Marine Pollution Bulletin 214 (2025) 117786

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Assessment of microplastics particles (0.3–5 mm) in sandy beaches of Cuba

Marco Antonio García-Varens [a], Carlos Manuel Alonso-Hernandez [b], Arianna García-Chamero [a], Dariadelys Reyes-Noa [a], Joan Hernández-Albernas [c], Ada María del Rosario-Silva [a], François Oberhaensli [b], Marc Metian [b], Lorena M. Rios Mendoza [d], Nathalie Bernard [b,*], Yusmila Helguera-Pedraza [a]

[a] *Centro de Estudios Ambientales de Cienfuegos (CEAC), AP 5. Ciudad Nuclear, CP 59350, Cienfuegos, Cuba*
[b] *International Atomic Energy Agency-Marine Environment Laboratories (IAEA-EL), 4 Quai Antoine 1er, MC-98000, Monaco, Principality of Monaco*
[c] *Refugio de Fauna Cayo Santa María, Plaza Las Terrazas, Caibarién, Villa Clara, Cuba*
[d] *Natural Sciences Department, University of Wisconsin-Superior, P.O. Box 2000, Superior, WI 54880, USA*

A R T I C L E I N F O

Keywords:
Microplastics
Beach sand
Cuba
Caribbean Sea

A B S T R A C T

Microplastics (MPs) are considered one of the main pollution issues on the planet. This study constitutes the initial assessment of MPs on sandy beaches in Cuba. Four beaches with different characteristics and anthropogenic activities were selected on the north and south coasts of the island's central region. MPs (0.3–5 mm) were identified at three out of four beaches studied, with 0–196 MPs m^2 (0–47 MPs kg^{-1}). The MPs found on the south coast, Tetas de Tomasa Beach in Cienfuegos Bay, exhibited the highest average abundance, 95 ± 61 MPs m^2, followed by Rancho Luna with 3 ± 4 MPs m^2. On the north coast, Las Gaviotas Beach showed an average abundance of 2 ± 4 MPs m^2, and no MPs were found at Cañón Beach. Fragments were the main morphology (55 %), while the most prevalent colors were white/transparent (65.2 %) and blue (19.4 %). Polyethylene was the predominant synthetic polymer (52 %), followed by polypropylene (32 %) and polystyrene (14 %).

Plastic debris in marine and coastal environments is a pressing global issue (UNEP, 2021), and addressing it has become a top environmental priority, as emphasized by the United Nations' Sustainable Development Goal 14 (SDG14). A key indicator of SDG14 focuses on assessing microplastics in various marine matrices, including beaches, surface waters, sediments, and marine organisms.

Microplastics (MPs) accumulate in oceans, posing a threat to marine ecosystems and human health as they enter the food chain (Mamun et al., 2023). Their impact requires urgent action to reduce their release and mitigate their harmful effects (Yu and Singh, 2023). Collecting accurate data on MP prevalence in various marine environments is a crucial step in effectively addressing this growing environmental challenge (UNEP, 2022).MP pollution in sandy beaches has been reported by various authors around the world (Lots et al., 2017; Rahman et al., 2020; Urban-Malinga et al., 2020). Nevertheless, despite its importance, data on the distribution and abundance of plastic debris in the Caribbean islands, particularly for MP particles, is limited. Only a few studies on the abundance of MPs floating in surface waters or present on sandy beaches in the Caribbean are available. Ita-Nagy et al., 2022 reviewed 23 articles on MPs in Latin America and the Caribbean, reporting an abundance range between 0 and 1037 MPs m^{-2} in beach sands across the region. However, the authors caution that comparing these studies requires careful consideration due to diverse methodologies in sample collection and analysis. The lack of standardized protocols for monitoring MPs in beach sands (GESAMP, 2015), coupled with the absence of a unified reporting methodology for SDG14 indicator 14.1.1b, poses a significant challenge within the scientific community.

To overcome this challenge, since 2018, laboratories from 18 countries in the Latin America and Caribbean (LAC) region have been collaboratively working on the development of a manual for harmonized protocols to monitor MPs (0.3–5 mm) in beach sands. These efforts have been carried out within the Research Network of Marine-Coastal Stressors in Latin America and the Caribbean (REMARCO network) with the support of the International Atomic Energy Agency (IAEA). This work is part of the NUTEC Plastics initiative (NUclear TEChnology for Controlling Plastic Pollution), which aims to assist its member states in integrating isotopic and nuclear-derived techniques into their efforts to address the challenges of plastic pollution.

The aim of this study is to provide robust information on the presence, abundance, and types of MPs in the sands of four Cuban beaches

* Corresponding author.
E-mail address: n.bernard@iaea.org (N. Bernard).

https://doi.org/10.1016/j.marpolbul.2025.117786
Received 23 January 2025; Received in revised form 3 March 2025; Accepted 3 March 2025
Available online 6 March 2025

characterized by differing levels of anthropogenic influence. This study is based on a harmonized methodology endorsed by 18 countries in the LAC region.

This study was carried out between January 2020 and December 2022 on four Cuban beaches. Cuba is the largest island in the Antilles and holds a strategic position in the Caribbean Sea, experiencing the influence of the Caribbean, Gulf of Mexico, and Atlantic Ocean currents, which play a crucial role in modulating regional climate patterns, nutrient transport, marine biodiversity, and pollutant dynamics, including MPs. The Cañón and Las Gaviotas beaches are located in the northern cays. The area has experienced the impact of coastal development since the mid-1920s. However, the establishment of Marine Protected Areas has helped to avoid extreme pollution. Tetas de Tomasa and Rancho Luna are located on the central-southern coast of Cuba, within and at the mouth of Cienfuegos Bay, respectively (Fig. 1). The northern basin of Cienfuegos Bay faces significant anthropogenic impact from several sources. The primary inputs are the discharge from the city of Cienfuegos (housing around 150,000 inhabitants), a large industrial park situated in the northern part of the bay contributing organic and inorganic pollutants (Alonso-Hernández et al., 2011; Fattorini et al., 2004; García-Chamero et al., 2016; Peña-Icart et al., 2017), and freshwater inputs from the Damují and Salado rivers, which traverse agricultural and urban areas. Additionally, in 2009, a polyethylene (PE) pellet factory was established in the bay, raising concerns about negative environmental effects.

