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Assessment of floating marine debris density, composition, chemical characteristics, and recycling potential along Gajah Beach and Pasir Putih Tabing Beach, Padang City, Indonesia

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Abstract: Floating marine debris is one of the major environmental challenges affecting coastal ecosystems and marine activities. Accumulation of floating debris can interfere with fishing operations by increasing the amount of debris captured in fishing nets and reducing fishing efficiency. This study evaluated the density, composition, chemical characteristics, and recycling potential of floating marine debris along Gajah Beach and Pasir Putih Tabing Beach, Padang City, Indonesia. Floating marine debris was collected using fishing trawls under two environmental conditions: normal weather and one day after a rainfall event. Samples were collected from three sampling points representing the study area and analyzed for debris density, material composition, proximate characteristics, and recycling potential. The average debris density increased from 1.18 g/m^2 under normal weather conditions to 3.13 g/m^2 after rainfall. Five material categories were identified, namely plastic, wood, rubber, fabric, and coconut husk. Plastic was the dominant material, accounting for 90% of the debris under normal weather conditions and 50% after rainfall, with corresponding densities of 0.90 g/m^2 and 1.66 g/m^2, respectively. Proximate analysis showed average values of 25.05% moisture content, 56.33% volatile matter, 8.53% ash content, and 9.09% fixed carbon. The results also indicate that plastic, wood, fabric, and coconut husk have potential for recycling or resource recovery. These findings provide baseline information for marine debris monitoring and support the development of more effective coastal waste management and resource recovery strategies in Padang City.

Keywords: floating marine debris; debris density; marine debris composition; chemical characteristics; recycling potential; coastal waste management

1. Introduction

Marine debris is recognized as one of the major environmental challenges affecting coastal and marine ecosystems worldwide because of its persistence, transboundary transport, and widespread ecological and socioeconomic impact (Wijesinghe et al., 2026). Floating marine debris refers to solid waste that remains on the sea surface or within the upper two meters of the water column. Unlike stranded or benthic debris, it is continuously transported by rivers, tides, and ocean currents before accumulating in coastal environments (Luo et al., 2024). Floating marine debris comprises various size classes, including meso-debris, macro-debris, and mega-debris, with plastic materials dominating due to their low density, buoyancy, and resistance to degradation in the marine environment (Waqas et al., 2023). The accumulation of floating marine debris degrades coastal environmental quality, threatens marine biodiversity, promotes the formation of microplastics, and disrupts fisheries by reducing fishing efficiency, as nets frequently capture more debris than commercially valuable fish (Geng et al., 2023). Collectively, these impacts highlight the need for systematic investigations of floating marine debris to support long-term monitoring and effective coastal waste management, particularly in rapidly developing coastal regions (Luo et al., 2024).

Marine debris is generally classified into three categories according to its position in the marine environment: beach debris, floating debris, and benthic debris. Beach debris accumulates within the intertidal zone, floating debris remains on the sea surface or within the upper two meters of the water column, whereas benthic debris settles on or becomes entangled with the seafloor. This classification has been widely adopted in marine debris monitoring because each category exhibits distinct transport mechanisms, environmental impacts, and sampling approaches (KLHK, 2020). In Indonesia, studies on floating marine debris remain relatively limited compared with investigations of beach litter. Previous studies have investigated floating marine debris across Indonesian coastal waters as well as in broader regional and global marine environments. Most previous studies have focused on debris density, composition, transport pathways, and the hydrodynamic processes controlling the distribution of floating marine debris (Aziz et al., 2023; Iskandar et al., 2021; van Sebille et al., 2020). Although these studies have advanced the current understanding of floating marine debris in Indonesian coastal waters, information integrating debris density, composition, physical and chemical characteristics, and recycling potential remains limited, particularly in the coastal waters of Padang City.

