



ANTHROPOGENIC DRIVERS AND ECOLOGICAL IMPACTS OF MICRO-PLASTIC POLLUTION IN NIGERIA WATERWAYS: A REVIEW

¹*Oghenerukevwe Ruth Eyankware ²Kesiena Clementina Eyankware

¹Department of Environmental Management & Toxicology, Dennis Osadebay University, Asaba

²Department of Plant Science and Biotechnology, Dennis Osadebay University, Asaba,

¹<https://orcid.org/0000-0002-8947-7600>

²<https://orcid.org/0009-0006-7361-25001>

*Corresponding Author Email: rutheyankware@yahoo.com

ABSTRACT

*This peer-reviewed field studies examines microplastic pollution in Nigerian waterways, by focusing on sources, distribution, ecological effects and human-health risks. Searches employed terms such as microplastic, Nigeria, Lagos Lagoon, Niger Delta, river, estuary and coastal; only papers supplying original data on particle numbers, shapes, polymer types or organism uptake were retained. Rapid expansion of the plastics industry, heavy reliance on single-use polyethylene water sachets and weak solid-waste systems drive widespread contamination. The review revealed that fibres dominate most samples, polyethylene, polypropylene and polyethylene terephthalate appear most frequently, urban and industrial zones carry higher loads than rural sites and seasonal rains influence both transport and timing. It was also observed that microplastics occur in the guts of key food fish including *Clarias gariepinus* and *Oreochromis niloticus*. Ecological effects such as gut blockage, altered feeding and possible transfer of adsorbed chemicals is derive largely from laboratory work and limited field observations as clear evidence of broader population impacts remains scarce. Consequently, health estimates based on seafood intake rest on particle counts rather than toxicological data and must be treated carefully. Frequent consumers may ingest tens of thousands of particles yearly, yet the clinical meaning remain unclear. Moreover, major gaps persist there is scarce long-term data outside the South-West, inconsistent methods and almost no studies linking microplastics with other contaminants. In addition, the review recommends that standardised protocols, broader geographic coverage and stronger waste management plus regulation are required to limit further risks as these measures would help curb ongoing exposure.*

Keywords: Plastic pollution, Nigerian waterways, Ecological impacts , Anthropogenic driver

1. INTRODUCTION

Contemporary patterns of plastic production and consumption have driven a rapid accumulation of waste in marine ecosystems, creating a persistent environmental problem (Hossain & Engelhardt, 2025). Solid waste pollution of the oceans now ranks among the most serious global threats, with long lasting ecological effects (Eshom-Arzadon, Conway, Masura, & Baker, 2025; Michal et al., 2025). Despite decades of national and international efforts to curb the problem, the volume of debris continues to rise in parallel with population growth and the widespread use of single-use items. Each year millions of tonnes of plastic enter the marine environment; roughly 80 percent originates from land-based sources (Ghiglione & ter Halle, 2025; Wu, et al., 2025).

Plastics are synthetic organic polymers derived chiefly from petroleum feedstocks. The most common types polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC) and polyethylene terephthalate (PET) can be moulded when heated and therefore appear in packaging, bags, bottles and a wide range of consumer goods (Chaukura et al., 2021; Viel et al., 2023; Rebecca & Md Saydur, 2025).

Global production has expanded from approximately 2 million tonnes in 1950 to more than 390 million tonnes in the early 2020s and reached about 430 million tonnes in 2024 (Ritchie, Samborska, & Roser, 2026). Projections indicate that output could exceed 450 million tonnes in the near term and approach 800–1 000 million tonnes annually by mid-century if current trends persist (Hossain & Engelhardt, 2025). Many of these products have short useful lives,

often less than a year, and inadequate waste management allows large quantities to escape into rivers, coastal waters and the open ocean (Ibrahim et al., 2025; Rebecca & Md Saydur, 2025).

Once in the environment, plastics degrade extremely slowly. Ocean currents, waves and wind disperse fragments over long distances, forming accumulation zones even in remote regions. Coastal areas, where human activity is most intense, experience the heaviest impacts. Larger debris breaks down into microplastics (particles smaller than 5 mm), which now outnumber plankton in some marine habitats and disrupt food webs (Kumar et al., 2024). These particles originate both from the fragmentation of larger items and from primary sources such as industrial pellets and synthetic fibres. Their resistance to biodegradation, combined with the additives used to enhance flexibility and durability, ensures long-term persistence in water, sediments and biota (Pankaj, Sutkar, & Gadewar, 2023; Ibrahim, et al., 2025; Muschter, 2026).

In African aquatic systems the problem is compounded by limited waste-collection and treatment infrastructure. Nigeria, the continent's most populous country, has seen rapid growth in plastic production and consumption, as shown in (Figure 1, 2a and 2b). Yet only a modest number of peer-reviewed studies have examined the sources, distribution and ecological effects of microplastics in its waterways. Existing research remains concentrated in the South-West, leaving large regions under-sampled. Consequently, the anthropogenic drivers and ecological consequences of microplastic pollution in Nigerian rivers, lagoons and coastal waters are still incompletely understood (Eyankware, Igwe, Ogwah, & Eyankware, 2020).

It is based on this premise that this review therefore synthesises the available evidence on the principal human activities that release microplastics into Nigerian waterways and the documented ecological impacts of those particles. By critically evaluating the current literature, identifying regional gaps and moderating claims that exceed the strength of existing data, the paper aims to provide a clearer foundation for future research and for more effective management of plastic pollution in the country's aquatic environments.

