

Microplastic contamination in coastal sediments along the northern Cirebon coast, West Java, Indonesia: A preliminary assessment

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Abstract

Microplastic pollution in coastal sediments is a growing concern in tropical Southeast Asia, yet published data for the north coast of West Java remain scarce. This study reports a preliminary survey of microplastic occurrence in surface sediments (0 to 5 cm) at four sites along the northern Cirebon coast, West Java, Indonesia: Kejawanan, Mundu, Gebang and Losari. One composite sample per site was processed by saturated NaCl density separation, filtration and stereomicroscopic examination. Forty-five suspected microplastic particles were recovered from 297.59 g of dry sediment, giving site abundances of 125 to 178 particles per kg dry weight (site mean 152), highest at Losari and lowest at Kejawanan. Fibres dominated the assemblage (29 particles, 64.4 per cent), followed by fragments (11), films (4) and a single pellet. Twenty particles measured below 1 mm, and no colour category was dominant. Because polymer identity was not confirmed spectroscopically, no blanks were processed, and the pooled count is only 45 particles, these values are upper bound estimates rather than verified concentrations, and no ecological risk classification is assigned. The fibre share is the result most exposed to airborne contamination, and two particles separate the highest and lowest sites, so the spread is not read as a gradient. Values fall below those reported for beach sediments elsewhere in Cirebon and for estuarine sediments in Surabaya and Jakarta Bay, most plausibly reflecting methodological heterogeneity. The results give a provisional reference point and identify the steps still required: spectroscopic confirmation, blank correction, larger processed masses and replication.

Keywords: *Microplastics; Coastal sediments; Cirebon; Quality assurance; Preliminary survey*

Introduction

The rapid growth of plastic production and consumption has led to a significant increase in plastic waste entering natural environments, particularly marine and coastal ecosystems. Plastics degrade into smaller particles known as microplastics, typically defined as plastic fragments smaller than 5 mm, which can persist in the environment for long periods due to their resistance to biological degradation. Microplastics have become a global environmental concern because they accumulate in oceans, sediments, and coastal zones, potentially affecting ecosystem health

and biodiversity (Andrady, 2011; Barnes et al., 2009; Thompson et al., 2004). Coastal environments are especially vulnerable because they act as sinks for land-based plastic waste transported through rivers and coastal currents, resulting in the accumulation of microplastics in sediment layers (Browne et al., 2011; Jambeck et al., 2015; Van Sebille et al., 2015). As plastic pollution continues to increase globally, understanding the distribution and ecological risks of microplastics in coastal sediments has become an important topic in environmental quality research (GESAMP, 2015; Moore, 2008; Shahul Hamid et al.,

2018). Microplastics can originate from both primary sources, such as industrial plastic pellets and microbeads, and secondary sources derived from the fragmentation of larger plastic debris in the environment. Once present in marine ecosystems, microplastics may interact with physical, chemical, and biological components of the environment. Their small size allows them to be easily ingested by marine organisms, including zooplankton, fish, and benthic organisms, potentially causing physiological stress and toxicological effects (Cole et al., 2011; Wright et al., 2013; Galloway et al., 2017). Furthermore, microplastics can act as vectors for hazardous chemicals and persistent organic pollutants, which may adsorb onto their surfaces and subsequently enter the food chain (Hartmann et al., 2019; Rochman et al., 2013). These characteristics make microplastic contamination a complex environmental issue that not only threatens marine biodiversity but also poses potential risks to human health through seafood consumption (Prata, 2018; Ziani et al., 2023). Sediments generally retain higher microplastic concentrations than the overlying water column, so they are widely used as the reference compartment for assessing coastal contamination (Browne et al., 2011; Peng et al., 2017). Quantification of microplastics in sediment normally proceeds through density separation, filtration and microscopic sorting (Hidalgo-Ruz et al., 2012; Coppock et al., 2017). Visual sorting alone, however, is now regarded as insufficient: reported false positive rates are substantial for particles below 1 mm, and current guidance requires spectroscopic confirmation of a random subset together with procedural blanks and recovery testing before abundance values can be compared across studies (Brander et al., 2020). Risk frameworks that weight particles by polymer hazard, such as the polymer hazard index and the potential ecological risk index, therefore cannot be applied to datasets that lack polymer identification; only abundance based indices such as the contamination factor and the pollution load index remain available in that situation (Ranjani et al., 2021). Within Indonesia, sediment microplastic concentrations reported to date span more than two orders of magnitude, from about 31 particles per kg in Benoa Bay, Bali (Suteja et al., 2024), through 414 to 590 particles per kg in the Jagir estuary and Wonorejo coast of Surabaya (Firdaus et al., 2020), to values exceeding 30,000 particles per kg reported for Jakarta Bay (Azizi et al., 2021). Much of this spread is attributable to differences in flotation salt, digestion protocol, filter pore size and lower size cut off rather than to real dif-