Despite recent advances in floating marine debris research, most studies have focused on debris occurrence, distribution, transport pathways, or plastic pollution monitoring. Studies that simultaneously evaluate debris density, material composition, physical and chemical characteristics, and recycling potential remain scarce (Waqas et al., 2023). In Indonesia, available studies on floating marine debris have mainly reported debris density, composition, and transport patterns in several coastal regions, including Padang, Makassar, and Ambon, with relatively limited attention given to the simultaneous evaluation of debris characteristics and resource recovery potential (Aziz et al., 2023). Consequently, baseline information required to support integrated marine debris management at the local coastal scale remains limited, particularly in coastal environments influenced by river discharge, fishing activities, and nearby settlements (Luo et al., 2024). Therefore, this study provides a comprehensive assessment of floating marine debris along Gajah Beach and Pasir Putih Tabing Beach, Padang City, by integrating debris density, composition, physical and chemical characteristics, and recycling potential under both normal and post-rainfall conditions. This integrated approach provides baseline scientific evidence for supporting long-term marine debris monitoring, resource recovery strategies, and evidence-based coastal waste management in Padang City.

To address this gap, the present study evaluates the density, composition, physical and chemical characteristics, and recycling potential of floating marine debris along Gajah Beach and Pasir Putih Tabing Beach, Padang City, Indonesia, under normal and post-rainfall conditions. The study provides baseline scientific information for long-term marine debris monitoring, resource recovery planning, and coastal waste management. The findings are expected to support local authorities and policymakers in developing more effective waste management strategies for coastal areas of Padang City.

2. Material and methods

2.1 Study area

This study was conducted at Gajah Beach and Pasir Putih Tabing Beach, Padang City, Indonesia. A preliminary visual survey was conducted to identify suitable sampling locations. Sampling sites were selected based on the presence of river mouths, nearby settlements, and fishing activities, which were identified as potential sources of floating marine debris. Sampling was conducted in the morning under two environmental conditions: during normal weather (without rainfall) and following a rainfall event. The locations of the sampling sites are shown in Figure 1.

Figure 1. Sampling locations at Gajah Beach and Pasir Putih Tabing Beach, Padang City, Indonesia

2.2 Equipment and materials

The equipment and materials used during field sampling and subsequent laboratory analyses are presented in Table 1.

Table 1. Equipment and materials used in this study

Equipment/Material	Function
Trawl net	Collection of floating marine debris samples
GPS	Identification of sampling locations
Scales	Measurement of debris weight
Trash bag	Collection and storage of samples
Compactor	Sample compaction
Evaporating dish	Container for furnace analysis
Crucible pliers	Handling evaporating dishes during heating
Desiccator	Cooling samples after heating
Oven	Drying samples at 150°C

2.3 Sample collection

Floating marine debris was collected using the trawl method in accordance with the *Marine Debris Monitoring Guidelines* (KLHK, 2020) Sampling was conducted in the morning at each sampling point under two environmental conditions: during normal weather (without rainfall) and one day after a rainfall event. All sampling points were located approximately 1 km offshore from the coastline. The collected debris was weighed after each sampling event, and the measured weights were compared between normal and post-rainfall conditions.

2.4 Sample preparation

Following collection, the marine debris samples were transferred into collection bags for subsequent analyses of weight, density, composition, physical and chemical characteristics, and recycling potential. Prior to analysis, the samples were washed with fresh water, dried, and weighed using a laboratory balance. Debris weight and density were calculated using the dimensions of the fishing trawl following the procedures described in the Marine Debris Monitoring Guidelines (KLHK, 2020). The trawl range was defined as the sampling distance plus the length of the towing rope on each side of the trawl, whereas the trawl length referred to the effective length of the trawl used for debris collection. The distance from the coastline and the trawl range were incorporated into the debris density calculations.

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2.5 Data analysis

Data analysis consisted of determining debris density, composition, recycling potential, and the chemical characteristics of the collected floating marine debris. The chemical characteristics were evaluated through proximate analysis, including moisture content, volatile matter, ash content, and fixed carbon. Debris density, composition, and recycling potential were calculated using Equations (1)–(3), whereas the chemical characteristics were determined using Equations (4)–(7).