Sand samples from the beaches were collected using a harmonized protocol for sampling and analysis of microplastics on sandy beaches in the Latin American and Caribbean region, developed by the IAEA Technical Cooperation Project RLA7025 (Barrientos et al., 2024). This protocol was partly based on the method designed by GESAMP and NOAA (GESAMP, 2015; NOAA Marine Debris Program, 2017).

All procedures were carried out following best practices to minimize microplastic contamination, as outlined in the standardized protocol (Barrientos et al., 2024). All materials used were plastic-free and meticulously cleaned or burned at 450 °C for 2 h before use. Solutions and water were pre-filtered through 250 μm filters, and synthetic fabrics were strictly avoided. To assess potential laboratory contamination, blanks were processed every 10 samples by treating 1 L of filtered water under the same conditions as the samples.

A 100 m horizontal transect was established at the high tide line closest to the water, divided into five equidistant points. The sampling strategy was repeated 4 times in Cañón and Las Gaviotas beaches and 3 times in Rancho Luna and Tetas de Tomasa beaches. At each point, a 0.25 m^2 (50 cm × 50 cm) quadrat was delimited. Each quadrat was divided into four equal sub-quadrats, and samples were collected from one of them randomly chosen prior to sampling. The superficial layer (1.0 cm thickness) was collected using a stainless-steel spatula, obtaining about 2.5 L of wet sand. Samples were stored in closed aluminum containers and transported to the laboratory, where they were dried at 60 °C until constant weight.

To obtain the physical characterization of the MPs debris fraction, the total volume of dry sand was sequentially sieved through 0.3 mm, 1 mm, and 5 mm metal meshes. Fractions of 0.3 to 1 mm and 1 to 5 mm were further processed, while all material larger than 5 mm and smaller than 0.3 mm was discarded.

To isolate MP particles in each fraction, a density separation process was applied using a saturated NaCl solution (1.2 g cm^{-3}). Each sample was gently stirred with the solution for 10 min to ensure effective mixing and allowed to settle for a minimum of 6 h. Once this time was elapsed, the supernatant solution was filtered through 250 μm metal filters. This

Fig. 1. Location of studied beaches in Cuba: (I) Cañón, (II) Las Gaviotas, (III) Tetas de Tomasa and (IV) Rancho Luna.

step was repeated once.

Filters were dried and examined under a stereomicroscope (at up to 40× magnification), identifying potential MPs and classifying them by size, shape (fragments, films, fibers, foam, and pellets), and color. For each fraction, the number of potential MPs per m^{-2} and kg^{-1} was reported, as well as the total sum of potential MPs (0.3–5 mm) per m^{-2} and per kg^{-1}. The suspected MPs were removed and placed in glass vials coded for chemical characterization. This analysis of all the suspected MPs was conducted using Micro-Raman spectroscopy (WITec alpha300-R confocal Raman imaging microscope, WITec, Ulm, Germany) at the IAEA Marine Environment Laboratories in Monaco. The instrument was equipped with a 532-nm wavelength laser and operated at a power of between 2 and 10 mW (usually 5 mW). Raman spectra were obtained at variable magnifications of 10× to 20×, resulting in spatial resolutions of up to 360 nm. The Raman spectra were collected in the 200–3500 cm^{-1} range using a 600 lines per millimeter grating, providing a spectral resolution of 4 cm^{-1}. The integration time was 1–10 s (usually 5 s), and the cumulation number was 1–10 times (usually 4). To identify the synthetic polymers, the particle analysis tool "ParticleScout" was utilized in conjunction with IAEA spectral databases (HQI > 80 %).

After careful examination, it was estimated that 34 % of the 70 sand samples collected from the four sites contained possible MPs upon visual inspection, yielding a total of 405 particles. Among these, 376 were conclusively identified as MPs using Raman spectroscopy, demonstrating a 93 % accuracy in visual identification for the work range of 0.3–5 mm. Confirmed MPs were detected at three out of the four study areas. The abundance of MPs ranged from 0 to 196 MPs m^{-2} (0–47 MPs kg^{-1}). The distribution of MPs abundance in the studied beaches is shown in Table 1 and Fig. 2. Tetas de Tomasa from Cienfuegos Bay exhibited the highest average abundance at 95.4 ± 61.8 MPs m^{-2}, followed by Rancho Luna with 2.66 ± 4.45 MPs m^{-2} (ranging from 0 to 16 MPs m^{-2}), and Las Gaviotas with 1.6 ± 3.53 MPs m^{-2} (ranging from 0 to 12 MPs m^{-2}). Notably, no plastic particles (0.3–5 mm) were detected at Cañón.

Overall, five forms of MPs were identified among the sampling sites: fragment (55 %), film (17 %), foam (14 %), pellet (12 %), and fiber (2 %) (Fig. 3a). Among the three areas where MPs were found, Tetas de Tomasa showed the greatest diversity of forms, with fragments being the most abundant and standing out as the only beach where primary MPs (pellets) were found. Foams (60 %) predominated at Rancho Luna, while films (63 %) were the main form found at Las Gaviotas (Fig. 3b). This aligns with other reports that show fragments, films, and foam are the most abundant forms of MPs in the Caribbean (Orona-Návar et al., 2022). These results differ from those reported for beaches in the Lesser Antilles, where 97 % of the MPs consist of fibers (Bosker et al., 2018). This discrepancy may be attributed to intrinsic differences between the study areas. However, methodological variations could also play a role, as Bosker et al. (2018) identified potential MPs using a stereo microscope without further chemical characterization, which may have contributed to the higher proportion of fibers reported in their study.