ferences in contamination, which is precisely why methodological reporting has become the limiting factor for regional comparison (Brander et al., 2020; Cordova et al., 2021). For the northern coast of West Java the evidence base is much thinner. The Cirebon coastline supports capture fisheries, brackish water aquaculture, salt production and a national fishing port, and its estuarine waters are already documented as receiving substantial land derived contaminant loads (Hartiningsih et al., 2024) and poorly managed riverine plastic waste (Astuti et al., 2023). Only one peer reviewed sediment microplastic dataset has been published for this coast, covering beach sediments at five sites and reporting a mean of 583 particles per kg dry weight dominated by films (Ratu and Utami, 2026). No comparable data exist for the intertidal and estuarine sediments that adjoin the fishing harbour, the managed mangrove blocks and the fishpond belt, and no Cirebon dataset has yet been accompanied by the blank correction and recovery testing needed to bound its uncertainty. This study therefore has two limited and explicitly bounded objectives. The first is to report the occurrence, apparent abundance and physical characteristics of suspected microplastic particles in surface sediments at four contrasting sites along the northern Cirebon coast. The second is to place those values in the context of previously published Indonesian sediment datasets and to identify, transparently, which analytical requirements the present dataset does not yet meet. We test the working expectation that apparent abundance is higher at sites receiving direct riverine and agricultural drainage than at the harbour site, where a mangrove fringe may intercept buoyant debris (Martin et al., 2019). No ecological risk classification is attempted, because the polymer information such a classification requires was not obtained.

Materials and Methods

Research design

This study used an exploratory, single visit field survey design. One composite surface sediment sample was collected at each of four sites and processed in the laboratory to record the occurrence, apparent abundance and physical characteristics of suspected microplastic particles. The design is descriptive rather than inferential. With a single composite sample per site there is no within site replication, so the data cannot separate between site differences from within site heterogeneity and no significance testing is performed or implied anywhere in this manuscript. In addition, the

study adopted standardized analytical procedures for the detection, identification, and classification of microplastics in environmental samples, which have been widely applied in marine pollution studies. Such methodological approaches are essential for ensuring comparability of results across different microplastic studies and for improving the reliability of environmental contamination assessments (Hidalgo-Ruz et al., 2012). The protocol followed here reproduces the core steps of that approach but omits two elements that current guidance treats as mandatory, namely procedural blank correction and spectroscopic polymer confirmation (Brander et al., 2020). Both omissions are stated at the point of occurrence in the sections below and their consequences are carried through to the Results and Discussion.

Population and location

The sampling frame was the intertidal surface sediment of the northern Cirebon coast between Kejawanan and Losari, a stretch of roughly 25 km of shoreline. The research locations were selected using a purposive sampling technique to span four contrasting coastal settings: a national fishing harbour, a managed mangrove estuary, an accreting shoreline under fishpond conversion, and a river fed shoreline adjacent to agricultural land. Purposive selection is appropriate for an exploratory survey but is not probabilistic, so the four sites are not a random sample of the coastline and the values reported here should not be extrapolated to unsampled stretches. The study was conducted at four coastal sampling sites along the northern coast of Cirebon, West Java, Indonesia (Fig. 1). Full site coordinates, sampling dates, tidal stage and antecedent rainfall are given in Table 1. Positions were recorded with a Garmin eTrex 22x handheld GPS receiver, for which the manufacturer states a horizontal accuracy of approximately 3 m under open sky conditions; coordinates are reported in WGS84 and are quoted to a precision consistent with that accuracy rather than to 0.1 arc-second. Sampling on the shoreline adjacent to Pelabuhan Perikanan Nusantara Kejawanan and within the managed mangrove block at Mundu Pesisir. The area is characterised by mixed land use including fishponds (tambak), mangrove remnants, rice paddies, fishing settlements, and active fishing harbours. Each site was selected to represent a distinct combination of anthropogenic pressure and coastal setting:

Site 1 – Kejawanan (6°44'1.0" S, 108°35'8.8" E)

Located adjacent to the Pelabuhan Perikanan Nusantara (PPN) Kejawanan, the principal fishing har-

Table 1. Sampling site metadata for the four coastal sediment stations, northern Cirebon coast. Coordinates are WGS84. Tidal stage is that observed at the time of sampling, and rainfall is the cumulative total recorded over the seven days before each sampling date.

Site	Coordinates (WGS84)	Sampling date	Tidal stage / rainfall, 7 days prior
1 Kejawanan	6°44'01" S, 108°35'09" E	15 January 2025	Falling tide / 42 mm
2 Mundu	6°45'20" S, 108°34'20" E	16 January 2025	Low tide / 38 mm
3 Gebang	6°49'06" S, 108°43'42" E	17 January 2025	Rising tide / 51 mm
4 Losari	6°48'56" S, 108°48'14" E	18 January 2025	Low tide / 57 mm

bour of Cirebon city. The site is characterised by high vessel traffic, fish landing activities, and urban surface runoff reaching the shore from the adjacent catchment. A mangrove buffer zone and sandy beach front define its northern boundary.

Site 2 – Mundu (6°45'19.5" S, 108°34'19.6" E)

Situated at Mundu Pesisir within Muara Mundu estuary, featuring approximately 9.95 ha of managed mangrove forest. The surrounding area is dominated by small scale fisheries and extensive brackish water aquaculture. Potential plastic inputs include riverine transport and material associated with aquaculture infrastructure.