Debris density

$$D = \frac{w}{A} \tag{1}$$

where:

D = debris density (kg m^{-2})
W = weight of a specific type of floating marine debris (kg)
A = trawl sampling area (m^2)

Composition

$$C = \left(\frac{Wi}{WT}\right) \times 100\% \tag{2}$$

where:

C = composition of floating marine debris (%)
Wi = weight of each debris type (kg)
WT = total weight of floating marine debris (kg)

Recycling potential

$$RP = \left(\frac{WR}{WT}\right) \times 100\% \tag{3}$$

where:

RP = recycling potential (%)
WR = weight of recyclable floating marine debris (kg)
WT = total weight of floating marine debris (kg)

Moisture content

$$MC = \left[\frac{(B - C)}{(B - A)}\right] \times 100\% \tag{4}$$

where:

MC = moisture content (%)
A = weight of the empty evaporating dish (g)
B = weight of the evaporating dish containing the sample before drying (g)
C = weight of the evaporating dish containing the sample after drying at 105°C (g)

Volatile matter

$$VM = \left[\frac{(C - D)}{(B - A)}\right] \times 100\% \tag{5}$$

where:

VM = volatile matter (%)
C = weight after drying at 105°C (g)
D = weight after heating at 600°C (g)

Ash content

$$AC = \left[\frac{(D - E)}{(B - A)}\right] \times 100\% \qquad (6)$$

where:

AC = ash content (%)
D = weight after heating at 600°C (g)
E = weight after heating at 900°C (g)

Fixed carbon

$$FC = 100\% - (MC + VM + AC) \qquad (7)$$

where:

FC = fixed carbon (%)
MC = moisture content (%)
VM = volatile matter (%)
AC = ash content (%)

3. Results and discussion

3.1 Density of floating marine debris

Floating marine debris was classified into five material categories: plastic, wood, rubber, fabric, and coconut husk. Debris density was evaluated under two environmental conditions: normal weather and post-rainfall. Figure 2 presents the density of floating marine debris under normal weather conditions, whereas Figure 3 shows the corresponding density under post-rainfall conditions.

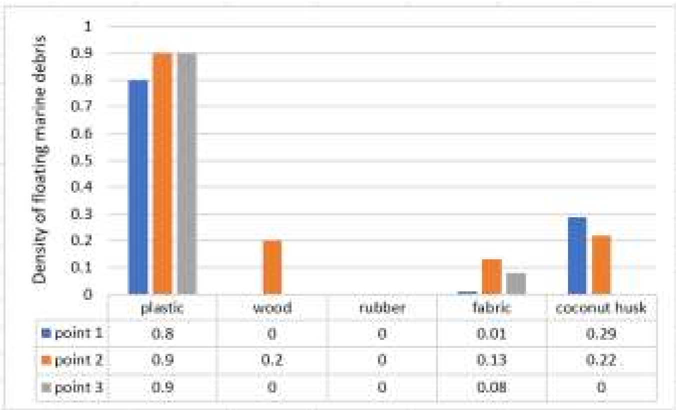

Figure 2. Density of floating marine debris under normal weather conditions

Figure 2 shows that plastic was the dominant type of floating marine debris at all three sampling points under normal weather conditions. Plastic debris density ranged from 0.80 to 0.90 g m^{-2}, while coconut husk was the second most abundant debris type, with densities ranging from 0.22 to 0.29 g m^{-2}. Wood debris was only detected at Point 2 with a density of 0.20 g m^{-2}, whereas fabric debris ranged from 0.01 to 0.13 g m^{-2}. Rubber debris was not detected at any sampling point. The predominance of plastic debris is consistent with recent studies showing that buoyant plastics constitute the dominant fraction of floating marine debris because of their low density, long residence time, and extensive global consumption (Kaandorp et al., 2023). Rivers are recognized as the primary pathway transporting land-based floating marine litter into coastal waters, particularly in areas affected by intensive human activities (Luo et al., 2024). Therefore, the dominance of plastic debris observed in the present study is likely associated with anthropogenic activities and riverine transport.

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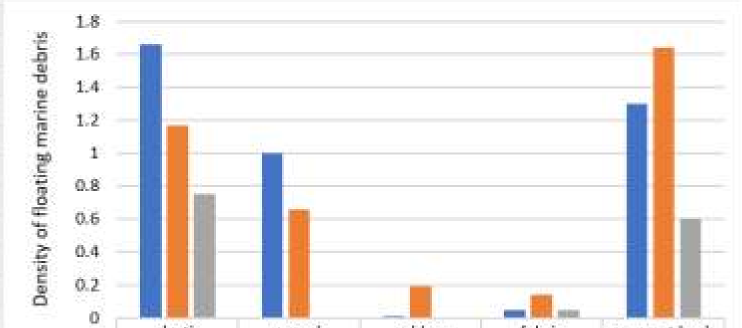
The highest density of floating marine debris under post-rainfall conditions was observed for plastic, reaching 1.66 g m⁻² at Point 1. Higher densities of wood and coconut husk were also recorded after rainfall compared with normal weather conditions. The density of floating marine debris under post-rainfall conditions is presented in Figure 3.