The color of MP particles was also investigated as it is essential for visual identification among other debris and provides information on chemical composition, potential sources, and the level of degradation (Castro et al., 2016; Imhof et al., 2016), serving as an indicator of the age of plastics. The distribution of MPs by color is shown in Fig. 4. White/transparent pieces were the predominant color (65.2 %), followed by blue/green (19.4 %), then red/orange/brown (4.5 %), yellow (3.2 %), and other colors (7.7 %).

Four types of polymers were identified: PE representing 52 % of the total MPs, followed by polypropylene (PP) with 33 %, polystyrene (PS) with 14 %, and polyamide (PA) with 1 % (Fig. 6a). The greatest range of polymer types was found at Tetas de Tomasa, where 52 % of the MPs were identified as PE. This was also the only site where PA was found. At Rancho Luna, 60 % of the MPs were PS, and the remaining 40 % was PP. In Las Gaviotas, PE accounted for 75 % and PS for 25 % (Fig. 6b). All primary MPs (pellets) were identified as PE. Some typical Raman spectra are shown in Fig. 5.

The highest concentrations of MPs reported at Tetas de Tomasa in Cienfuegos Bay are linked with the highest level of anthropogenic activity among the studied beaches. Furthermore, significant amounts of macroplastics were found during sampling on this beach, compared to the rest of the studied beaches. These results, plus the presence of PE primary pellets and the high diversity of shapes, colors, and types of polymers, evidence the inadequate solid waste management practices and the influence of marine currents that turn this area into an accumulation zone, as reported by (PNUMA, 2007). The rest of the sampling sites are subjected to much less anthropogenic impact, as evidenced by the lower amounts of MPs found. However, it is worth noting that MPs found in Rancho Luna were mostly foam PS, commonly used in single-use disposable products in the restaurant and hospitality industry such us cups, food containers and packages, suggesting tourism in this area could be the principal source of contamination. Nevertheless, accumulations of Sargassum seaweed from the open sea are frequent in this ecosystem (Moreira and Alfonso, 2013) indicating that MPs from distant sources could also be present on Rancho Luna.

The current lack of standardized protocols for monitoring MPs on beaches represents a significant challenge for the scientific community. There is no uniform methodology for the collection, preparation, and analysis of samples, which hinders comparisons between various studies and, consequently, the identification of global patterns (Simon-Sánchez et al., 2022). Several factors may affect the results. For instance, it has been shown that smaller particles are the most abundant (Lares et al., 2018), which is why it is essential to report the studied size range. Furthermore, establishing a standard in terms of units of measurement contributes to consistency and clarity in the presentation of results. "MPs m^{-2}" or "MPs kg^{-1}" are the most suitable for understanding the density of MPs in a sample. Additionally, results obtained using different solutions for organic matter digestion and density separation are hardly comparable, as each solution has different MP extraction power and some may be too aggressive, leading to the loss of fibers and smaller MPs. The instrument used for counting and identifying MPs also plays an important role. Newer technologies like FTIR and Raman are the most commonly chosen; however, there is no one-size-fits-all technique. Recently, various working groups have recommended a specific protocol for determining the abundance of MPs in beach sand. This protocol suggests reporting MPs in the size range of 0.3–5 mm with densities of 1.2 g cm^{-3} using a NaCl-saturated solution (GESAMP, 2015). It has been adopted due to its simplicity, cost-effectiveness, environmental sustainability, and effectiveness in ensuring the reporting of the most common polymers in the marine environment, such as polyethylene (PE), polypropylene (PP), and polystyrene (PS). This facilitates the comparison and understanding of data across different studies.

Table 1
Abundance of MPs reordered in beach sand samples in Cuba during 2020–2022. ND: No detected.

Location (Beach Name)	Coordinates		Sample number	MP abundance (MPs m^{-2}) Average	MP abundance (MPs m^{-2}) STDEV	MP abundance (MPs kg^{-1}) Average	MP abundance (MPs kg^{-1}) STDEV
Cañón	22.66704	−79.07738	20	ND	ND	ND	ND
Las Gaviotas	22.66471	−78.96549	20	1.6	3.53	0.3	0.66
Rancho Luna	22.66471	−78.96549	15	2.66	4.45	0.6	1.29
Tetas de Tomasa	22.13595	−80.52089	15	95.4	61.8	23.3	13.6