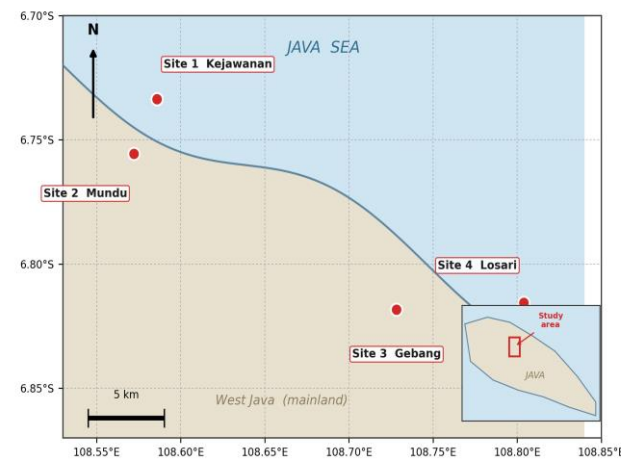


Figure 1. Map of the four coastal sediment sampling sites along the Cirebon coastal region, West Java, Indonesia, showing coastal land cover, the fishing harbour, managed mangrove blocks and the fishpond belt. Coordinates are WGS84.

Site 3 – Gebang (6°49'5.7" S, 108°43'41.6" E)

Located at Pantai Baro in Kecamatan Gebang, Cirebon Regency, a coastal zone characterised by progressive accretion and conversion of mangrove land to fishponds and salt ponds. The site is flanked by coastal settlements (Gebang Kulon and Gebang Ilir) and a small fishing pier.

Site 4 – Losari (6°48'56.3" S, 108°48'14.4" E)

The easternmost site, near the Cirebon–Brebes administrative boundary. Surrounded by fishpond areas, rice paddies, and a coastal fishing village. Potential plastic debris pathways at this site are riverine discharge draining agricultural land and material associated with fishing gear.

Data collection

Data collection involved field sampling followed by laboratory analysis of sediment samples.

Field Sampling. Sediment samples were collected from the surface layer (0 to 5 cm) because microplastics are typically concentrated in the upper sediment layers where recent deposition occurs. This depth range has been widely adopted in coastal microplastic studies to capture contemporary contamination patterns (Hidalgo-Ruz et al., 2012). A stainless steel grab sampler was used throughout, to minimise contamination from plastic equipment. At each site, five sub-samples were collected along a 10 m shore parallel transect at 2 m intervals, above the most recent high water mark, and homogenised into a single composite sample. The composites were placed in clean glass containers sealed with aluminium foil lined lids and transported to the laboratory. Field wet mass was not recorded; all quantities in this manuscript are expressed on a dry mass basis, and the dry mass actually processed at each site is reported in Table 3.

Density separation. In the laboratory, each composite was oven dried at 40 °C to constant weight over 24 h and then homogenised. A weighed sub-portion of the dried, homogenised composite was carried forward to density separation; this sub-portion was weighed to 0.01 g and its mass is the denominator of every abundance value reported here (Table 3). Abundance is expressed throughout as the number of suspected particles divided by that recorded dry mass, so each value in the Results can be recomputed from the two figures given. A saturated NaCl solution (density approximately 1.2 g cm⁻³, pre-filtered through a 0.45 µm membrane) was added to the weighed sub-portion, the mixture was left to settle for 30 min, and the floating

fraction was carefully collected; the flotation step was repeated on each sub-portion. No organic matter digestion step (for example hydrogen peroxide or potassium hydroxide) was applied. Two consequences follow and are carried into the Discussion. First, saturated NaCl cannot float denser polymers such as polyvinyl chloride, polyethylene terephthalate and polyurethane, so this protocol systematically under-reovers that fraction, and a denser flotation medium such as zinc chloride or sodium iodide would be required to capture it (Coppock et al., 2017). Second, in organic rich mangrove and fishpond sediments, undigested plant and detrital material remains on the filter and can be mistaken for particles during visual sorting.

Filtration. The collected floating fraction was passed through Whatman GF/A glass fibre membranes of 1.6 µm nominal pore size, which also defines the lower size detection limit of this study, to retain microplastic particles. The retained material on each filter was then dried in covered glass Petri dishes at 40 °C and prepared for microscopic examination.

Microscopic identification and classification. Retained particles were examined under an Olympus SZ61 stereomicroscope (Olympus Corporation, Japan) at 40x magnification to identify suspected microplastics based on morphological characteristics including shape, colour, size and texture. Particles were classified as suspected microplastics using the visual criteria of Hidalgo-Ruz et al. (2012), namely absence of visible cellular or organic structure, homogeneous colouration, and uniform thickness, supplemented by the hot needle test where a particle was ambiguous. All particles reported in this manuscript are therefore suspected microplastics. No spectroscopic confirmation was performed, and visual criteria alone are known to misclassify a substantial share of particles below 1 mm, so the counts reported here should be read as upper bounds (Brander et al., 2020). Particles were further classified into four morphological categories following Hidalgo-Ruz et al. (2012): fibres (elongated, thread like particles from synthetic textiles and fishing gear), fragments (irregular, angular particles from mechanical or photochemical breakdown), films (thin, flexible, often transparent sheets from plastic bags and packaging), and pellets (spherical or ovoid pre-production granules). Particle size was measured along the longest dimension using calibrated ocular micrometry and grouped into four size classes: below 1 mm, 1 to 2 mm, 2 to 3 mm, and 3 to 5 mm. Colour of each particle was recorded visually as transparent, blue, black, white or red.

