Colegio de Postgraduados

Analysis of the number of bibliographic publications on the presence of microplastics in sediments in the Americas

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Citation: Castañeda-García, F., Castañeda-Chávez, M.R., Navarrete-Rodríguez, G., & Zamudio-Alemán, R.E. (2025). Analysis of the number of bibliographic publications on the presence of microplastics in sediments in the Americas. *Agro Productividad*. https://doi.org/10.32854/x60vz574

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: June 20, 2024.
Accepted: May 28, 2025.
Published on-line: July XX, 2025.

Agro Productividad, 18(6). June. 2025. pp: 35-44.

ABSTRACT

Objective: To examine the scientific activity of the American continent in detail during a period of ten years (from 2014 to 2024).

Design/Methodology/Approach: A quantitative methodology was employed, analyzing articles related to the presence of microplastics (MPs) in sediments, sourced from the Scopus database.

Results: A total of 2,050 articles were retrieved, of which 123 (6%) focused specifically on MPs in sediments. The leading contributors were Brazil, the United States, Canada, and Mexico. The most frequently cited authors included Alexander Turra, Patricia L. Corcoran, and A.D. Vethaak. A variety of methodologies were used, including density separation of MPs, oil extraction protocols, and FTIR spectroscopy, among others.

Study limitations/Implications: No standardized methodology exists for the main steps involved in the determination of microplastics (MPs), even as their detection continues to increase across diverse environmental sediments.

Findings/Conclusions: The production of scientific articles on microplastics (MPs) in sediments has increased over the past ten years, driven by the growing detection of these contaminants in sediment samples.

Keywords: microplastics; sediments; marine pollution; ocean, American continent.

INTRODUCTION

The increasing use of single-use plastic products and various types of packaging is a growing trend in today's society (Ronda *et al.*, 2023). As a result, an estimated 11 million additional tons of plastic waste are expected by 2025 (Naidu *et al.*, 2022). Although many plastics can be recycled or reused, the majority are still disposed of through incineration, landfilling, or simply released into the terrestrial environment (Bi *et al.*, 2023). Once released into the environment, plastics undergo physicochemical and biological processes —such as mechanical abrasion, photodegradation, hydrolysis, thermal oxidation, chemical oxidation, and biodegradation (Iannacone *et al.*, 2019; Wang *et al.*, 2022)— which lead to

the aging and fragmentation of plastic materials into tiny particles smaller than 5 mm, known as microplastics (MPs). Due to their abundance, persistence, and unregulated components, MPs are considered a high-impact threat to marine ecosystems, particularly in sediments, where economically important benthic species inhabit (Gil *et al.*, 2012; Olivatto *et al.*, 2019; Jorquera *et al.*, 2022).

Currently, MPs are predominantly found in seawater, marine organisms, and coastal sediments (Olivatto *et al.*, 2019; Rusinque-Quintero *et al.*, 2022). It has been identified that the terrestrial environment accounts for approximately 80% of marine plastic pollution, making it a major source of contamination (Wang *et al.*, 2022). A gradual increase in MP abundance has been reported across different land uses, with urban areas contributing more significantly to MP presence and transport than fishing-related activities (Naidu *et al.*, 2022). In densely populated areas, MP pollution levels have been found to closely correlate with population density (Bi *et al.*, 2023). For instance, Guanabara Bay in Brazil exhibits some of the highest levels of microplastic pollution worldwide, which is attributed to inadequate urban solid waste management. In general, developing countries often lack appropriate solid waste management technologies, contributing to MP accumulation in marine sediments (Olivatto *et al.*, 2019; Nchimbi *et al.*, 2022).

The objective of this study was to examine the scientific output of the American continent over the period 2014-2024, using a quantitative approach based on articles referring to the presence of MPs in sediments.

MATERIALS AND METHODS

This analysis focused on scientific activity based solely on articles published in the Scopus database, selected for its recognized rigor in the indexing process, which adheres to criteria of editorial quality, peer review, and scientific relevance. Scopus provides broad multidisciplinary coverage, granting access to specialized literature across a wide range of fields. Additionally, it offers standardized bibliometric indicators and robust analytical tools that are essential for conducting quantitative studies on scientific output, collaborative networks, and thematic trends. Its technical features further facilitate data collection, organization, and analysis. The platform's widespread acceptance within the scientific community reinforces the methodological validity of this study (Baas *et al.*, 2020).