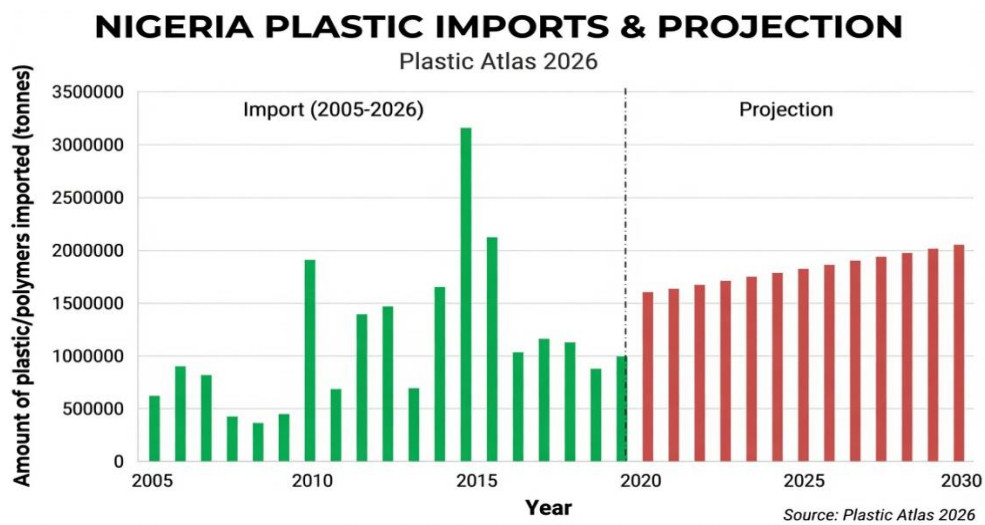


Figure 1: Shows the Nigerian plastic production trend (Plastic Atlas, 2020)

Nigeria Plastic Trends (2007–2026)

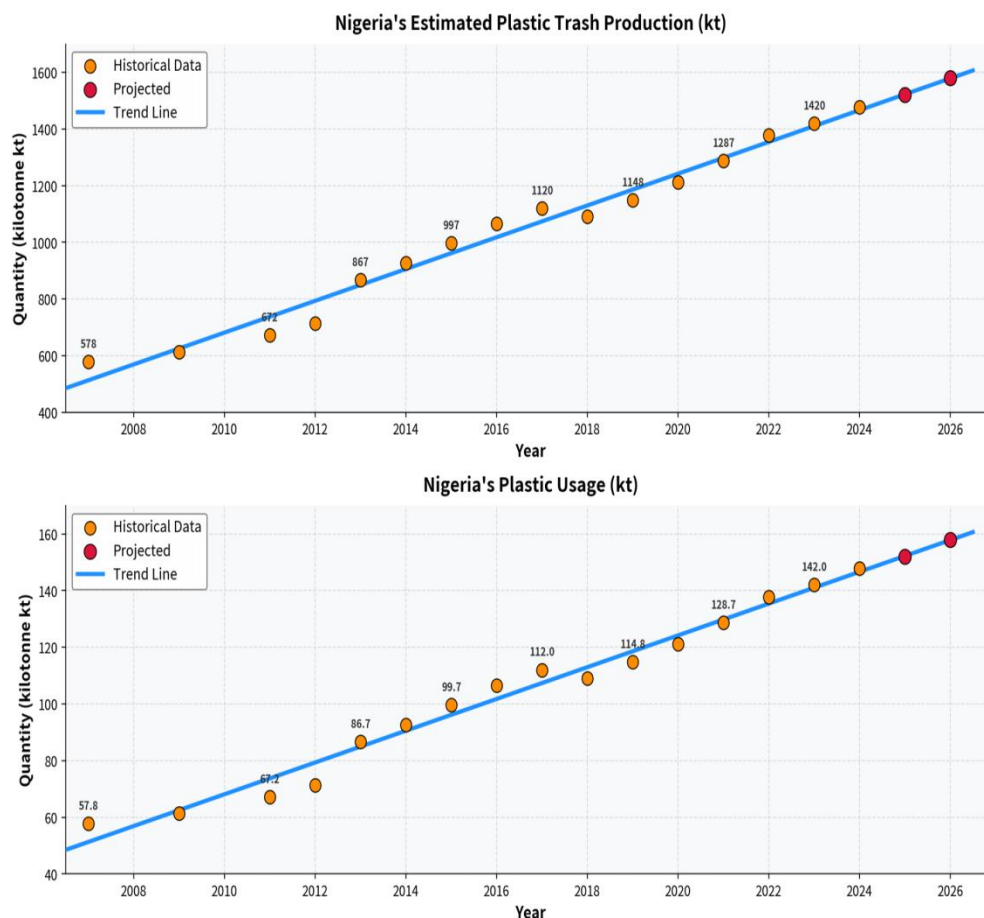


Figure 2a and Figure 2b: Nigeria's estimated plastic trash production as well as the country's usage of plastic
Source Author's Field Work, (2026)

2. MATERIALS AND METHODS

This review systematically examined peer-reviewed studies on microplastic occurrence, sources, distribution and risks in Nigerian aquatic systems. Searches used combinations of the terms microplastic, Nigeria, Lagos Lagoon, Niger Delta, river, estuary and coastal. Only studies reporting original field data on particle abundance, morphology, polymer type or biota uptake from Nigerian freshwater, brackish or marine environments were retained. Extracted information included sampling location and matrix, particle size range, dominant shapes and polymers, concentrations, and quality-control measures. Because protocols and reporting units varied widely, data were synthesised narratively. Emphasis was placed on geographical coverage, seasonal patterns, and the distinction between local field observations and inferences from laboratory or non-Nigerian studies.

3.0 RESULTS AND DISCUSSION

3.1 Primary and Secondary Micro-plastics: Sources, Formation, and Environmental Behavior Microplastics are plastic particles smaller than 5 mm and fall into two categories that differ in origin (Pant & Valapa, 2023). Primary microplastics are manufactured at microscopic size for specific uses. Secondary microplastics form when larger plastic items break down (Pant & Valapa, 2023). In Nigeria, primary inputs include microbeads from personal-care products that enter drains and pass through wastewater systems with limited capture capacity. Synthetic textiles release large numbers of fibres during domestic laundry; for instance, a single 6 kg wash can shed hundreds of thousands of fibres into local sewers and rivers (Ugosor, Terna, Timothy, David, & Kaana, 2025). Industrial spills of resin pellets (nurdles) and discharges from manufacturing and medical facilities add further primary particles,

particularly in urban centres such as Lagos and Port Harcourt (Okwere, Danquah, Miyittah & Amoah -Nuamah, 2025).