Quality assurance and quality control. The following controls were not implemented in the present study and are reported here as a declared deficiency rather than omitted, because the dominant morphotype recovered was fibre, which is the category most susceptible to airborne and textile derived cross contamination (Brander et al., 2020). No air blanks, no reagent blanks and no filter blanks were processed, and no blank correction was therefore applied to the counts reported in the Results. No spike recovery test was performed, so extraction efficiency for this sediment matrix is unknown. Cotton laboratory coats were worn during processing, but samples were not covered during handling, which leaves an unquantified route for airborne fibre deposition. For any resubmission of this dataset as a definitive rather than preliminary record, the minimum additions required are three air blanks and three reagent blanks per processing batch reported separately from sample counts, a spike recovery test using polymer particles of known size and count, and attenuated total reflectance FTIR confirmation of a randomly selected subset of at least 10 per cent of particles with a library match threshold of 70 per cent or higher.

Data Analysis

Microplastic abundance. Microplastic abundance was calculated as the number of particles per kilogram of dry sediment (particles kg⁻¹), that is the raw particle count for a site divided by the recorded dry mass of that composite sample. Both the numerator and the denominator are reported for every site in Table 3 so that readers can recompute the values, providing a standardized measure for comparing contamination levels across sampling sites.

Morphological, size and color analysis. Microplastic particles were grouped according to morphological type, size class, and color. Relative proportions were calculated as simple percentages of the total particle count and are reported alongside the underlying counts, because a percentage without its denominator cannot be evaluated. No inferential statistics were applied. With one composite sample per site there is no measure of within site variance, so neither analysis of variance nor any other between site test is admissible on these data, and none is reported.

Contamination indices. Two abundance based contamination indices that do not require polymer identification are applied (Ranjani et al., 2021). The contamination factor is $CF = C_i / C_0$, where C_i is the

suspected microplastic abundance at site i and C_0 is a regional background value; following the practice of using the lowest abundance in the survey as the reference, C_0 was set to 125 particles kg⁻¹ (Site 1). The pollution load index for a site is $PLI = \sqrt[n]{CF}$, and for the survey as a whole $PLI\text{-zone}$ is the n th root of the product of the site PLI values. Indices that weight particles by polymer hazard, including the polymer hazard index and the potential ecological risk index, are not computable from this dataset and are therefore not reported. Because the underlying counts are neither blank corrected nor spectroscopically confirmed, the indices reported here are provisional relative descriptors of contamination and are not translated into an ecological risk statement. The classification bands used for reference are shown in Table 2.

Table 2. Reference classification bands for the pollution load index (PLI) after Ranjani et al. (2021). The bands are reproduced for orientation only; no risk category is assigned to the present dataset.

PLI Value	Contamination level	Interpretation
0 to 10	Low	Abundance close to the survey reference value.
11 to 20	Moderate	Abundance elevated relative to the survey reference value.
> 20	High	Abundance strongly elevated relative to the survey reference value.

Results

Abundance of microplastics in coastal sediments

Suspected microplastic particles were recorded in all four coastal sediment samples, indicating that plastic derived particles are present along this stretch of the Cirebon coast. Abundance values ranged from 125 particles kg⁻¹ dry wt at Site 1 (Kejawanan) to 178 particles kg⁻¹ at Site 4 (Losari), with a site mean of 152 particles kg⁻¹ and a pooled value of 151.2 particles kg⁻¹ (Table 3). Raw particle counts and the dry sediment mass from which each abundance value was derived are given in Table 3. The counts are small: between 10 and 13 particles per site, and 45 particles in total across the survey. At these masses a single particle shifts site abundance by roughly 13 to 15 particles kg⁻¹, so the observed spread between sites corresponds to a difference of only two particles and cannot be treated as a spatial signal. Because each value also rests on a single composite sample, the differences between sites

Table 3. Suspected particle counts, mass of the dried sub-portion processed, and derived abundance for each composite sample. Abundance is the count divided by the processed dry mass. The pooled value (151.2 particles kg⁻¹) is the total count divided by the total processed mass; the site mean (152 particles kg⁻¹) is the unweighted mean of the four site values and is the figure quoted elsewhere in this manuscript.