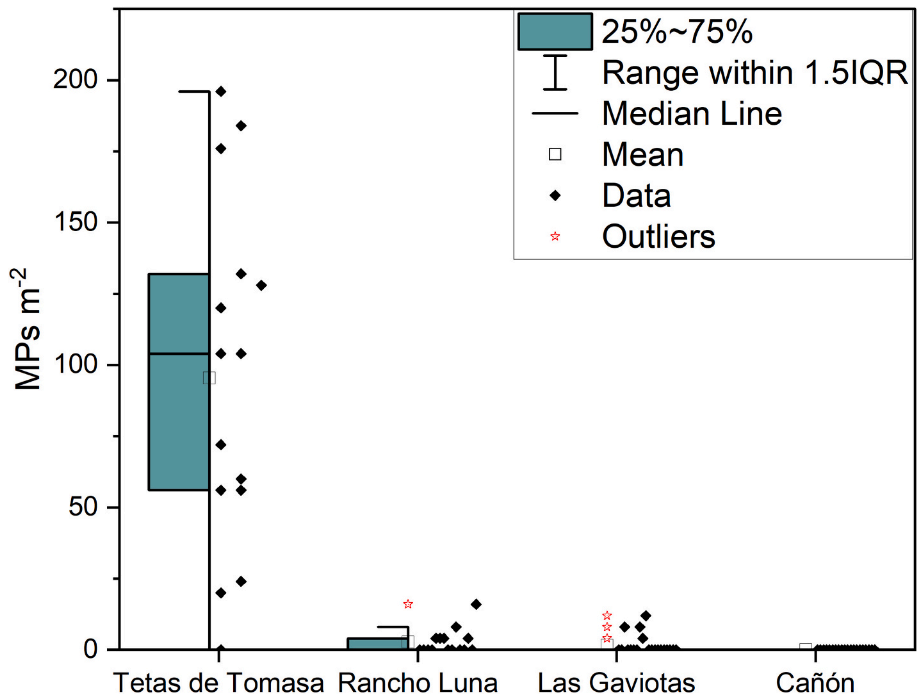

Fig. 2. Abundance of MPs m^{-2} in four studied beaches.

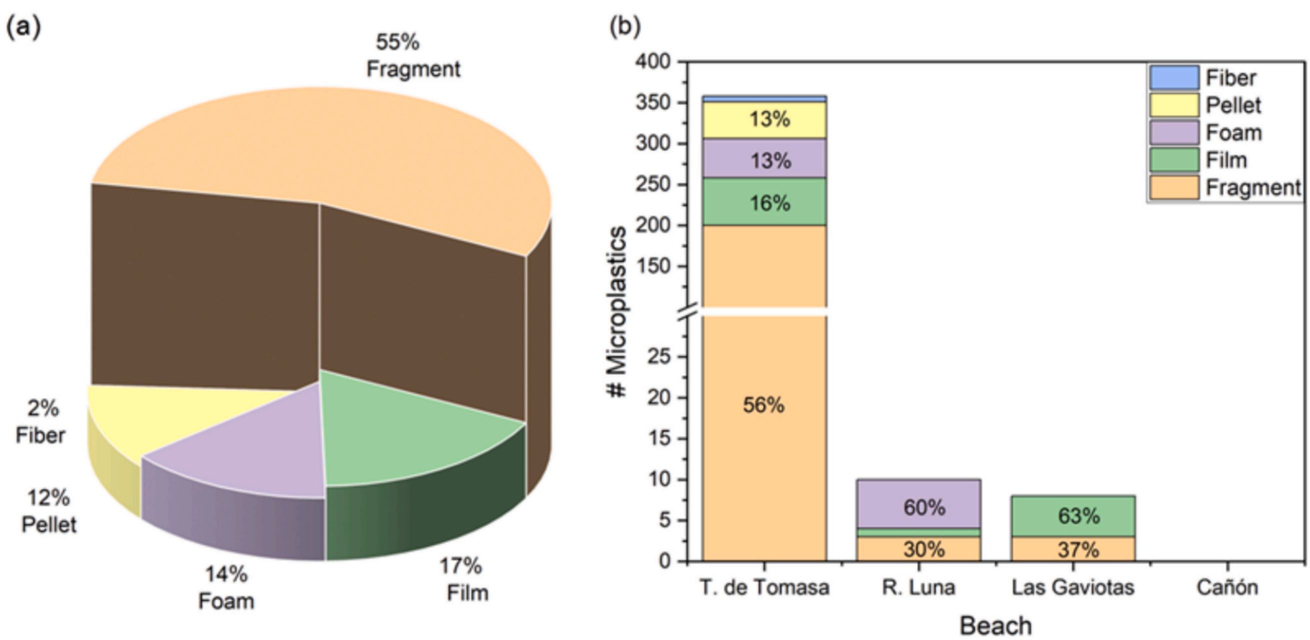

Fig. 3. Percentage of different shape of MPs in all samples (a) and its distribution by shape for each of studied beach (b).

Based on the above, Table 2 highlights our results in comparison with data reported under similar design conditions and protocols assessing the abundance of MPs in beach sands. The obtained abundance results (MPs m^{-2} and MPs kg^{-1}) for Cuba fall within the reported ranges for countries in the region. However, the maximum value in our study (196 MPs m^{-2}) is lower than those reported on beaches in Nicaragua (304 MPs m^{-2}) and Colombia (318 MPs m^{-2}). Additionally, the maximum MPs abundance reported in our study concerning kilograms of dry sand (47 MPs kg^{-1}) was lower than that reported across 21 beaches in the Lesser Antilles, where values reach up to 396 MPs kg^{-1}.

It is worth noting that several authors extrapolate the results of the chemical composition of particles identified as possible MPs by analyzing a fraction of the sample, typically between 10 % and 20 % of the particles (Alvarez-Zeferino et al., 2020a). This approach increases the uncertainty in the reports of abundance and polymer composition. In the present study, we analyzed 100 % of the particles flagged as potential MPs using Raman spectroscopy. The methodology employed demonstrated a confirmation rate of 93 % for MPs (376 out of 405 particles visually identified as potential), providing a high level of reliability in the obtained results.

Microplastics present in seawater can become trapped in beach sand, turning sandy shores into long-term sinks for plastic pollution. This issue can be exacerbated by MP pollution resulting from beach users, such as tourists or recreational activities (Gopakumar et al., 2024). This