Secondary microplastics arise from the fragmentation of bags, bottles, packaging and discarded fishing gear. In Nigerian waterways this process is driven by intense ultraviolet radiation, high temperatures, oxidation and mechanical abrasion by waves, currents and human activity (Yadav et al., 2025). The rate of breakdown depends on polymer type and local conditions. Low-density polymers such as polyethylene and polypropylene tend to remain buoyant, while denser particles settle into sediments. Fibres, fragments, films and beads of varying colour and density are therefore widely distributed through rivers, lagoons and coastal waters (Ashrafy, et al., 2023). Physical and chemical properties control transport. Storm-water runoff, river flow and wind carry particles from densely populated catchments into the Lagos Lagoon, Niger Delta creeks and other waterways. Once released, both primary and secondary particles persist because of their resistance to biodegradation, continuing to accumulate in water, sediment and biota. (Table 1) summarises the primary and secondary microplastics found in Nigeria environment. The combination of ongoing primary releases and continuous fragmentation of mismanaged plastic waste maintains a chronic contamination problem that requires improved waste management and monitoring.

Table 1: Summary of Primary and Secondary MPs in the Environment

Source	Description/Examples	References
Primary MPs		
Cosmetics and personal care products	Microbeads in facial scrubs, toothpaste, shower gels, exfoliants as abrasives	Bikiaris, Nikolaidis, & Barmpalexis, (2024); Han & Kim, (2025)
Plastic pellets/nurdles (pre-production)	Resin pellets lost during manufacturing, transport, or processing	Song et al., 2026; Perumal & Kolandhasamy, 2026; Ivar do Sul, Reineccius, Waters, Zalasiewicz & Waniek, 2026.
Synthetic textiles (manufacturing/release)	Fibers shed during production, finishing, or initial use (debated classification; often primary when intentional small fibers)	Akyildiz et al., 2024; Han, McQueen, & Batcheller, 2024; Hossain, Zhang, Haque, & Naebe, 2025; Osman, et al., 2023.
Industrial abrasives and applications	Air-blasting, occupational uses, medicine (e.g., dental polish), drilling fluids	Eram, et al., 2024; Kui, et al., 2025)
Paints, coatings, and road markings	Synthetic polymer particles in marine/road paints and protective coatings	Turner, 2019; Ibrahim, et al., 2025)
Secondary MPs		
Tire wear and vehicle abrasion	Particles from road friction, runoff	Osman, et al., 2023; Ibrahim et al., 2025; Song at al., 2026.
Synthetic textile fibers (laundry/wear)	Microfibers released during washing and use of clothing/household textiles	Akyildiz et al., 2024; Ibrahim, 2025; Ali & Khan, 2026.
Fragmentation of larger plastic waste/litter	Breakdown of bottles, bags, packaging, fishing nets/gear via weathering, UV, waves	Ashrafy et al., 2023; Ibrahim, et al., 2025.
Paints, coatings, and road markings abrasion	Weathering/spillage of house/road/marine paints	Ibrahim et al., 2025.
Agricultural plastics	Mulch films, greenhouse materials, polymer-coated fertilizers/sludge	Salama & Geyer, 2023; Hayes, 2025; Wan, Yang, & Zhou, 2025)
General littering, landfills, recycling losses, and dumping	Mismanaged waste, urban dust, ship/pleasure craft losses	Ibrahim, 2025; Khanjani & Mohammadi, 2026.
Other household/industrial abrasion	Breakdown of everyday plastics, construction dust	Song, et al., 2026.

3.2 Abundance and Distribution of Micro-plastics

Microplastics are synthetic polymer. Their size, density-dependent buoyancy, chemical stability and slow degradation enable transport via rivers, tidal exchange and residual currents into Nigerian freshwater, brackish and coastal systems (Lin, et al., 2023; Vainberg, Abakumov, & Nizamutdinov, 2025). Primary particles enter already microscopic (microbeads, resin pellets, textile fibres); secondary particles form through ultraviolet-driven oxidation,

thermal stress and mechanical abrasion of larger debris (Kamalasekaran & Sundramoorthy, 2026). Though urban surface runoff remains the dominant entry route in Nigeria as indicated in (Figure 3), inadequate collection and open dumping allow plastics to reach rivers during rainfall. Beach and river surveys in Imo State and along the Cross River, Qua Iboe River and Jaja Creek in Akwa Ibom State show plastics routinely exceeding 50 % of total macrodebris, with a clear positive correlation between macroplastic density and subsequent MP abundance as larger items fragment (Yalwaji, John-Nwagwu, & Sogbanmu, 2022; Toheeb, et al., 2025). Moreover, domestic, commercial and industrial discharges further amplify loads, especially where wastewater plants retain only a fraction of the smallest particles.

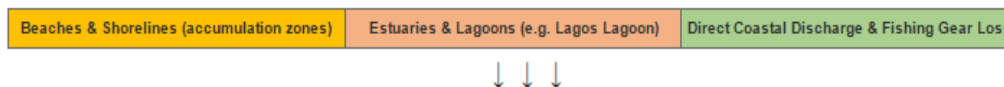
1. Land-based Sources



2. Primary Transport Pathways



3. Coastal & Intermediate Compartments



4. Marine Receiving Environment



Colour Legend



Figure 3: Conceptual pathway of microplastic movement from land-based sources through Nigerian transport routes into coastal and marine receiving environments.
Source Author's Field Work, (2026)