Site	Dry sub-portion processed (g)	Particles counted (n)	Abundance (particles kg ⁻¹)
1 Kejawanan	80.00	10	125
2 Mundu	79.75	13	163
3 Gebang	70.42	10	142
4 Losari	67.42	12	178
Total / mean	297.59	45	151.2 pooled 152 site mean

are reported as observed values without any claim that they are statistically distinguishable, and possible explanations are considered as hypotheses in the Discussion rather than as demonstrated causes. The highest abundance at Site 4 (Losari, 178 particles kg⁻¹) coincides with a shoreline receiving drainage from adjacent agricultural land, and the lowest value at Site 1 (Kejawanan, 125 particles kg⁻¹) occurs at the site with a mangrove fringe, but with one sample per site neither association can be distinguished from chance and both are treated as hypotheses in the Discussion. Placing these values in the Indonesian context is not straightforward. They are roughly a quarter of the mean reported for beach sediments elsewhere on the same Cirebon coastline (583 particles kg⁻¹; Ratu and Utami, 2026), below the range reported for the Jagir estuary and Wonorejo coast in Surabaya (414 to 590 particles kg⁻¹; Firdaus et al., 2020), and far below values reported for Jakarta Bay (Azizi et al., 2021), while exceeding those reported for Benoa Bay in Bali (31 particles kg⁻¹; Suteja et al., 2024). Because those studies differ in flotation salt, digestion, filter pore size and lower size cut off, and because the present study applied no blank correction, this spread cannot be read as a contamination gradient (Table 8). The comparison is presented to bound the plausible range rather than to rank sites. A global range of 100 to 300 particles kg⁻¹ drawn from a worldwide review would be too coarse to support a claim at this scale.

Morphological characteristics of microplastics

Analysis of morphological composition revealed that fibres were by far the most frequent morphotype, at 29

Table 4. Morphological composition of suspected microplastic particles, pooled across the four sampling sites (n = 45). Counts are not blank corrected.

Morphological type	Count (n)	Proportion (%)
Fibre	29	64.4
Fragment	11	24.4
Film	4	8.9
Pellet	1	2.2
Total	45	100.0

of the 45 particles recovered (64.4 per cent), followed by fragments (11 particles, 24.4 per cent), films (4 particles, 8.9 per cent) and pellets (Table 4). Only a single pellet was recovered across the entire survey, so no inference about pre-production resin input is drawn from it. Counts are pooled across the four sites; per site compositions are not reported because with 10 to 13 particles per site a site level comparison of four morphological categories is not meaningful. The fibre result carries a specific qualification. Fibres are the morphotype most readily introduced by airborne and textile derived laboratory contamination, and because no procedural blanks were processed and samples were not covered during handling, the value of 64.4 per cent must be treated as an upper bound. The higher the fibre share, the larger the fraction of the dataset that a blank correction could in principle remove, so this figure is the single result in this manuscript most in need of verification. The prevalence of fibre type particles is consistent with the widespread release of synthetic textile fibres from domestic laundry and with the degradation of fishing ropes, nets and lines used in the Cirebon coastal area (Browne et al., 2011; Napper et al., 2022). Fragments, the second most frequent type, indicate breakdown of larger plastic debris including packaging materials and disposable consumer goods within the intertidal and subtidal zones. Films (4 particles) and pellets (1 particle) were recovered in numbers too small to support any source statement. It is worth noting that the only other published sediment dataset from this coastline found films rather than fibres to be dominant, at 84 per cent (Ratu and Utami, 2026). Whether this contrast reflects a real difference between beach and intertidal or estuarine settings, or a difference in sorting protocol and contamination control, cannot be resolved without blank corrected and spectroscopically confirmed data from both studies.

Size distribution of microplastics

The size distribution analysis showed a dominance of the smallest particles: 20 of 45 particles (44.4 per cent) measured below 1 mm (Table 5). The 1 to 2 mm class contained 15 particles (33.3 per cent), the 2 to 3 mm class 7 particles (15.6 per cent), and the 3 to 5 mm class 3 particles (6.7 per cent). Two constraints apply. The lower bound of the reported range is set by the 1.6 µm filter pore size rather than by the particle population itself, so the sub millimetre fraction is truncated and its true share is unknown. In addition, visual identification is least reliable precisely in this size class, so the 44.4 per cent value carries the largest uncertainty of any figure in this manuscript (Brander et al., 2020). The predominance of sub-millimetre particles has potential ecological significance: particles smaller than 1 mm are the most bioavailable to a wide range of benthic and coastal organisms, including polychaetes, bivalves, and small crustaceans that form part of the local food web (Galloway et al., 2017; Hidalgo-Ruz et al., 2012). The decline in proportional share with increasing size class is consistent with progressive fragmentation, although fragmentation rate was not measured here and the pattern is equally consistent with size selective deposition. A comparable predominance of the sub millimetre fraction, at 51 per cent, was reported for beach sediments on the same coastline (Ratu and Utami, 2026). The earlier comparison drawn from lakeshore sediments on the Tibetan Plateau has been excluded as environmentally inapposite.