The selected documents were meticulously analyzed using a quantitative approach, year by year, over a ten-year period (2014 to 2024) across the American continent. Articles in English and Spanish were filtered using the keywords "*microplastics*", "*microplastic*", and "*sediments*" in the title and abstract fields, with data collected up to April 15, 2024. The search criteria within the Scopus database were restricted to research articles and review papers within the subject areas of Environmental Science, Agricultural and Biological Sciences, Chemistry, and Chemical Engineering. Finally, the search was refined by selecting countries in the American continent, including: the United States, Brazil, Canada, Mexico, Chile, Peru, Colombia, Ecuador, Uruguay, Costa Rica, Venezuela, Panama, Dominican Republic, Bahamas, Puerto Rico, Paraguay, Guatemala, Trinidad and Tobago, Jamaica, Cuba, Bolivia, Belize, Barbados, and Honduras. This process resulted in a total of 2,050 articles.

From the 2,050 articles obtained, a detailed review was conducted to extract information specifically related to the presence of MPs in sediments across the American continent. During this process, studies focusing solely on organisms inhabiting marine sediments were excluded. An Excel database was developed to record key information from each publication, including the year of publication, study location, and types of MPs identified (Supplementary Material 1). A total of 123 articles met the inclusion criteria.

To support the analysis, VOSviewer and Research Rabbit software were used to construct bibliometric networks and trace connections between studies. These tools helped identify patterns of collaboration, key authors, and emerging research trends in the field. A Pearson correlation analysis was also performed to assess whether article production was strongly correlated among countries in the Americas. Additionally, journals with the highest number of publications on MPs in sediments were identified.

The image generated in VOSviewer is composed of colors, edges, and nodes. The proximity between two nodes indicates the strength of their relationship: the closer they are, the stronger the connection. Edges (lines between nodes) represent relationships such as co-citation, co-authorship, or co-occurrence of terms, with thicker lines denoting stronger associations. The size of the labels or nodes reflects the frequency or relevance of the term —larger labels correspond to terms that appear more frequently in the analyzed documents.

In the visualizations, the size of the circles and the distance between nodes indicate the number of publications and the strength of the relationships between items. Node color represents thematic groupings or clusters —nodes sharing the same color are more closely related to each other, suggesting subtopics within the broader field of study.

Additionally, a Pearson correlation analysis was conducted to determine whether article production was strongly correlated among countries in the Americas. The journals with the highest number of publications on MPs in sediments were also identified.

RESULTS AND DISCUSSION

The bibliographic analysis identified the presence of MPs in sediments based on 123 studies conducted in the American continent over the past 10 years, as indexed in the Scopus database. The lowest publication outputs were recorded in 2014 and 2017. However, a notable increase occurred over a four-year period, peaking in 2021 with 30 published articles, followed by 25 articles in 2023. Although the publication trend is not linear, there is clear evidence of growing research interest and scientific production in this field (Table 1). It is important to note that different sampling and analytical strategies used across studies contribute to significant variations in reported MP concentrations (Wang *et al.*, 2022).

The analysis of the relationship between the number of documents published each year and time, using Pearson correlation analysis, yielded a correlation coefficient of P=4.3512 with 95% confidence. This suggests a significant relationship between the number of articles published and the year of publication over the last decade. The predominant subject area was Environmental Science, with 314 documents, followed by Agricultural and Biological Sciences, with 129 documents. Additionally, among the 75 selected articles, the majority

Table 1. Overview of recent studies reporting MP concentrations across the Americas.

Country	Study area	Sample type	MPs concentration	MPs type of form or color	Source
USA	San Andres Bay	Sediment	3,16 ± 1,59 MP kg^{-1} at 34,03 ± 11,69	11,600 particles per kg dry sediment	Ridall *et al.* (2022)
Argentina	Central Andes	Trout intestines, and catfish streams		85% fiber, 15% blue fragments, 50% brown	Ríos *et al.* (2022)
Ontario, Canada	Muskoka -Haliburton Ontario	Terrestrial and aquatic environment	1.78 pieces from May to June	In the lake: fibers (70%) Sediment (fibers and fragments 51-67%)	Welsh *et al.* (2022)
Ecuador	San Cristobal Island Beaches and Tortuga Island	Sediment	2213 MPs, where 93% were of 1mm	Rubber presence	Jones *et al.* (2022)
USA	Narragan-sett Bay, Rhode Island	Sediment	40 and 4.6 million pieces per 100 g	Cellulose acetate fibers	Cashman *et al.* (2022)
Mexico	Tampico Beach	Sediment	256 to 283 particles in 20 g	Transparent (32%), White (8%), Yellow (6%), Pink (4%), Red (1%) Multicolored (1%) fibers.	Flores-Ocampo *et al.* (2023)
Mexico	Southern Gulf of Mexico	Sediment	1.3 to 95.2 particles per kg	Fragments (82.44%), Fibers (16.19%), Films (1.35%)	Rendón-von Osten *et al.* (2023)
Argentina	Bahía Blanca Estuary	Sediment	1693 ± 2315 MPs kg^{-1}	Pellets	Arias *et al.* (2023)