Local concentration data illustrate both spatial heterogeneity and methodological variation. In Lagos Lagoon (Epe, Makoko, SagboKoji, Badagry), surface water averaged approximately 65 particles L^{-1} and sediments approximately 3 906 particles kg^{-1} , with fibres dominant and particle sizes spanning 0.45–1 000 μm (Akinhanmi, Ayanda, & Dedeke, 2023). Additionally, touristic beaches along the Lagos Atlantic coast recorded 1 278–5 688 MPs kg^{-1} in sands and 776–2 104 MPs kg^{-1} in intertidal sediments; pollution-load indices exceeded 1 at every site (Idowu, et al., 2024). Coastal communities in Ondo State yielded 1 257–2 844 particles L^{-1} in water, with sediment inventories higher in the dry season and LDPE comprising roughly 64 % of recovered particles (Olanipekun, Idowu, & Aiyesanmi, 2024). Offshore Gulf of Guinea waters ranged from 48–705 particles L^{-1} and sediments from 73–1 033 particles kg^{-1} , accompanied by elevated potential ecological-risk indices in several zones (Yakub et al., Izge, 2024). Similarly, brackish and freshwater creeks off the Gulf of Guinea produced 100–490 particles L^{-1} in water and 70–220 particles kg^{-1} in sediment, fibres accounting for 33–80 % of particles and PP, PE, PS, PA and PET the principal polymers (Popoola, et al., 2026). In addition, Araromi seaside surveys recorded plastics as 86–92 % of total litter items (Fadare, et al., 2022). Morphology and polymer composition are relatively consistent across these sites. Fibres predominate in most water and sediment samples; fragments, films and occasional pellets make up the remainder. Polyethylene, polypropylene and polyethylene terephthalate are the most frequently identified polymers, followed by PVC, PS and nylon. Density controls vertical partitioning: PE and PP remain suspended or float, while PET and PVC accumulate in sediments. Seasonal sampling in ox-bow lakes near Yenagoa, Bayelsa State, showed coloured fibres dominant in surface water and elevated PET and plasticised PVC in dry-season sediments, with measurable shifts in LDPE and PVC proportions between wet and dry periods (Oni, Ayeni, Agboola, Oguntade, & Obanla, 2020). Subsequently, across inland rivers spanning Nigeria's six geopolitical zones, fibre abundance typically rises during the wet season (Doherty et al., 2024). Comparative figures from Qatar (≈ 0.71 particles m^{-3}), selected South African near-shore zones (0.15 to several hundred particles m^{-3}) and Lake Victoria fish (50–75 % prevalence) provide context only (Nel & Froneman, 2015; Biginagwa,

Mayoma, Shashoua, Syberg, & Khan, 2016; Castillo, Al-Maslamani, & Obbard, 2016). However, differences in mesh size, extraction protocols and reporting units preclude quantitative cross-regional ranking. According to Ugosor, Terna, Timothy, David, & Kaana, (2025) Nigerian datasets themselves remain geographically skewed toward the South-West and Lagos, as they rely on modest sample sizes, and rarely incorporate procedural blanks or standardised polymer confirmation. Consequently, statements about absolute abundance, long-range transport efficiency or quantitative ecological risk must be treated as provisional pending harmonised, multi-season surveys that include the Niger Delta, North-Central rivers and seasonal water bodies.

Persistence is assured by high molecular weight and hydrophobicity. Once released, particles continue to redistribute among the water column, shoreline and benthos under the influence of weathering, biofouling and residual currents. Current Nigerian evidence therefore demonstrates widespread occurrence driven by urban runoff, waste mismanagement and seasonal hydrology; yet the quantitative strength of that evidence is still limited by uneven spatial coverage and non-uniform methods. Table 2 shows some microplastics abundance in marine and coastal debris in Nigeria.

Table 2: Recent Studies on Plastic Content and MPs Abundance in Marine and Coastal Debris, Nigeria

Locality	Marine Litter / MP Type	Plastic / MP Content or Abundance	Sources
Araromi Seaside, Gulf of Guinea coastline, Ondo State	Macro litter (various single-use plastics dominant)	Plastics: 86% (dry season), 91.8% (rainy season) of total litter items; avg. 0.61–1.80 items/m ²	Fadare at al., 2022.
Touristic beaches (Landmark, Tarkwa Bay, Elegushi, Lighthouse, Oniru), Atlantic coast, Lagos	MPs in beach sands and intertidal sediments (fibres, fragments, films; PS, LDPE, EVA dominant)	1278 ± 655 to 5688 ± 1377 MPs/kg (sands); 776 ± 214 to 2104 ± 1065 MPs/kg (sediments); all sites polluted (PLI >1)	Idowu at al., 2024.
Coastal communities, Ondo State (e.g., Awoye, Igbokoda)	Meso- and MPs in water and sediments (fibres dominant; LDPE 64% in sediments)	Water: 1257–2844 particles/L; Sediments: higher in dry season (~17k–22k total particles across samples); plastics ubiquitous	Olanipekun, Idowu, & Aiyesanmi, 2024.
Lagos Lagoon (Epe, Makoko, SagboKoji, Badagry)	MPs in surface water and sediment (fibres dominant; nylon, foam, others)	Water: ~65.2 particles/L (avg.); Sediment: ~3906 particles/kg (avg.); sizes 0.45–1000 µm	Akinhanmi, Ayanda, & Dedeke, 2023.
Woji River Port-Harcourt, Nigeria	MPs in water, sediment, and biota (fibres, fragments; nylon, PVC, PET)	N/A	Field Study
Goi, Rivers State, Nigeria	MPs litter (various single-use plastics dominant)	N/A	Field Study
Offshore waters, Gulf of Guinea (Eastern, Central, Western zones)	MPs in water and sediment (filaments, films, fibres, microbeads; PVA, CR, others)	Water: 48–705 particles/L (varies by zone); Sediment: 73–1033 particles/kg; high ecological risk (pERI)	Yakub at el., Izge, 2024.
NPA Wari Jetty	MPs in water and sediments (various single-use plastics dominant)	N/A	Field Study
Gbaramatu, Niger Delta	MPs in water and sediments (various single-use plastics dominant)	N/A	Field Study
Creeks off Gulf of Guinea (brackish/freshwater, SW Nigeria)	MPs in water/sediment (fibres 33–80%; PP, PE, PS, PA, PET)	Water: 100–490 particles/L; Sediment: 70–220 particles/kg	Popoola, et al., 2026.