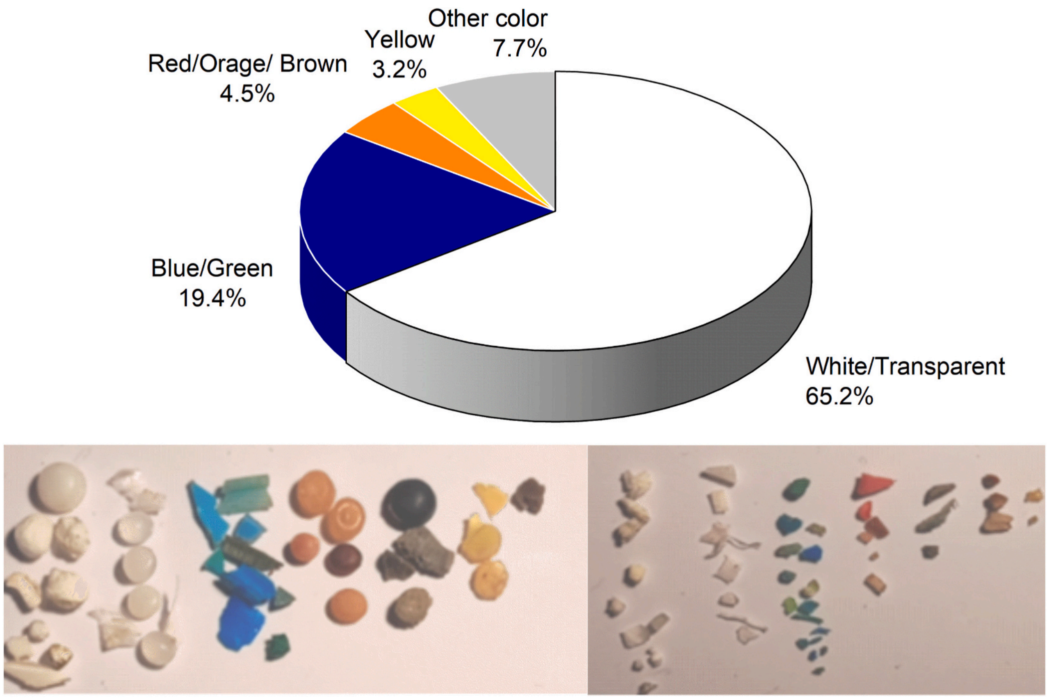

Fig. 4. Percentage contribution of color to the total amount of MPs at all study sites and examples of various microdebris types recorded on Cuban beaches.

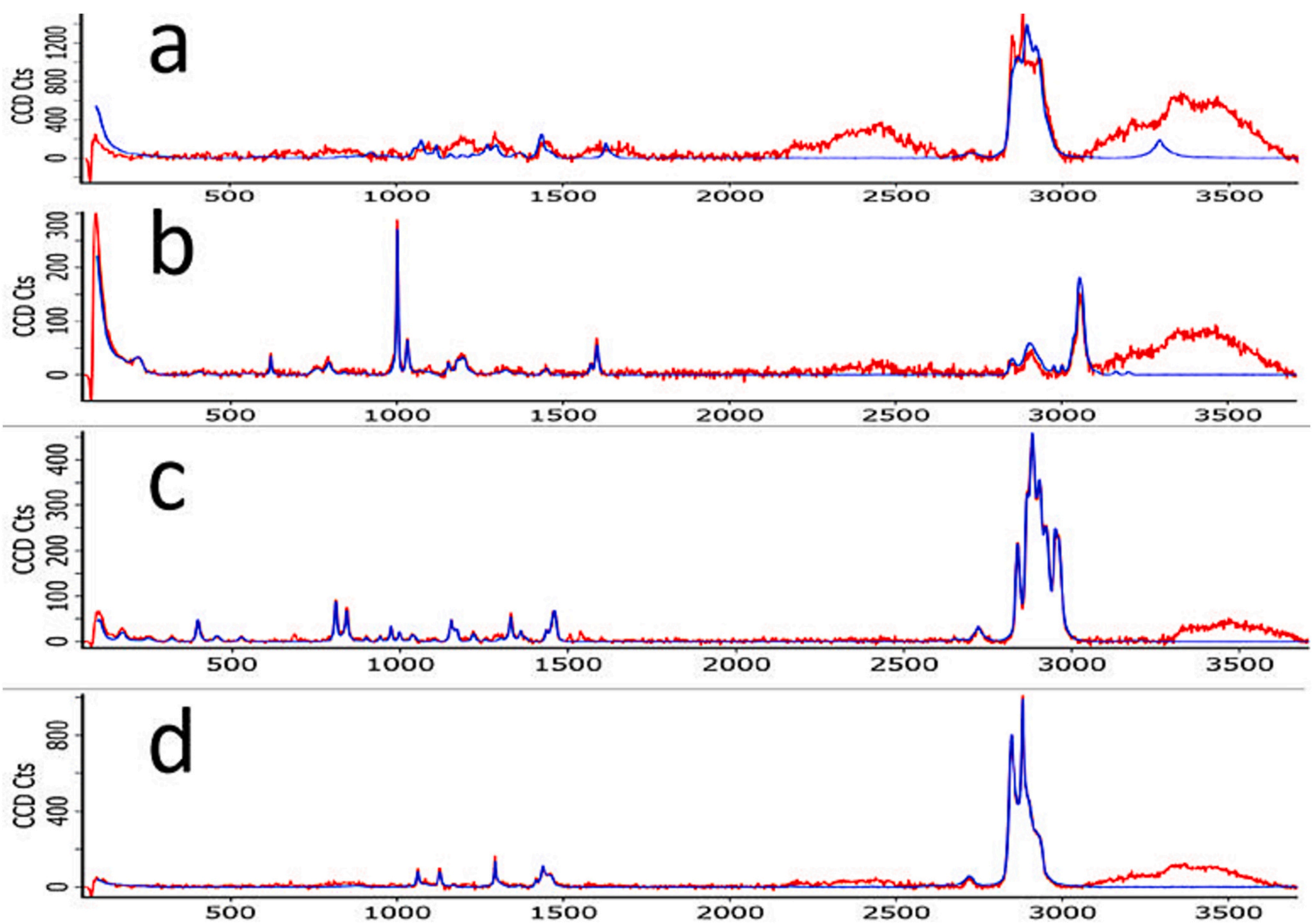

Fig. 5. RAMAN spectra, the blue lines are the reference spectra from the IAEA library while the red lines are the spectra obtained for the studied particles: a) Polyamide, b) Polystyrene, c) Polypropylene, d) Polyethylene. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