	plastic	wood	rubber	fabric	coconut husk
point 1	1.66	1	0.01	0.05	1.3
point 2	1.17	0.66	0.19	0.14	1.64
point 3	0.75	0	0	0.05	0.6

Figure 3. Density of floating marine debris under post-rainfall conditions

Figure 3 shows that plastic remained the dominant type of floating marine debris after rainfall, followed by coconut husk and wood debris. Plastic debris density ranged from 0.75 to 1.66 g m⁻², while coconut husk ranged from 0.60 to 1.64 g m⁻². Wood debris was detected at Point 1 (1.00 g m⁻²) and Point 2 (0.66 g m⁻²), whereas rubber and fabric debris were present at relatively low densities. Compared with normal weather conditions, the density of floating marine debris increased after rainfall, particularly for plastic, wood, and coconut husk. The highest density was recorded at Point 1, which is located near the river mouth. Increased river discharge during rainfall is likely to transport greater amounts of terrestrial debris into coastal waters, resulting in higher debris accumulation. Recent studies have demonstrated that river discharge, tides, winds, and coastal hydrodynamics strongly influence the transport, retention, and accumulation of buoyant plastic debris in estuarine and nearshore environments (Chen et al., 2023; Kim & Kim, 2024). These processes may explain the higher debris density observed after rainfall in the present study.

3.2 Composition of floating marine debris

The floating marine debris collected along Gajah Beach and Pasir Putih Tabing Beach, Padang City, consisted of five categories: plastic, wood, fabric, rubber, and coconut husk. The composition of floating marine debris under normal weather conditions and post-rainfall conditions is presented in Figure 4 and Figure 5, respectively.

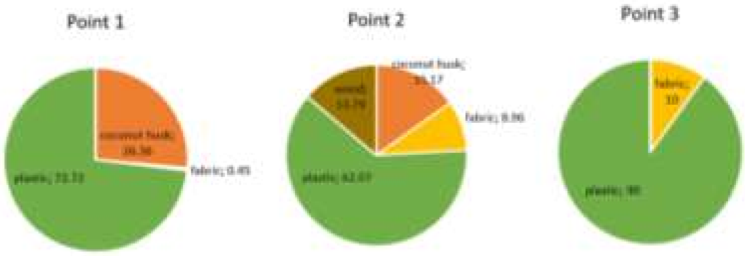


Figure 4. Composition of floating marine debris under normal weather conditions

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Figure 4 shows that plastic was the dominant component of floating marine debris at all three sampling points during normal weather conditions. At Point 1, plastic accounted for 72.72% of the total debris, followed by coconut husk (26.36%) and fabric (0.45%). At Point 2, plastic remained dominant (62.07%), followed by coconut husk (15.17%), wood (13.79%), and fabric (8.96%). At Point 3, plastic represented 90% of the total debris composition, while the remaining 10% consisted of fabric. The predominance of plastic debris indicates that lightweight and buoyant materials are more likely to remain afloat and accumulate in coastal waters. Similar findings have been reported in coastal environments worldwide, where plastic consistently represents the largest fraction of floating marine debris because of its extensive use, persistence, and low density (Kaandorp et al., 2023; United Nations Environment Programme, 2021)). The absence of rubber at all sampling points under normal weather conditions also suggests that heavier or reusable materials are less likely to remain as floating debris or are removed through reuse and recycling before reaching the marine environment.