Table 5. *Size class distribution of suspected microplastic particles, pooled across the four sampling sites (n = 45). The lower size limit is set by the 1.6 µm filter pore size and is not a property of the particle population.*

Size class	Count (n)	Proportion (%)
< 1 mm	20	44.4
1 to 2 mm	15	33.3
2 to 3 mm	7	15.6
3 to 5 mm	3	6.7
Total	45	100.0

Color characteristics of microplastics

Colour classification of the 45 suspected particles gave transparent 12 (26.7 per cent), black 11 (24.4 per cent), blue 10 (22.2 per cent), white 8 (17.8 per cent) and red 4 (8.9 per cent) (Table 6). No category is clearly dominant: the top three differ by two particles, which

Table 6. *Colour distribution of suspected microplastic particles, pooled across the four sampling sites (n = 45).*

Colour category	Count (n)	Proportion (%)
Transparent	12	26.7
Black	11	24.4
Blue	10	22.2
White	8	17.8
Red	4	8.9
Total	45	100.0

is within the counting variation of a sample this size. Colour is recorded here as a descriptive attribute only and is not used as evidence of source, for the reasons set out in the Discussion. Transparent (12 particles), black (11) and blue (10) particles occur in almost equal numbers, and no colour category dominates. These counts are reported as description only. Blue is commonly associated with synthetic rope and netting and with textile fibres, and abrasion of maritime rope is a documented release pathway for such fibres (Napper et al., 2022). No source attribution is made from these proportions, however, because colour is altered by ultraviolet bleaching and biofouling during environmental residence, because the transparent category will absorb particles that were originally coloured, and because a two particle difference between categories cannot be distinguished from counting variation at this sample size. Source assignment requires polymer identification, which this study did not perform.

Contamination indices

Because no polymer identification was performed in this study, indices that require polymer hazard weighting, including the polymer hazard index and the potential ecological risk index, cannot be computed for this dataset. Contamination factors and pollution load indices computed from abundance alone are reported in Table 7, using the lowest surveyed abundance (125 particles kg⁻¹) as the reference value C0. Contamination factors range from 1.00 at Kejawanan to 1.42 at Losari, and the corresponding site pollution load indices from 1.00 to 1.19, giving a zone value of 1.09. These figures describe relative differences within this survey only. They are deliberately not converted into a risk category, because the underlying counts are neither blank corrected nor spectroscopically confirmed. The spread of contamination factors across the four sites is narrow, from 1.00 to 1.42. A difference of this magnitude is well within the range that could be produ-

Table 7. Contamination factor (CF) and pollution load index (PLI) for each sampling site, computed from suspected microplastic abundance with $C0 = 125$ particles kg^{-1} . No risk category is assigned.

Sampling Site	Abundance (particles kg^{-1})	CF	PLI
Site 1 – Kejawanan	125	1.00	1.00
Site 2 – Mundu	163	1.30	1.14
Site 3 – Gebang	142	1.14	1.07
Site 4 – Losari	178	1.42	1.19

ced by sub-sampling variability alone in a survey with no within site replication, and it should not be read as an established spatial gradient. Suspected microplastic particles were present at every site, and their presence rather than their relative ranking is the finding this dataset supports. Any statement about toxicological consequence would require polymer identification, sorbed contaminant measurement and organism level exposure data, none of which were collected here.

Discussion

Microplastic abundance and spatial distribution

Suspected microplastic particles were recorded at all four sites, which is consistent with the established role of coastal sediments as accumulation zones for land derived plastic debris (Browne et al., 2011; Peng et al., 2017). The mean of 152 particles kg^{-1} dry weight sits in the lower part of the published Indonesian range. It is below the 583 particles kg^{-1} reported for beach sediments on this same coastline (Ratu and Utami, 2026),

below the 414 to 590 particles kg^{-1} reported for the Jagir estuary and Wonorejo coast (Firdaus et al., 2020), and above the 31 particles kg^{-1} reported for Benoa Bay (Suteja et al., 2024). Interpreting this position requires caution. The studies compared in Table 8 differ in flotation medium, digestion step, filter pore size and lower size cut off, and the present study additionally lacks blank correction, all of which shift measured abundance independently of true contamination (Brander et al., 2020; Cordova et al., 2021). The most defensible reading is that this survey did not detect abundance markedly higher than elsewhere in Indonesia, not that the Cirebon intertidal zone is less contaminated than comparable coasts. The ordering of sites, with Losari highest and Kejawanan lowest, is offered as a hypothesis rather than an explained result. Two mechanisms are plausible. Riverine transport from agricultural land is a documented land to sea pathway for plastic debris in Indonesia and could elevate the Losari value (Jambeck et al., 2015), and mangrove stands are documented to intercept buoyant litter and could depress the Kejawanan value (Martin et al., 2019). Neither mechanism is tested here. No measurements of riverine debris flux, mangrove extent, current velocity or sediment grain size were taken, and with a single composite sample per site the observed spread of 53 particles kg^{-1} cannot be distinguished from within site heterogeneity. Testing either hypothesis would require replicated sampling paired with granulometry and organic matter measurement, since microplastic retention in sediment correlates strongly with the fine fraction.

Table 8. Published sediment microplastic abundances from Indonesian coastal and estuarine settings, shown together with the methodological choices that most strongly affect the reported value. The table is presented to demonstrate that cross study ranking is not warranted on present evidence.