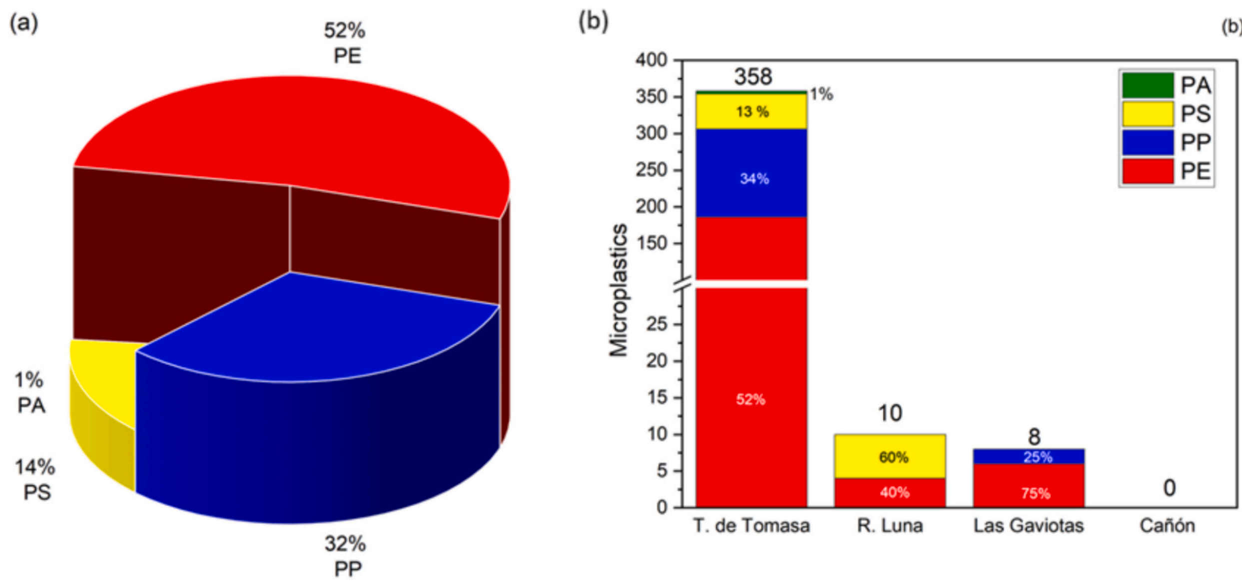

Fig. 6. Total percentage distribution of polymeric composition in all sand samples (a) and polymer composition of MPs at different sites (b).

Table 2
Different MPs levels recorded in sandy beaches in the LAC region in comparison with this study.

Country	Research area	Abundance	Forms dominant	Polymer type	Reference
Panama	3 beaches in the province of Los Santos	9.2–37.2 MPs m^{-2}	Foam (42.1 %), fragment (22.8 %), films (17.8 %)	NA	(Barrera et al., 2023)
Nicaragua	Bay of San Juan del Su	304 MPs m^{-2}	Fragment (82.9 %), Film (7.4 %), foam (6.0 %), fiber (2.4 %), pellet (1.3 %)	PE, PP, PS and PVC were identified, PE predominating	(Díaz Domínguez and Sarria Sacasa, 2019)
Colombia	Cispata Marine Protected Area, Colombian Caribbean	8–36 MPs m^{-2}	Films and fragments dominated in Blanca beach and the filaments and foams in Manzanillo beach	NA	(Ordóñez, 2022)
Mexico	33 beaches	133 MPs m^{-2}	Fragments (56 %), foam (15 %), fiber (11 %), film (10 %), pellets (5 %), others (3 %)	56 % PE, 21 % PP, 12 % PS	(Alvarez-Zeferino et al., 2020b)
Colombia	43 beaches	318 ± 314 MPs m^{-2}	52 % Fragments, 20 % filaments, 11 % pellets, 10 % foams, 4 % granules, 3 % films	50 % PE, 28 % PS, 20 % PP, 0.6 % PVC, 0.5 % PU, 0.4 % HIPS, 0.3 % PE	(Garcés-Ordóñez et al., 2019)
Lesser Antilles	21 beaches	68–396 MPs kg^{-1}	Fiber 97 %, Other 3 %	NA	(Bosker et al., 2018)
Peru	3 sandy beaches on the central coast	116–202 MPs kg^{-1}	Fiber and fragment type MPs predominated	NA	(Zarate and Iannacone, 2021)
Cuba	4 sandy beaches	0–196 MPs m^{-2} (0–47 MPs kg^{-1})	55 % fragments, 17 films and 14 % foams.	52 % PE, 32%PP, 14 % PS.	This study

accumulation poses a threat to ecosystems, as organisms such as birds may ingest these particles, suffering may ingest them, causing physical harm and exposure to harmful chemicals (NOAA Marine Debris Program, 2017).

This study marks the initial assessment of MPs debris (0.3–5 mm) on Cuban beaches. The methodology implemented by the REMARCO network allowed for the evaluation of MPs abundance and diversity based on their shape, color, size, and chemical composition, enabling comparisons of MP pollution levels among the studied beaches.

The implementation of a regular monitoring program on Cuban coasts is crucial to measure the pollution level over time and also to study the sources of these pollutants, facilitating the analysis of potential effects on marine ecosystems and the food chain (Ghosh et al., 2023). Furthermore, this detailed information propels the implementation of more effective mitigation strategies and contributes to designing environmental policies aimed at reducing the accumulation and impact of MPs in our natural environments.