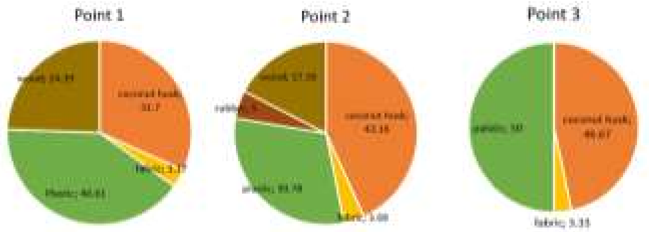

Figure 5. Composition of floating marine debris under post-rainfall conditions

Figure 5 illustrates the composition of floating marine debris after rainfall. At Point 1, plastic remained the dominant component (40.61%), followed by coconut husk (31.70%), wood (24.39%), fabric (3.17%), and rubber (0.12%). At Point 2, coconut husk became the dominant component (43.16%), followed by plastic (30.78%), wood (17.36%), rubber (5.00%), and fabric (3.68%). At Point 3, plastic accounted for 50.00% of the debris composition, followed by coconut husk (46.67%) and fabric (3.33%). Compared with normal weather conditions, the composition of floating marine debris after rainfall became more diverse, particularly with increased proportions of wood, coconut husk, and rubber. This pattern suggests that rainfall enhances river discharge, transporting a broader variety of terrestrial materials into coastal waters. Recent studies have demonstrated that rivers are the primary pathway through which land-based debris is transported to the marine environment, with rainfall and increased discharge substantially increasing debris flux into estuarine and coastal ecosystems (Chen et al., 2023; Luo et al., 2024).

The high proportion of plastic observed under both environmental conditions reflects its high buoyancy and persistence in aquatic environments, allowing it to remain afloat and be transported by waves, tides, and coastal currents (Kaandorp et al., 2023). Wood represented the second most abundant natural material at several sampling points after rainfall. This material most likely originated from tree branches and other vegetative debris transported by rivers during periods of increased runoff. Coconut husk also increased considerably after rainfall, indicating that natural organic debris contributes substantially to floating marine debris during high-discharge events. Rubber constituted the smallest proportion of floating marine debris at all sampling points. Its limited occurrence may be associated with lower environmental availability and greater potential for reuse or recycling before entering aquatic environments. Although international monitoring frameworks classify rubber as one of the common categories of marine debris, its abundance is generally much lower than that of plastic in floating marine debris surveys (United Nations Environment Programme, 2021).

The composition observed in the present study differs from that reported in other coastal regions. Previous investigations have identified additional categories of marine debris, including glass, metal, foam, paper, fishing gear, and other anthropogenic materials (Morales-Caselles et al., 2021; Ryan et al., 2009). The absence of glass and metal in this study may be related to their relatively high density, causing these materials to sink rapidly and reducing the likelihood of being captured during floating debris sampling. Differences in debris composition among studies are also influenced by local environmental conditions, sampling methods, hydrodynamic processes, and the dominant sources of marine debris.

3.3 Characteristics of floating marine debris

3.3.1 Physical characteristics

One of the physical characteristics evaluated in this study was the specific weight of floating marine debris. Specific weight was determined by comparing the weight of the collected debris with its corresponding volume. The results are presented in Figure 6.

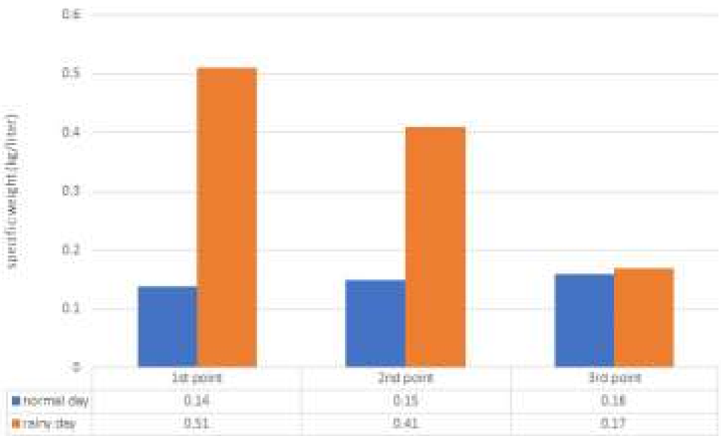

Figure 6. Specific weight of floating marine debris under normal weather and post-rainfall conditions

Figure 6 illustrates the specific weight of floating marine debris collected under normal weather conditions and after rainfall at the three sampling points. Under normal weather conditions, the specific weight was 0.14 kg L^{-1} at Point 1, 0.15 kg L^{-1} at Point 2, and 0.16 kg L^{-1} at Point 3, indicating only slight variation among the sampling locations. In contrast, the specific weight increased substantially after rainfall, reaching 0.51 kg L^{-1} at Point 1, 0.41 kg L^{-1} at Point 2, and 0.17 kg L^{-1} at Point 3. The greatest increase was observed at Point 1, while only a slight increase was recorded at Point 3. These results indicate that the specific weight of floating marine debris was generally higher after rainfall than under normal weather conditions. The differences in specific weight are associated with variations in the weight and volume of the collected debris. Samples collected after rainfall tended to have greater weight relative to their volume, resulting in higher specific weight values than those collected during normal weather conditions.