were authored by researchers from the Americas, with 27 publications highlighting the presence of MPs in marine sediments (Figure 1). Although research on MPs is ongoing, it remains limited: out of 2,050 studies published in the last ten years on this topic, only 6% focused specifically on MPs in sediments. This indicates a significant gap in assessment and monitoring efforts. It has been reported that at least 66.7% of plastics in the ocean are difficult to monitor under current observation frameworks (Ugwu *et al.*, 2022).

Significant knowledge gaps remain regarding the occurrence, distribution, aging, fragmentation, transport, flux, fate, and sinks of microplastics (MPs) in urban runoff, particularly from a continental perspective and its impact on the oceans (Wang *et al.*, 2022)

The indiscriminate use of plastic products, coupled with a deficient recycling culture, has led to the widespread disposal of plastic waste into the environment, causing significant harm to biota. The reviewed studies report a high presence of microplastics (MPs), predominantly fibers and fragments (Olivatto *et al.*, 2019). Authors with greater seniority tend to receive a higher number of citations. The data obtained from the network of cited authors across the 123 articles on microplastics in sediments in the Americas highlight key research works and their impact. These references are concentrated in six major scientific journals from the region. The journal with the highest impact factor was *Science of the Total Environment*, with an impact factor of 10.753 and 29 published articles. It was followed by *Environmental Pollution*, which has an impact factor of 8.9 and 12 articles published. The third journal in terms of impact factor was *Marine Pollution Bulletin* with 5.8; this journal, however, published the greatest number of articles, totaling 34. The lowest impact factors were found in *Marine Environmental Research* and *Journal of Great Lakes Research*, with 3.3 and 2.2 respectively, each having

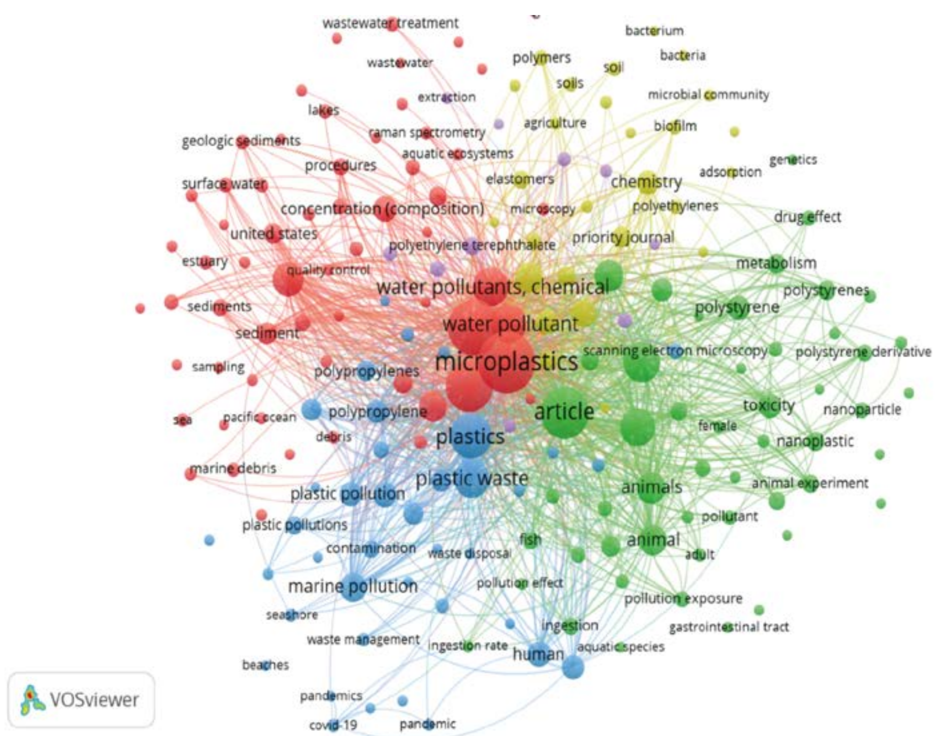

Figure 1. Keyword network of publications on microplastics.

only 3 published articles. Meanwhile, *Bulletin of Marine and Coastal Research* had the lowest number of articles published, with only 2. The keywords commonly used across these publications include water pollution, plastics, animals, chemicals, and microscopy, indicating shared thematic concerns. The analysis of microplastic (MP) levels found in urban runoff indicates higher concentrations compared to those released in wastewater effluents. The small size of MPs accelerates their transport in urban runoff waters. Most MPs (up to 97-98%) entering wastewater treatment plants (WWTPs) become trapped in the sludge (Wang *et al.*, 2022). Fibers are the most abundant type of MPs attributed to wastewater discharges (Jorquera *et al.*, 2022).