CRediT authorship contribution statement

Marco Antonio García-Varens: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Carlos Manuel Alonso-Hernandez:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Arianna García-Chamero:** Writing – review & editing, Visualization, Investigation. **Dariadelys Reyes-Noa:** Writing – review & editing, Visualization. **Joan Hernández-Albernas:** Writing – review & editing, Writing – original draft, Visualization. **Ada María del Rosario-Silva:** Writing – original draft. **François Oberhaensli:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Formal analysis. **Marc Metian:** Writing – review & editing, Writing – original draft, Visualization. **Lorena M. Rios Mendoza:** Writing – review & editing, Visualization, Methodology. **Nathalie Bernard:** Writing – review & editing, Visualization, Methodology. **Yusmila Helguera-Pedraza:** Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research work has been undertaken in the framework of the IAEA TC Project CUB/7/010 "Improving National Capacities for Monitoring the Impacts of Climate Change on the Marine Environment Using Nuclear and Isotopic Techniques" and the National Program of Nanosciences and Nanotechnologies-contract PN211LH008-011". The polymer analyses were performed at IAEA Marine Environment Laboratories, in the context of a fellowship supported by the TC project RLA/70/025.

The IAEA is grateful to the Government of the Principality of Monaco for the support provided to its Marine Environment Laboratories.

Data availability

No data was used for the research described in the article.

References

Alonso-Hernández, C.M., Bernal-Castillo, J., Bolanos-Alvarez, Y., Gómez-Batista, M., Diaz-Asencio, M., 2011. Heavy metal content of bottom ashes from a fuel oil power plant and oil refinery in Cuba. Fuel 90 (8), 2820–2823. https://doi.org/10.1016/j.fuel.2011.03.014.

Alvarez-Zeferino, J.C., Cruz-Salas, A.A., Vázquez-Morillas, A., Ojeda-Benitez, S., 2020a. Method for quantifying and characterization of microplastics in sand beaches. Revista Internacional de Contaminacion Ambiental 36 (1), 151–164. https://doi.org/10.20937/RICA.2020.36.53540.

Alvarez-Zeferino, J.C., Ojeda-Benítez, S., Cruz-Salas, A.A., Martínez-Salvador, C., Vázquez-Morillas, A., 2020b. Microplastics in Mexican beaches. Resour. Conserv. Recycl. 155 (December 2019), 104633. https://doi.org/10.1016/j.resconrec.2019.104633.

Barrera .C., M, Fuentes, M., Cedeño, J., Domínguez, E., Cedeño, A., Argüello, B., Irias, A., 2023. Diagnóstico de la abundancia de microplástico en tres playas del distrito de Las Tablas, Pacífico panameño, durante agosto y octubre de 2022. Visión Antataura 7 (1), 77–91. https://doi.org/10.48204/j.vian.v7n1.a3927.

Barrientos, E. E., Carrasco Palma, D., C. M., M., Díaz-Jaramillo, M., González, M., H., Pedraza, Y., Lozoya Azcárate, J.P., ObandoMadera, P.S., Ontiveros Cuadras, J.F., P., Cuicapusa, S., Ramírez Álvarez, N., R., Mendoza, L.M., Ruiz-Fernández, A.C., Y., & Saldarriaga-Vélez, J. F. (2024). Determinación de la abundancia de microplásticos en arenas de playa. Red de Investigación de Estresores Marinos - Costeros en Latinoamérica y El Caribe – REMARCO. 18 pp. https://remarco.org/manual- de-procedimientos-tecnicos-contaminacion-por- microplasticos/.

Bosker, T., Guaita, L., Behrens, P., 2018. Microplastic pollution on Caribbean beaches in the Lesser Antilles. Mar. Pollut. Bull. 133, 442–447. https://doi.org/10.1016/j.marpolbul.2018.05.060.

Castro, R.O., Silva, M.L., Marques, M.R.C., de Araújo, F.V., 2016. Evaluation of microplastics in Jurujuba cove, Niterói, RJ, Brazil, an area of mussels farming. Mar. Pollut. Bull. 110 (1), 555–558. https://doi.org/10.1016/j.marpolbul.2016.05.037.

Díaz Domínguez, J.M., Sarria Sacasa, K. del C., 2019. Microplásticos en las costas del Pacífico de Nicaragua. Revista Compromiso Social 1 (2), 51–60. https://doi.org/10.5377/recoso.v1i2.13327.

Fattorini, D., Alonso-Hernandez, C.M., Diaz-Asencio, M., Munoz-Caravaca, A., Pannacciulli, F.G., Tangherlini, M., Regoli, F., 2004. Chemical speciation of arsenic in different marine organisms: importance in monitoring studies. Mar. Environ. Res. 58 (2–5), 845–850. https://doi.org/10.1016/j.marenvres.2004.03.103.

Garcés-Ordóñez, O., Castillo-Olaya, V.A., Granados-Briceño, A.F., Blandón García, L.M., Espinosa Díaz, L.F., 2019. Marine litter and microplastic pollution on mangrove soils of the Ciénaga Grande de Santa Marta, Colombian Caribbean. Mar. Pollut. Bull. 145 (2), 455–462. https://doi.org/10.1016/j.marpolbul.2019.06.058.

García-Chamero, A., Gómez-Batista, M., Alonso-Hernández, C.M., Helguera-Pedraza, Y., Chamero-Lago, D., Torres-Martín, A.M., 2016. Distribución de mercurio en la Bahía de Cienfuegos. Evaluación de Perna viridis (Mollusca: Bivalvia) como bioconcentrador. In: Revista Cubana de Química, Vol. 28, pp. 507–519 scielocu.

GESAMP, 2015. Sources, fate and effects of microplastics in the marine environment: a global assessment. (Kershaw, P. J., ed.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP joint Group of Experts on the scientific aspects of marine environmental protection). Rep. Stud. GESAMP No. 90 (96 p).

