).

Across all samples, 488 particles were recorded. Overall composition was dominated by fragments (41.8%) and fibers (35.7%), while pellets (10.2%), films (7.2%), and foams (5.1%) were less common. Type composition varied by station: fibers dominated Stations 1 and 2, whereas fragments dominated Station 3 (Figure 5, 6, 7, 8).

Type-specific plots indicate that fibers were consistently present across stations, while fragments were markedly elevated at the port station. Figures 9 and 10 show replicates with station means and 95% t-based confidence intervals for fibers and fragments.

The strong abundance peak at the port station suggests concentrated local inputs typical of high-activity coastal infrastructure zones. The dominance of fragments at the port station is consistent with breakdown of larger rigid plastics and packaging materials under mechanical stress and weathering. Fiber dominance at fishing and residential stations is

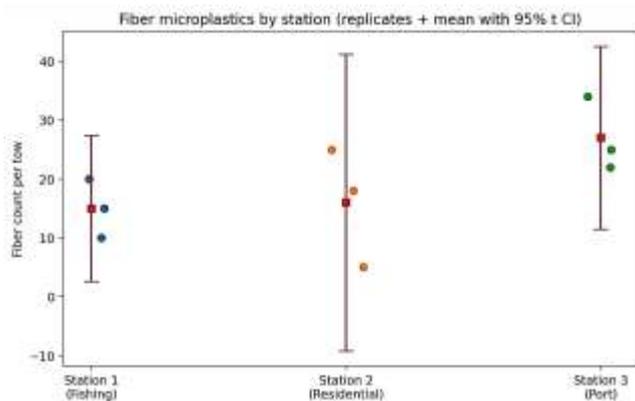


Figure 9. Fiber counts per tow by station (replicates + mean with 95% t CI)

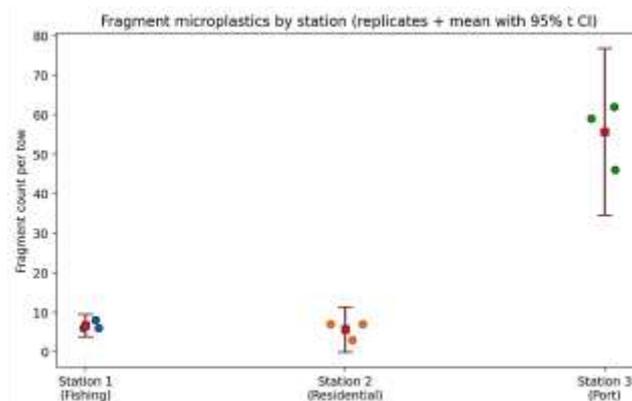


Figure 10. Fragment counts per tow by station (replicates + mean with 95% t CI)

consistent with sources such as synthetic textiles (wastewater pathways) and abrasion or degradation of ropes, lines, and fishing gear. While the laboratory workflow (WPO digestion + NaCl density separation + microscopy) is widely used, future work should strengthen QA/QC procedures (field/lab blanks) and confirm a subset of particles using FTIR/Raman spectroscopy when feasible. Reporting standardized concentration units (e.g., particles  $m^{-3}$ ) would also improve comparability across studies.

## CONCLUSIONS

Microplastics were present at all three stations in Bitung coastal waters (July 2025), totaling 488 particles across nine tows. The port station showed the highest abundance (mean  $106.7 \pm 10.2$  particles per tow), and overall composition was dominated by fragments and fibers. Type composition differed among stations: fibers dominated fishing and residential areas, while fragments dominated the port area. These findings support zone-specific mitigation, including improved waste handling at ports, strengthened domestic waste and wastewater management in residential areas, and reduction of gear-loss and improved disposal in fishing areas.

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