Nevertheless, the import pattern illustrated in Figure 4 provides an important upstream driver that helps explain the widespread occurrence of secondary MPs now documented in Nigerian freshwater, brackish and coastal systems. Furthermore, it shows that China supplies the largest share of Nigeria's plastic imports at 20 %, followed by the United States (17 %) and the Republic of Korea (13 %). India, Saudi Arabia and Brazil together account for a further 22 %, while the remaining volume is distributed among France, Germany, South Africa, the United Kingdom and several smaller suppliers. This concentration of imports from a limited number of major manufacturing economies underlines the scale of primary plastic entering the Nigerian market and, by extension, the potential secondary microplastic load generated once these materials reach the end of their short service lives.

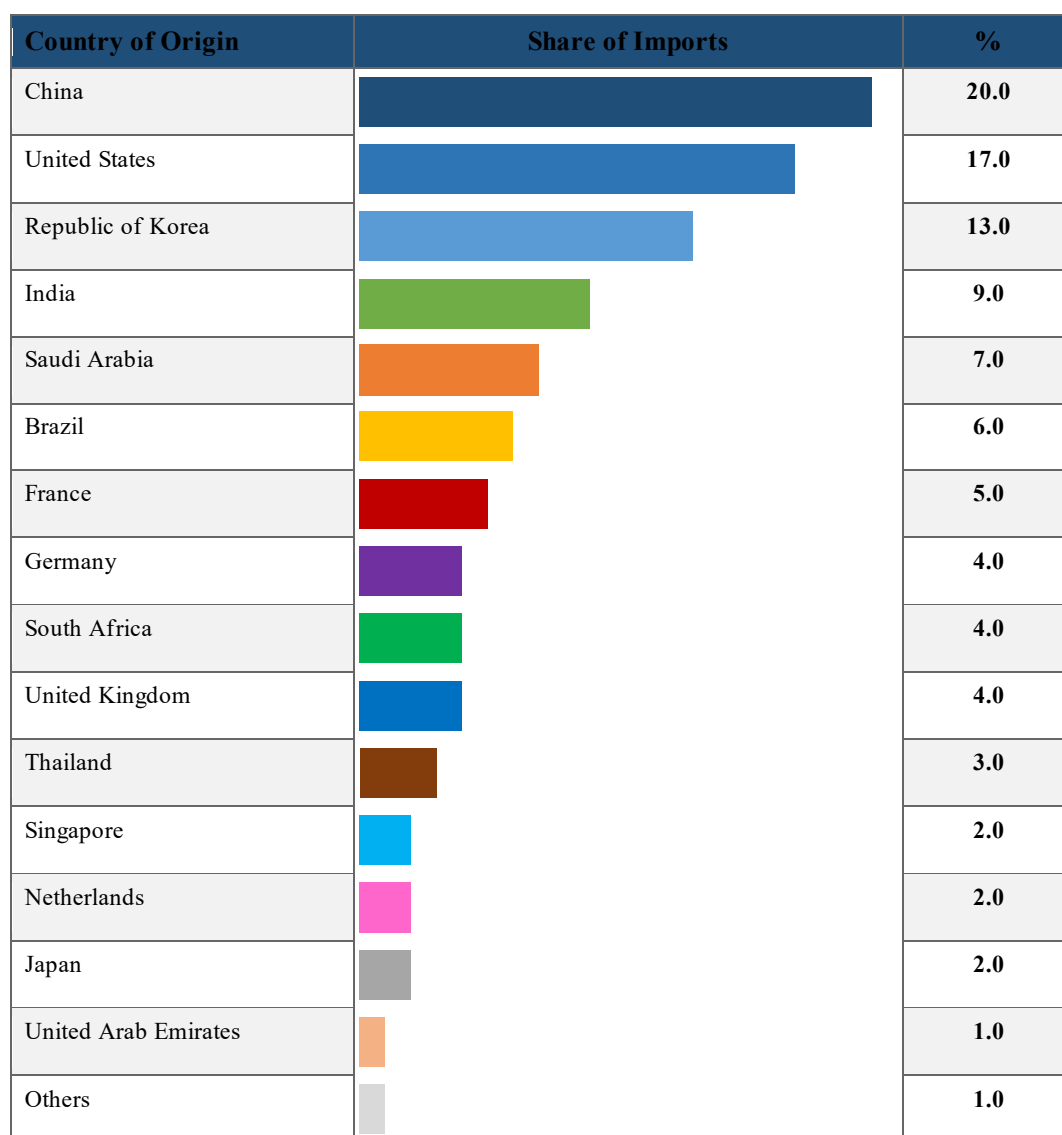


Figure 4: Nigeria's importation of plastic.
Source: Author's Field Work, (2026)

3.3 Micro-plastics in the Nigerian Environment (Sources and Fate)

The presence of microplastics in Nigerian aquatic and terrestrial systems is sustained by a combination of industrial expansion, high per-capita use of disposable plastics and chronic shortfalls in collection and treatment infrastructure. Since the 1960s the domestic plastics sector has grown from a handful of small plants to an industry capable of producing hundreds of thousands of tonnes each year (Yalwaji, John-Nwagwu, & Sogbanmu, 2022). Concurrently,

Nigeria has become one of the continent's principal importers of both raw resins and finished goods. The resulting supply of polyethylene, polypropylene and related polymers enters a consumption pattern dominated by short-lived items such as polyethylene bags, food containers, drinking straws and the ubiquitous sachet-water packs known locally as "pure water" (Enyoh et al., 2022; Idowu et al., 2024). Once discarded, these materials constitute the main reservoir for secondary particle formation.