Ghosh, S., Sinha, J.K., Ghosh, S., Vashisth, K., Han, S., Bhaskar, R., 2023. Microplastics as an emerging threat to the global environment and human health. Sustainability (Switzerland) 15 (14). https://doi.org/10.3390/su151410821.

Gopakumar, G., Senthil Nathan, D., Harikrishnan, S., Sridharan, M., Jilsha, V., 2024. An investigation on the presence and risk assessment of microplastics in Quilon Beach, south west coast of India. Environ. Pollut. Manag. 1 (June), 99–108. https://doi.org/10.1016/j.epm.2024.08.002.

Imhof, H.K., Laforsch, C., Wiesheu, A.C., Schmid, J., Anger, P.M., Niessner, R., Ivleva, N. P., 2016. Pigments and plastic in limnetic ecosystems: A qualitative and quantitative study on microparticles of different size classes. Water Res. 98, 64–74. https://doi.org/10.1016/j.watres.2016.03.015.

Ita-Nagy, D., Vázquez-Rowe, I., Kahhat, R., 2022. Prevalence of microplastics in the ocean in Latin America and the Caribbean. J. Hazard. Mater. Adv. 5. https://doi.org/10.1016/j.hazadv.2021.100037.

Lares, M., Ncibi, M.C., Sillanpää, M., Sillanpää, M., 2018. Occurrence, identification and removal of microplastic particles and fibers in conventional activated sludge process and advanced MBR technology. Water Res. 133, 236–246. https://doi.org/10.1016/j.watres.2018.01.049.

Lots, F.A.E., Behrens, P., Vijver, M.G., Horton, A.A., Bosker, T., 2017. A large-scale investigation of microplastic contamination: abundance and characteristics of microplastics in European beach sediment. Mar. Pollut. Bull. 123 (1–2), 219–226. https://doi.org/10.1016/j.marpolbul.2017.08.057.

Mamun, A. Al, Prasetya, T.A.E., Dewi, I.R., Ahmad, M., 2023. Microplastics in human food chains: food becoming a threat to health safety. Sci. Total Environ. 858 (July 2022), 159834. https://doi.org/10.1016/j.scitotenv.2022.159834.

Moreira, Á., Alfonso, G., 2013. Unusual drift of Sargassum fluitans (Børgesen) Børgesen in the southern-central coast of Cuba. Rev. Investig. Mar. 33 (2), 17–20. http://www.rim.uh.cu/index.php/RIM/article/view/199.

NOAA Marine Debris Program, 2017. Quantification of microplastics on National Park Beaches NPS technical coordinators: southeast regional marine scientist / oceans program coordinator cliff McCreedyMarine resource management specialist. https://marinedebris.noaa.gov/sites/default/files/publications-files/Quantification_of_Microplastics_on_National_Park_Beaches.pdf.

Ordóñez, O.G., 2022. Microplastic Pollution in Mangroves and Beaches of the Cispata Marine Protected Area. Revista Ciencias Marinas y Costeras, Colombian Caribbean Coast. https://doi.org/10.15359/revmar.14-2.1.

Orona-Návar, C., García-Morales, R., Loge, F.J., Mahlknecht, J., Aguilar-Hernández, I., Ornelas-Soto, N., 2022. Microplastics in Latin America and the Caribbean: A review on current status and perspectives. J. Environ. Manag. 309. https://doi.org/10.1016/j.jenvman.2022.114698.

Peña-Icart, M., Pereira-Filho, E.R., Lopes Fialho, L., Nóbrega, J.A., Alonso-Hernández, C., Bolaños-Alvarez, Y., Pomares-Alfonso, M.S., 2017. Combining contamination indexes, sediment quality guidelines and multivariate data analysis for metal pollution assessment in marine sediments of Cienfuegos Bay, Cuba. Chemosphere 168, 1267–1276. https://doi.org/10.1016/j.chemosphere.2016.10.053.

PNUMA, P. de las N. U. para el M. A. (2007). Geo Cienfuegos. Perspectivas del Medio Ambiente Urbano. http://www.pnuma.org/deat1/pdf/2008GEOCienfuegos.pdf.

Rahman, S.M.A., Robin, G.S., Momotaj, M., Uddin, J., Siddique, M.A.M., 2020. Occurrence and spatial distribution of microplastics in beach sediments of Cox's Bazar, Bangladesh. Mar. Pollut. Bull. 160 (May), 111587. https://doi.org/10.1016/j.marpolbul.2020.111587.

Simon-Sánchez, L., Grelaud, M., Franci, M., Ziveri, P., 2022. Are research methods shaping our understanding of microplastic pollution? A literature review on the seawater and sediment bodies of the Mediterranean Sea. Environ. Pollut. 292. https://doi.org/10.1016/j.envpol.2021.118275.

UNEP. (2021). From pollution to solution. In new scientist (Vol. 237, issue 3169). doi: https://doi.org/10.1016/S0262-4079(18)30486-X.

UNEP, 2022. Addressing marine litter and microplastics - UN system-wide contributions, pp. 1–160. https://unemg.org/wp-content/uploads/2022/01/UNEP_EMG-REPORT_Marine-Litter-Microplastics.pdf.

Urban-Malinga, B., Zalewski, M., Jakubowska, A., Wodzinowski, T., Malinga, M., Pałys, B., Dąbrowska, A., 2020. Microplastics on sandy beaches of the southern Baltic Sea. Mar. Pollut. Bull. 155 (April), 111170. https://doi.org/10.1016/j.marpolbul.2020.111170.

Yu, R.S., Singh, S., 2023. Microplastic pollution: threats and impacts on global marine ecosystems. Sustainability (Switzerland) 15 (17). https://doi.org/10.3390/su151713252.

Zarate, M., Iannacone, J., 2021. Microplásticos en tres playas arenosas de la costa central del Perú. Revista Salud Ambiental 21 (2), 123–131.