In a 2014 study conducted in Canada, 52 microbeads per square meter were reported in freshwater sediments (Castañeda-Rowshyra *et al.*, 2014). That same year, bibliographic records already documented the ingestion of MPs by plankton, mostly juvenile vertebrates and invertebrates, as well as interactions between MPs and chemical contaminants present in sediments worldwide (Ivar do Sul & Costa, 2014). By 2015, microbeads were identified in facial cleansing products, which can enter the marine environment, leading to bioaccumulation and the transmission of organic toxins to predators (Chang, 2015).

The elutriation method was implemented to separate sediment using a PVC device, followed by filtration with coffee filters and characterization under a 40x magnification loupe (Zhu, 2015). On the southeastern coasts of Brazil in 2016, researchers investigated MPs using a density separation methodology, applying a gradient approach in dune regions with transects and depth profiling (Moreira *et al.*, 2016). Santana *et al.* (2016) identified and quantified MPs using a polarized light microscope.

In 2017, Canadian researchers proposed a novel method for collecting MPs on sandy beaches, suggesting the replacement of conventional density separation techniques with a protocol inspired by petroleum extraction processes used in the oil industry (Crichton *et al.*, 2017). In Brazil, additional efforts focused on determining the optimal diameter of a manual auger, aiming to estimate sediment volume and enable heterogeneous sampling based on beach profiles (Fisner *et al.*, 2017).

In 2018, studies conducted in Canada reported higher concentrations of MPs at the mouths of the Detroit and Grand Rivers, areas characterized by significant urban influence, as well as in tributaries with high population densities and maritime traffic (Dean *et al.*, 2018).

Researchers in Mexico monitored 21 beaches over the course of a year, detecting MPs through filtration, visual observation, and verification using FTIR spectroscopy (Piñon-Colin *et al.*, 2018). In Campeche, Mexico, monitoring was conducted at seven sampling sites to detect MPs and phthalate esters using a Varian 3800 gas chromatograph (Borges-Ramírez *et al.*, 2019). In Brazil, the presence of MPs in sediments was observed in 2019 using flotation techniques involving the addition of NaCl to the samples, followed by filtration through commonly used coffee filters (Baptista-Neto *et al.*, 2019).

Concerns regarding the quality of sample collection and analysis across various matrices —such as sediment, tissue, water, and air— have prompted a strong response from the scientific community. In the United States, scientists have proposed the development of standardized guidelines to address the challenges associated with sampling in diverse environments. These guidelines aim to streamline collection methods, optimize sample processing while minimizing secondary contamination, and establish a comprehensive database of identified MPs (Brander *et al.*, 2020). In Canada, a prospective model developed in 2020 assessed the potential accumulation of MPs in crustaceans in the Northeastern Pacific, enabling the evaluation of risks associated with inadequate plastic waste management (Alava, 2020).

In 2021, there was a notable increase in scientific publications related to MPs in sediments, including the first report from Puerto Rico. This study employed a methodology similar to that of Baptista-Neto (2019), in which six sandy beaches were sampled and the results were compared with beaches from other parts of the world (Pérez-Alvelo *et al.*, 2021).

In Mexico, samples of water, sediment, and commercially available fish were analyzed through visual inspection. For sediment samples, the methodology involved drying, followed by wet oxidation, and the subsequent addition of $ZnCl_{2}$2—an approach capable of extracting up to 90% of the polymers. This represents a novel advancement in MP identification. Additionally, chemical characterization was performed using Fourier-transform infrared spectroscopy (Sánchez-Hernández, 2021).

In 2022, Brazil introduced an innovative approach to MP analysis by using a hot needle as an alternative to chemical analysis for confirming whether particles are composed of plastic. Meanwhile, in the United States, the presence of MPs in coastal sediments had already been documented using X-ray fluorescence (XRF) for physical identification, along with the application of potassium metaphosphate for organic matter degradation (Culligan *et al.*, 2021).

It has been demonstrated that the sedimentation time of MPs positively correlates with the frequency of wind speed >1 m, especially for coarse particles, the dry sedimentation rate of coarse particles increases with the increase in wind speed (Jia *et al.*, 2022). This implies that their concentration will be higher in areas with favorable wind conditions. In addition to the high concentration of sediments and sand particles, the transport of MP particles is favored (Zhao *et al.*, 2023).