The increase in specific weight after rainfall is likely related to the transport of additional debris from upstream areas through river discharge. Rainfall increases surface runoff and river flow, allowing both natural and anthropogenic materials to be transported into coastal waters. Consequently, the collected debris after rainfall tended to contain heavier materials, resulting in higher specific weight values. Similar observations have been reported in previous studies, which demonstrated that rainfall events and river discharge significantly influence the transport characteristics and physical properties of floating marine debris in coastal environments (Chen et al., 2023; Luo et al., 2024). In addition to hydrodynamic conditions, the physical characteristics of floating marine debris are influenced by the intrinsic properties of the debris materials, including density, shape, and buoyancy. These properties determine the floating behaviour and transport pathways of marine debris in coastal waters (Calvert et al., 2024; Núñez et al., 2023). Therefore, the higher specific weight observed after rainfall in the present study is consistent with the greater transport of terrestrial debris into the coastal environment during periods of increased river discharge.

3.3.2 Chemical characteristics

The chemical characteristics of floating marine debris were evaluated by determining the moisture content, volatile matter, ash content, and fixed carbon of the collected samples. These parameters are widely used to assess the physicochemical properties of solid waste and provide essential information regarding its potential for biological treatment, thermal conversion, and resource recovery. The analytical results obtained from the three sampling locations under normal weather and post-rainfall conditions are presented in Table 2.

Table 2. Chemical characteristics of floating marine debris under different sampling locations and weather conditions

Weather Conditions	Chemical Characteristic	Point 1	Point 2	Point 3	Average
Normal days	Moisture content (%)	23	32.14	23	26.05
	Volatile matter (%)	49.63	58.7	60.66	56.33
	Ash (%)	12.20	2.60	10.80	8.53
	Fixed carbon (%)	15.17	6.56	5.54	9.09
Rainy days	Moisture content (%)	35.10	37.27	31.88	34.75
	Volatile matter (%)	43.04	54.75	46.18	47.99
	Ash (%)	3	4.40	4.21	3.87
	Fixed carbon (%)	18.86	3.58	17.73	13.32

Table 2 indicates that weather conditions influenced the chemical characteristics of floating marine debris. Overall, the average moisture content increased from 26.05% during normal weather conditions to 34.75% after rainfall. Conversely, the average volatile matter decreased from 56.33% to 47.99%, while the average ash content declined from 8.53% to 3.87%. In contrast, the average fixed carbon increased from 9.09% under normal weather conditions to 13.32% after rainfall. These variations suggest that rainfall primarily affected the moisture retained by the debris and subsequently altered the relative proportions of volatile, inorganic, and combustible fractions. Among the three sampling locations, point 2 consistently exhibited the highest moisture content under both weather conditions, reaching 32.14% during normal weather and increasing to 37.27% after rainfall. Under normal weather conditions, Points 1 and 3 recorded identical moisture contents of 23.00%, whereas after rainfall the moisture content increased at all sampling points to 35.10%, 37.27%, and 31.88%, respectively. The overall increase in moisture content after rainfall indicates that precipitation and increased river discharge enhanced water retention within the floating marine debris.

The average moisture content obtained in this study under normal weather conditions (26.05%) was lower than the average value reported for municipal solid waste in Padang City (32.42%), whereas the post-rainfall average (34.75%) was slightly higher. This difference suggests that weather conditions contributed to increased moisture accumulation in floating marine debris following rainfall while maintaining values comparable to those reported for municipal solid waste (Dewilda et al., 2020). Referring to SNI 19-7030-2004, the maximum allowable moisture content for compost is 50%, while the optimum moisture content for aerobic composting generally ranges between 50% and 60% (Tchobanoglous et al., 1993). The moisture contents observed under both normal and post-rainfall conditions remained below the maximum permissible limit, indicating that the biodegradable fraction of the collected marine debris has the potential to be utilized for composting following appropriate separation from non-biodegradable materials. Moisture content is widely recognized as one of the primary parameters influencing microbial activity, waste stabilization, storage behavior, and the efficiency of biological and thermochemical treatment processes (Vasileiadou et al., 2023).