Laundry activities add a further, continuous input of microfibrils. Washing of synthetic garments directly in rivers or the discharge of untreated washing-machine effluent releases large numbers of fibres into surface waters. Moreover, the majority of municipal wastewater plants remain either non-functional or capable of only partial solids removal, so that both primary particles and fragmented material reach rivers, lagoons and coastal waters with little interception (Yalwaji, John-Nwagwu, & Sogbanmu, 2022). Urban and industrial centres amplify these loadings. Coastal and riverine cities generate disproportionately high volumes of plastic waste; larger, relatively unweathered fragments are commonly recovered near manufacturing zones, while downstream reaches and depositional environments are enriched in secondary particles (Attah, Stanley, & Sikoki, 2023).

Open dumping along roadsides, in drainage channels and directly into watercourses remains widespread and continually replenishes the material available for fragmentation (Eyankware & Eyankware, 2021). These practices are clearly illustrated across a range of Nigerian aquatic environments in (Figure 5a) (Lagos Lagoon / Makoko area), (Figure 5b) (Niger Delta mangrove), Figure 5(c) (Ondo State coastline – Araromi / Igbokoda), (Figure 5d) (Cross River / Qua Iboe River, Akwa Ibom) and (Figure 5e) (Yenagoa ox-bow lake, Bayelsa State) The figures document the direct entry of plastic litter into surface waters and the subsequent fragmentation that sustains secondary microplastic loads.



Figure 5a: Lagos Lagoon / Makoko area).



Figure 5b: Niger Delta mangrove



Figure 5c: Ondo State coastline (Araromi / Igbokoda)



Figure 5d: Cross River / Qua Iboe River (Akwa Ibom)



Figure 5e: (Yenagoa ox-bow lake (Bayelsa State)
Source Author's Field Work, (2026)

Peer-reviewed investigations conducted within Nigeria remain limited in number and spatial coverage. Nevertheless, the studies that do exist document MPs in water, sediment and biota across several regions. Polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), and polystyrene (PS) are the polymers most frequently reported as illustrated in (Figure 6). Ingestion has been confirmed in commercially important fish, selected invertebrates and birds (Christian, 2021; Doherty, et al., 2024; Shokunbi, Idowu, Davidson, & Aiyesanmi, 2024). However, sample sizes are generally modest, analytical protocols vary, and procedural blanks are not always included. Consequently, quantitative estimates of flux or long-term accumulation must still be regarded as provisional.

Based on this, it was observed that the rising domestic production, intensive use of single-use plastics, inadequate waste infrastructure and direct environmental discharge maintain a steady supply of both primary and secondary MPs to Nigeria's terrestrial, freshwater and marine compartments. Strengthened collection systems, standardised monitoring programmes and targeted regulatory measures will be required to reduce further inputs.

Common Microplastic (MP) Polymer Types Observed in Nigerian Aquatic Environments

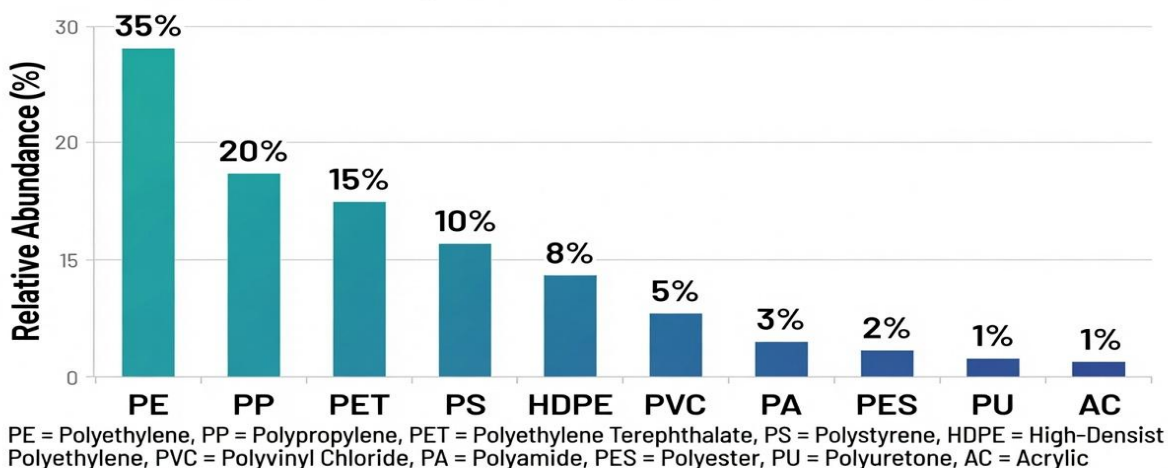


Figure 6: Shows the several MP polymer types that have been observed in aquatic environments in Nigeria (PE = polyethylene, PS = polystyrene, PET = Polyethylene terephthalate HDPE, AC = acrylic, PP = polypropylene, PA = polyamide, PVC = Polyvinyl chloride). PES stands for polyester, while PU stands for polyurethane.

Source Author's Field Work, (2026)

3.4 Micro-plastics Risk towards Marine Environment and Organisms in Nigeria

Field data from Nigerian rivers, lagoons and coastal systems confirm that microplastics are ingested by several commercially harvested species. In the Lagos Lagoon and adjoining coastal waters, it was observed that PE and PP particles have been recovered from the gastrointestinal tracts of fish, with fibres forming the dominant morphotype (Olarinmoye, et al., 2020; Akinhanmi, Ayanda, & Dedek, 2023; Shittu, Dedek, Aladesida, Akinbola, & Olude, 2025). Similarly, comparable recoveries occur farther inland. In the Osun River, the gastropods *Lanistes varicus*, *Melanoides tuberculata* and *Theodoxus fluviatilis* contained fibre and fragment loads composed chiefly of PE, PP, and nylon (Idowu, et al., 2024). Moreover, across rivers representing all six geopolitical zones, fibre abundance typically increases during the wet season, reflecting enhanced transport of land-derived material (Doherty, et al., 2024). In addition, in the Ikpoba River, *Clarias gariepinus* accumulated higher particle numbers than *Oreochromis niloticus*, with PE the most frequent polymer identified (Ogbomida, et al., 2023).