High-density MPs, such as PVC and PET, tend to accumulate in sediments rather than being transported over long distances (Wang *et al.*, 2022). In contrast, films and granules exhibit a greater tendency to settle on surfaces with larger specific surface areas compared to fiber-type MPs. Fibers are more likely to adhere to moisture and particulate matter in water during rainfall events, resulting in their broader dispersion into the atmosphere and soil (Jia *et al.*, 2022). Although data on MP pollution in soils with varying land uses remain limited, the occurrence, fate, and ecological impacts of MPs in terrestrial environments warrant further investigation (Bi *et al.*, 2023).

The abundance of MPs varies according to land use, nutrient content in surrounding soils, and atmospheric deposition (Table 1), which can act as a medium for transferring MPs from the atmosphere to terrestrial and aquatic ecosystems —an aspect that remains underexplored (Jia *et al.*, 2022). Factors such as unregulated municipal waste disposal, insufficient waste reduction strategies (Naidu *et al.*, 2022), and marine aquaculture practices (Jorquera *et al.*, 2022) contribute to the continuous accumulation of MPs, exerting harmful effects on aquatic ecosystems, organisms, and adjacent coastal communities (Naidu *et al.*, 2022). Moreover, MPs accumulated in soils during dry seasons may undergo seasonal mobilization, becoming incorporated into the hydrological cycle during rainy periods. Due to their small size and high mobility, MPs can serve as vectors for the transport of pathogenic microorganisms, heavy metals, invasive species, and other pollutants. During this process, they may also adsorb lipophilic contaminants, amplifying their ecological risks (Jorquera *et al.*, 2022; Rusinque-Quintero *et al.*, 2022).

MPs are transported by surface runoff to coastal areas, where they can enter the ocean and accumulate locally on beaches. Their distribution along the coastline is influenced by tidal cycles and sediment grain size, as soil characteristics determine the extent to which MPs can accumulate. These patterns also reflect the dynamic interactions of marine environments influenced by the sediment deposition capacities of rivers that discharge into the sea (Rusinque-Quintero *et al.*, 2022). Coastal hydrodynamic factors —including current direction and magnitude, wind, and tidal regimes— are key drivers of oceanic circulation and vertical mixing, which significantly affect MP distribution (Jorquera *et al.*, 2022). Additionally, marine dynamics and wave-induced abrasion promote the fragmentation of MPs, increasing their ecological risk. Studies have shown that deeper marine environments tend to harbor higher concentrations of MPs than coastal waters, due to reduced water movement and circulation (Rusinque-Quintero *et al.*, 2022; Jorquera *et al.*, 2022; Wang *et al.*, 2022). MPs with densities greater than seawater, or those subjected to biofouling by microorganisms, may settle and accumulate in marine sediments, the water column, and deep-sea environments.

Marine organisms provide valuable insights into the current state of marine biota, MPs can obstruct the digestive tract (Olivatto *et al.*, 2019) adhere to gills, potentially causing asphyxiation, and may be ingested accidentally or through contaminated food, negatively affecting the reproduction of oysters, the metabolism of copepods. In *Arenicola marina* polychaetes the ingestion of polystyrene MPs leads to weight loss (Olivatto *et al.*, 2019, Jorquera *et al.*, 2022). Future studies should consider wind as a transport factor for fibers since it is a factor that cleans areas where the wind favors, potentially transporting MPs to different locations and causing further impact. Furthermore, a strong correlation has been observed between the density of permanent residents and local MP contamination. In contrast, temporary residents primarily contribute to coastal water pollution through urban and terrestrial runoff, including riverine inputs, rather than fishing-related activities.

CONCLUSIONS

The production of scientific articles on MPs in sediments has increased significantly over the past decade; however, a standardized methodology for their separation, quantification, and classification is still lacking. Despite this, countries such as Brazil, the United States, Canada, and Mexico have continued to detect MPs in sedimentary environments by applying a variety of methodological approaches. Scientific journals have shown growing interest in publishing research related to MPs, particularly studies that include keywords such as plastics, water pollutants, chemical contaminants, toxic substances, microscopy, toxicology, polystyrene, scanning electron microscopy, animals, and fish. Additionally, relevant topics include MP concentration, agricultural contexts, lakes, geological sediments, and estuarine systems.

ACKNOWLEDGMENTS

This research was carried out with support to the Instituto Tecnológico Nacional de México/ Instituto Tecnológico de Boca del Río (TecNM/ITBOCA) and to the Consejo Nacional de Ciencia y Tecnología (CONAHCYT) for funding.

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