The higher volatile matter observed under normal weather conditions suggests that the collected debris contained a relatively greater proportion of volatile organic compounds than the debris collected after rainfall. The average volatile matter was 56.33% under normal weather conditions and decreased to 47.99% after rainfall, indicating a reduction in the volatile fraction following rainfall events. The volatile matter content obtained in this study falls within the typical range of 40–60% reported for municipal solid waste, indicating that the combustible organic fraction of the collected debris is comparable to that of conventional municipal solid waste (Tchobanoglous et al., 1993). Volatile matter is widely recognized as one of the principal indicators for evaluating fuel characteristics, ignition behavior, and the thermal conversion potential of solid waste (Vasileiadou et al., 2023).

The average ash content decreased from 8.53% under normal weather conditions to 3.87% after rainfall, indicating a lower proportion of inorganic residue in the collected debris following rainfall. Ash represents the inorganic material remaining after complete combustion and reflects the proportion of non-combustible constituents contained in solid waste. Although the average ash content obtained in this study was lower than the typical 10–30% range reported for municipal solid waste, lower ash content generally indicates a smaller amount of residual material remaining after thermal treatment and a relatively higher proportion of combustible components (Tchobanoglous et al., 1993). Based on these results, the combustible fraction of floating marine debris may be considered suitable for thermal treatment technologies, such as incineration or waste-to-energy systems. Proximate analysis, particularly ash content, is widely used to evaluate combustion characteristics, process efficiency, and the energy recovery potential of solid waste ((Vasileiadou et al., 2023).

The average fixed carbon increased from 9.09% under normal weather conditions to 13.32% after rainfall. However, the distribution of fixed carbon among the three sampling locations did not exhibit a consistent spatial pattern. This finding suggests that variations in fixed carbon were more closely associated with differences in the composition of the collected debris than with rainfall alone. Fixed carbon represents the solid combustible residue remaining after the release of moisture and volatile matter and is commonly used to evaluate the fuel quality and energy recovery potential of solid waste materials (Vasileiadou et al., 2023). Overall, the chemical characterization demonstrates that rainfall primarily influenced the moisture content, volatile matter, and ash content of floating marine debris, whereas variations in fixed carbon appeared to be more closely associated with differences in debris composition than with rainfall alone. These findings provide useful baseline information for determining appropriate management strategies, including biological treatment for biodegradable fractions and thermal conversion technologies for combustible materials. Furthermore, the proximate analysis indicates that the collected floating marine debris possesses characteristics that may support resource recovery following appropriate waste segregation and pretreatment (Vasileiadou et al., 2023).

3.4 Recycling potential of floating marine debris

The recycling potential of floating marine debris was evaluated based on the composition of organic and inorganic materials identified during the field survey. As presented in the composition analysis, the dominant recyclable materials collected from Gajah Beach and Pasir Putih Tabing Beach included plastic, wood, rubber, textile waste, and coconut husks. The presence of these materials indicates that a considerable proportion of floating marine debris has the potential to be recovered and reintroduced into the material cycle rather than being disposed of as waste. Plastic waste represented the largest proportion of floating marine debris and therefore exhibited the greatest recycling potential. Based on the observed waste characteristics, recyclable plastic materials primarily consisted of polyethylene terephthalate (PET) bottles, high-density polyethylene (HDPE) containers, and low-density polyethylene (LDPE) packaging. These materials are widely accepted in conventional recycling systems and can be processed into secondary products such as food containers, shopping bags, plastic bottles, buckets, pipes, hoses, and other plastic products. In addition, recycled plastics can be converted into plastic pellets that serve as raw materials for manufacturing new plastic products (Hopewell et al., 2009; Jeswani et al., 2021).