Physical effects observed or inferred from these local specimens include gut occupancy by fibres and fragments. However, chemical and biological effects sorption of co-contaminants, oxidative stress or altered feeding are largely extrapolated from laboratory exposures rather than quantified in free-living Nigerian populations (Mahu et al., 2023; Olanipekun, Idowu, & Aiyesanmi, 2024). In contrast, no published Nigerian study has yet measured population-level declines, reproductive impairment or community shifts attributable to microplastic exposure. Subsequently, methodological differences in mesh size, digestion protocols and polymer confirmation further limit direct comparison of particle loads among sites.

Consequently, the available Nigerian evidence establishes trophic transfer into local food webs but leaves the magnitude of ecological consequence unquantified (Eyankware, Uchenna, & Ulakpa, 2025). Standardised multi-season surveys, polymer-specific bioavailability measurements and long-term field monitoring are therefore required before risk estimates can move beyond occurrence data.

3.5 Micro-plastics and Associated Human Health Risks

Nigeria's coastal fishing communities depend heavily on seafood as a primary protein source (Idowu et al., 2024). Microplastics recovered from water, sediment and commercially harvested species in these areas raise legitimate questions about dietary exposure.

Baseline surveys in the Escravos Estuary and coastal communities of Ondo State documented particles in fish, crabs and periwinkles (Samuel, Olamide, & Kazeem, 2024). Similarly, recoveries have been reported from Lagos Lagoon and other south-western waters (Ugosor, Terna, Timothy, David, & Kaana, 2025). These findings establish that local populations consuming whole or gutted seafood are exposed to microplastics. However, current risk estimates rest almost entirely on particle counts rather than measured tissue concentrations or clinical endpoints.

High-frequency consumers have been projected to ingest tens of thousands of particles annually, with some estimates exceeding 170 000 particles per year. Such figures indicate the scale of potential exposure but do not establish dose-response relationships or demonstrable health outcomes (Kannan & Vimalkumar, 2021). In addition, no published Nigerian biomonitoring study has yet reported microplastics in human blood, stool or tissues. Consequently, statements linking dietary intake to specific clinical effects remain provisional.

Moreover, microplastics can sorb metals and hydrophobic organic contaminants. Laboratory work elsewhere has associated plastic additives with oxidative stress and inflammation, yet these mechanisms have not been quantified under Nigerian exposure conditions. In contrast, differences in particle size, polymer type, weathering state and co-occurring pollutants further complicate any extrapolation from experimental systems to local populations.

Subsequently, the available Nigerian evidence confirms dietary exposure pathways but leaves the magnitude of human health risk unquantified. Standardised monitoring of seafood and drinking-water sources, polymer-specific bioavailability studies, and targeted biomonitoring of high-consumption coastal communities are therefore required before firm conclusions can be drawn.

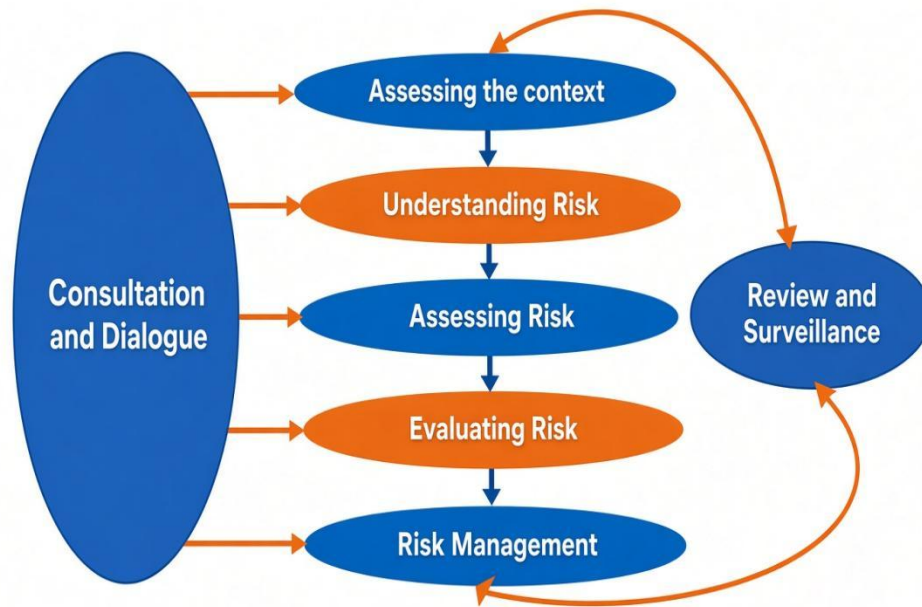


Figure 7: Environmental risk assessment proposed framework.
Source: Author's Field Work, (2026)

3.6 Gaps in micro-plastic research and future outlook

A critical appraisal of the existing literature reveals several persistent shortcomings. First, many Nigerian studies lack rigorous quality-control measures such as procedural blanks and contamination-prevention protocols, thereby limiting data reliability. Second, geographical coverage remains heavily skewed toward Lagos and the South-West; long-term data from the Niger Delta, North-Central rivers and seasonal water bodies are scarce. Third, interactive effects between MPs and co-occurring pollutants have received little systematic attention. Existing risk-assessment frameworks designed for conventional chemical contaminants are generally ill-suited to the particle-based and vector-mediated nature of MP pollution.

Addressing these gaps will require standardized analytical protocols, expanded spatial and temporal monitoring programmes, and more explicit critical evaluation of the strength of local evidence before broader ecological or health conclusions are drawn. An environmental risk assessment framework proposed for these pathways is presented in (Figure 7).