Study and location0	Abundance (particles kg^{-1} dw)	Polymer confirmation	Blanks / replication
This study, Cirebon intertidal	125 to 178 (mean 152)	none	none / 1 composite per site
Ratu and Utami (2026), Cirebon beaches	583 ± 166	FTIR and Raman	yes / 15 samples, 5 sites
Firdaus et al. (2020), Surabaya	414 to 590	FTIR	yes / replicated, 5 sites
Suteja et al. (2024), Benoa Bay, Bali	9.5 to 90.6 (mean 31.1)	FTIR, 17 polymers	yes / 8 stations, 4 surveys
Cordova et al. (2021), Muara Angke	see source	FTIR	yes / replicated

Morphological composition and source attribution

The dominance of fibres, at 29 of 45 particles (64.4 per cent), is consistent with the broader global pattern of fibre prevalence in coastal and marine sediment environments, where fibres typically constitute the largest morphological fraction due to their release from syn-

thetic textiles and fishing related materials (Browne et al., 2011; Cole et al., 2011). That said, the same pattern is also the expected signature of unmitigated airborne contamination in a laboratory without blank control, and the present study cannot separate the two explanations. This ambiguity is the single most consequential

limitation of the dataset, and it is more acute here than in most comparable surveys, because fibres make up nearly two thirds of the total recovered. If blank correction were to remove even a modest number of fibres, both the reported abundance and the compositional profile would shift materially. If the fibre signal does survive blank correction, two environmental pathways are plausible for this coastline. Abrasion of synthetic rope and netting is a quantified release mechanism in maritime settings (Napper et al., 2022), and untreated domestic wastewater is a documented conduit for laundry derived textile microfibres (Browne et al., 2011). Both are pathways associated with material and infrastructure rather than with the conduct of any particular community, and neither can be apportioned on present evidence. The second most frequent morphotype, fragments (11 particles, 24.4 per cent), indicates breakdown of larger plastic debris in the intertidal and subtidal zones. Packaging and post consumer solid waste are recognised precursors of fragment type particles under ultraviolet irradiation and mechanical abrasion (Andrady, 2011; Barnes et al., 2009), and inadequate riverine waste management has been documented for this specific catchment (Astuti et al., 2023). Films (4 particles) and pellets (1 particle) are reported without source inference, since counts of this size cannot support one. The film result is particularly striking against the 84 per cent film share reported for beach sediments on this coast (Ratu and Utami, 2026); until both datasets are placed on a common protocol, this divergence should be attributed to method rather than to setting.

Size distribution and ecological bioavailability

The predominance of particles smaller than 1 mm (20 of 45 particles, 44.4 per cent) in the Cirebon coastal sediments carries potential ecological implications. Sub-millimetre microplastics represent the size fraction most bioavailable to a wide range of benthic organisms, including polychaete worms, deposit feeding bivalves, small crustaceans, and echinoderms that inhabit sediment environments (Galloway et al., 2017; Wright et al., 2013). At this size range, particles are not only physically ingestible by small invertebrates but may also interfere with feeding selectivity, reduce nutrient absorption efficiency, and cause sublethal physiological effects even at moderate abundance levels (Cole et al., 2011). These effects are drawn from the experimental literature and are not evidence of effects at this coast. No benthic organisms were sampled in this study, and the size class carrying this inference is also the class

with the highest visual misidentification rate and the class truncated by the filter pore size used here. The decline in proportional share from 44.4 per cent below 1 mm to 6.7 per cent in the 3 to 5 mm class is consistent with progressive fragmentation under tropical irradiance and wave abrasion (Andrady, 2011), though the same distribution would also arise from size selective deposition, which was not tested. The practical implication is unchanged by that ambiguity: particles in the dominant size class are not recoverable by conventional beach cleaning, so upstream reduction of plastic input remains the only effective lever (GESAMP, 2015).

Color characteristics and source inference

Transparent (12 particles), black (11) and blue (10) particles occurred in almost equal numbers, with white (8) and red (4) less frequent. No colour category dominates, and the differences among the top three are within the counting variation expected at this sample size. These counts are reported as description only. An earlier reading of these data attributed contamination to packaging waste and to fishing gear on the strength of transparent and blue particles respectively; that attribution is not supported once the counts are examined, and it is not made here. It should be noted that color-based source attribution carries inherent limitations, as environmental weathering and UV bleaching progressively alter the original color of plastic particles over time. Transparent particles, in particular, may include specimens that were originally colored but have undergone extensive photobleaching, potentially resulting in an overestimation of clear-packaging-derived inputs (Hidalgo-Ruz et al., 2012). Polymer-level characterisation using spectroscopic methods such as FTIR or Raman spectroscopy would provide more definitive source attribution and is a prerequisite rather than a refinement for any source claim. Where such characterisation has been applied on this coastline, polyethylene was the dominant polymer at 50 per cent of confirmed particles (Ratu and Utami, 2026), which is the kind of evidence a source statement requires and which the present study does not have.