Wood waste also demonstrated considerable recycling potential. Following appropriate cleaning, sorting, and processing, recovered wood can be reused or remanufactured into furniture, household products, wall panels, flooring materials, decorative items, and other value-added products. Extending the service life of wood products through reuse and refurbishment contributes to material efficiency, reduces the demand for virgin timber resources, and supports circular resource utilization (Russell et al., 2023; Yang & Zhu, 2021). Similarly, textile waste recovered from floating marine debris can be recycled into various value-added products, including reusable bags, tablecloths, cushion fillings, insulation materials, and handicrafts. Textile recycling has become an important component of the circular economy because it reduces waste disposal, conserves raw materials, and minimizes the environmental impacts associated with textile production. Furthermore, increasing textile reuse and recycling can significantly reduce material consumption and environmental burdens across the textile life cycle (Keßler et al., 2021).

Among the organic materials, coconut husks also exhibited recycling potential because they can be utilized as organic growing media, mulch, compost feedstock, and natural soil conditioners. Owing to their high lignocellulosic content, water-holding capacity, and favorable physical properties, coconut husks have been widely utilized as renewable agricultural substrates and bio-based materials, thereby supporting the recovery and utilization of biodegradable waste (Agegnehu et al., 2016; Evans et al., 1996). Overall, the composition of floating marine debris observed in this study indicates that a substantial proportion of the collected materials has the potential to be recycled or recovered through appropriate waste segregation and processing. Strengthening waste segregation at the source, collection systems, and recycling infrastructure would improve material recovery while reducing the quantity of debris entering coastal ecosystems. These findings are consistent with the principles of the circular economy, which emphasize maintaining material value through reuse, repair, remanufacturing, and recycling to minimize waste generation and maximize resource efficiency (Kirchherr et al., 2017; Russell et al., 2023).

4. Conclusion

This study demonstrated that the density, composition, physical characteristics, chemical characteristics, and recycling potential of floating marine debris differed between normal and post-rainfall conditions along Gajah Beach and Pasir Putih Tabing, Padang City. Plastic waste remained the dominant component of floating marine debris under both environmental conditions, although its proportion decreased after rainfall due to the increased contribution of other waste types transported into the coastal environment. Rainfall also influenced the physical and chemical characteristics of the collected debris, resulting in higher average specific gravity, moisture content, and fixed carbon, while volatile matter and ash content generally decreased following rainfall. The composition analysis further revealed that a substantial proportion of floating marine debris possesses resource recovery potential. Organic materials, particularly coconut husks, have the potential to be utilized as composting feedstock and soil amendments, whereas recyclable inorganic materials, including plastics, wood, and textiles, can be recovered and processed into secondary products through appropriate recycling practices. These findings highlight the importance of implementing integrated marine debris management strategies that emphasize waste segregation, material recovery, and recycling to reduce coastal pollution while supporting circular resource utilization.

Author's declaration

Author contribution

Rizki Aziz: Conceptualization, methodology, validation, supervision, project administration, and writing, review and editing. **Budhi Primasari**: Methodology, investigation, formal analysis, data curation, and writing of the original draft. **Hirzan Salda Putra**: Investigation, field sampling, laboratory analysis, data curation, and visualization. **Cici Amelia Edriani**: Investigation, formal analysis, validation, and writing, review and editing. All authors contributed to the interpretation of the results, critically reviewed the manuscript, and approved the final version for publication.

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Data availability

The data supporting the findings of this study were generated from field sampling and laboratory analyses conducted at Gajah Beach and Pasir Putih Tabing Beach, Padang City, Indonesia. The data include floating marine debris density, composition, physical and chemical characteristics, and recycling potential. The supporting data are available from the corresponding author upon reasonable request.

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Conflict of interest

The authors declare that they have no financial or non-financial conflicts of interest that could have influenced the design, implementation, analysis, interpretation, or presentation of the results reported in this manuscript.

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Ethical clearance

Not applicable

AI statements

ChatGPT (OpenAI) was used solely to assist with English language editing, including grammar, sentence structure, clarity, and readability. All AI-assisted text was carefully reviewed, revised, and verified by the authors against the original field observations, laboratory results, and cited references. No AI tools were used to generate, analyze, or modify research data, statistical analyses, tables, figures, or scientific conclusions. The authors take full responsibility for the accuracy, originality, interpretation, and integrity of the manuscript.

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