Contamination indices and management implications

No ecological risk classification is assigned in this revised analysis. The contamination factors of 1.00 to 1.42 and site pollution load indices of 1.00 to 1.19 reported in Table 7 describe relative differences within this survey against an internal reference value, and no-

thing more. They cannot be compared with published PLI values from other studies, because those use different background values and because the counts here are not blank corrected. The direction of the uncertainty in these values cannot be stated. Absence of blank correction inflates counts, particularly for fibres, while the use of saturated NaCl without a digestion step depresses recovery of denser polymers and of particles bound in organic aggregates. Because these two errors act in opposite directions and neither has been quantified here, the reported abundances should be treated as provisional in both directions rather than as a conservative floor. A third and more basic constraint is the processed mass. Between 67 and 80 g of dried sediment was examined per site, yielding 10 to 13 particles. Counts of this order carry Poisson uncertainty of roughly 30 per cent on each site value before any methodological error is considered, which is larger than the entire spread observed between sites. Because only a sub-portion of each dried composite was processed, processing a larger share of the retained material would raise the counts proportionally without any further field work, and this is the single change that would most improve the reliability of a future analysis on this coast. Separately, the capacity of microplastic particles to adsorb persistent organic pollutants and trace metals is well established (Hartmann et al., 2019; Rochman et al., 2013), and the estuarine waters of this coast are already documented as carrying elevated trace metal loads (Hartiningsih et al., 2024), but no sorbed contaminant measurements were made in this study and no vector effect is claimed from it. From an environmental management standpoint, the results of this study support only general and precautionary conclusions. Suspected microplastic particles are present at all four sites, and the dominant size class is not recoverable by post hoc cleanup, so reducing plastic entering the coastal system through improved solid waste collection in the contributing catchment is the operative lever (GESAMP, 2015; Astuti et al., 2023). Measures aimed specifically at fishing gear are not recommended on present evidence, because the fibre signal is not blank corrected and cannot yet be apportioned to gear rather than to textiles or to laboratory contamination. It is also important to state that these findings do not attribute responsibility to the fishing and coastal communities of Kejawanan, Mundu, Gebang or Losari. Microplastic contamination in this setting reflects regional waste infrastructure and material flows, and the same particle types are recorded across Indonesian and global coastlines irrespective of

local livelihood. Standardised repeat monitoring, using the protocol set out in Section 3.5, remains the necessary next step (Ryan, 2015).

Conclusions

This study provides a preliminary, not a baseline, record of suspected microplastic particles in surface sediments at four sites along the northern Cirebon coast, West Java, Indonesia. Forty-five suspected particles were recovered from 297.59 g of dry sediment, giving site abundances of 125 to 178 particles kg⁻¹ dry weight with a site mean of 152. Fibres dominated the assemblage at 29 of 45 particles (64.4 per cent), followed by fragments (11), films (4) and one pellet; 20 particles measured below 1 mm; and no colour category was dominant. These values are reported as upper bound estimates. Four constraints prevent stronger conclusions. Polymer identity was not confirmed spectroscopically, so the particles remain suspected rather than verified. No procedural blanks were processed and samples were not covered during handling, which bears most directly on the fibre share that dominates the assemblage. Each site is represented by a single composite sample, so between site differences cannot be distinguished from within site heterogeneity, and the entire spread between the highest and lowest sites amounts to two particles. Finally, only 67 to 80 g of dry sediment was processed per site, which is the proximate reason the counts are so small. Accordingly, no ecological risk category is assigned and no source attribution is made. What the dataset does establish is that plastic derived particles are present along this coastline at concentrations that are not anomalous within the published Indonesian range, and that a defensible quantification for Cirebon still requires spectroscopic confirmation of a particle subset, procedural blanks with recovery testing, substantially larger processed masses, replicated sampling across at least two seasons, and paired grain size and organic matter measurement. Until those data exist, management should proceed on the general and well supported basis that reducing plastic input to the coastal system is more effective than attempting to remove particles once deposited.

Conflicts of interest

The authors declare no conflict of interest. This study was carried out purely for academic and environmental research purposes, with no involvement from any commercial or industrial party.

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Author contributions

Rani Santika: Conceptualization; Methodology; Investigation (field sampling and laboratory analysis); Data Curation; Formal Analysis; Writing – Original Draft; Writing – Review and Editing; Project Administration. Rafi Farizki: Conceptualization; Methodology; Validation; Formal Analysis; Writing – Review and Editing; Supervision. Both authors have read and approved the final version of the manuscript for submission. Data availability statement. All site level values reported in Tables 3 to 8, including the processed dry masses and the suspected particle counts from which every percentage in this manuscript is derived, are contained in full within this article. The original laboratory particle count sheets are available from the corresponding author on reasonable request. Funding. This research received no specific grant from any funding agency in the public, commercial or not for profit sectors. Permissions and ethical statement. Sediment sampling did not involve human participants, protected species or protected habitats requiring formal ethical review. Access to the shoreline adjacent to Pelabuhan Perikanan Nusantara Kejawan and to the managed mangrove block at Mundu Pesisir was granted by [authority and reference number to be inserted by the authors].

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