4. CONCLUSION

This review has examined the sources, distribution and reported ecological and human-health implications of MP pollution in Nigerian aquatic environments. The available evidence summarizes across Figures 1–7 and Tables 1–2, demonstrates that MPs are widespread contaminants, particularly in urbanized and industrial catchments, with fibres, PE, PP and PET predominating. Entry into local food webs has been documented through recovery from commercially important fish species. Ecological and human-health consequences, however, are currently inferred rather than conclusively demonstrated at the scale of Nigerian ecosystems or populations. Methodological inconsistencies, limited geographical coverage and the scarcity of long-term data constrain the strength of broader generalizations. Standardized protocols, expanded monitoring and more cautious interpretation of particle-count data are therefore essential. Prevention through improved waste management and targeted regulatory measures remains the most practicable pathway for limiting further contamination of Nigeria's waterways.

5. RECOMMENDATIONS

The study recommends that standardised sampling, extraction and polymer identification protocols should be adopted nationwide so that abundance data from different sites can be compared. Long-term monitoring programmes need to be extended beyond the South-West to cover the Niger Delta, North-Central rivers and seasonal water bodies, with sampling conducted in both wet and dry seasons.

Concurrent studies of microplastics and co-occurring contaminants are required to clarify possible synergistic effects. Risk assessments for seafood consumers must move beyond simple particle counts and incorporate toxicological endpoints and biomonitoring of high-consumption coastal communities. Most critically, investment in solid-waste collection, controlled disposal and enforcement of restrictions on single-use plastics remains the most practical route to reducing further inputs into Nigerian waterways.

REFERENCES

- Acharya-Patel, N., Cram, K., Groenwold, E. T., Lee, H., Keller, A. G., Bombach, B., ... Helbing, C. C. (2025). Monitoring marine pollution effects through targeted environmental DNA (eDNA) testing in the Pacific Northwest. *Marine Pollution Bulletin*, 216, 118036. <https://doi.org/10.1016/j.marpolbul.2025.118036>
- Adewuyi, A., & Li, Q. (2024). Emergence of microplastics in African environmental drinking water sources: A review on sources, analysis and treatment strategies. *Journal of Hazardous Materials Advances*, 16, 100465. <https://doi.org/doi:10.1016/j.hazadv.2024.100465>
- Ahmad, K., Badawi, R. H., & Bushra, I. (2025). Sustainable coagulative removal of microplastic from aquatic systems: Recent progress and outlook. *RSC Advances*, 15(31), 25256–25273. <https://doi.org/10.1039/d5ra04074d>
- Ajegi, J. O., Adie, P. A., Ubwa, S. T., Tyohemba, R. L., & Oklo, D. A. (2026). Distribution of microplastics in the sediment profiles of River Benue, North Central Nigeria. *Water, Air, & Soil Pollution*, 237, 348. <https://doi.org/10.1007/s11270-025-09050-3>
- Akinhanmi, F. O., Ayanda, O. I., & Dedek, G. A. (2023). Occurrence and characteristics of microplastics in the surface water and sediment of Lagos Lagoon, Nigeria. In *Biotechnological approaches to sustainable development goals* (pp. 103–118). https://doi.org/10.1007/978-3-031-33370-5_7
- Akyildiz, S. H., Fiore, S., Bruno, M., Sezgin, H., Yalcin-Enis, I., Yalcin, B., & Beloped, R. (2024). Release of microplastic fibers from synthetic textiles during household washing. *Environmental Pollution*, 357, 124455. <https://doi.org/10.1016/j.envpol.2024.124455>
- Ali, A., & Khan, M. Z. (2026). Textile microplastics in wastewater: A critical review of removal and carbonization technologies. *C*, 12(1), 24. <https://doi.org/10.3390/c12010024>
- Allen, E., Henninger, C. E., Garforth, A., & Asuquo, E. (2024). Microfiber pollution: A systematic literature review to overcome the complexities in knit design to create solutions for knit fabrics. *Environmental Science & Technology*, 58(9), 4031–4045. <https://doi.org/10.1021/acs.est.3c05955>
- Andrady, A. L. (2022). Weathering and fragmentation of plastic debris in the ocean environment. *Marine Pollution Bulletin*, 180, 113761. <https://doi.org/10.1016/j.marpolbul.2022.113761>
- Aranguren-Díaz, Y., Galán-Frey, N. J., Guerra, A., Manares-Romero, A., Pacheco-Londono, L. C., Romero-Coronado, A., ... Machado-Sierra, E. (2024). Aquifers and groundwater: Challenges and opportunities in water resource management in Colombia. *Water*, 16(5), 685. <https://doi.org/10.3390/w16050685>
- Aransiola, S. A., Babaniyi, B. R., Maddela, N. R., & Bello, O. S. (2025). *White pollution: Biodiversity and hazards in marine plastisphere* (1st ed.). Springer Nature Switzerland.
- Ashamo, M. O., Adu, B. W., Adeyemi, J. A., & Owaseye, R. O. (2026). Occurrence and distribution of microplastics in water, sediment, and aquatic insects of the Owena River, Osun State, Nigeria. *Environmental Monitoring and Assessment*, 198(2), 138. <https://doi.org/10.1007/s10661-026-14985-z>

- Ashrafy, A., Liza, A. A., Islam, M. N., Billah, M. M., Arafat, S. T., Rahman, M. M., & Rahman, S. M. (2023). Microplastics pollution: A brief review of its source and abundance in different aquatic ecosystems. *Journal of Hazardous Materials Advances*, 9, 100215. <https://doi.org/10.1016/j.hazadv.2022.100215>
- Attah, J. S. H. O., Stanley, F. D., & Sikoki, O. M. I. (2023). Assessment of microplastic pollution in selected water bodies in Rivers State, Nigeria. *Archives of Current Research International*, 23(7), 45–52. <https://doi.org/10.9734/acri/2023/v23i7591>
- Atukwatse, F., Nagawa, C. B., Omara, T., Kyarimpa, C., Lugasi, S. O., Basooma, R., ... Bwanika, G. N. (2026). Occurrence of microplastics in surface water, superficial sediments and Nile tilapia (*Oreochromis niloticus*) from fish breeding areas of Lake Victoria. *Discover Applied Sciences*, 8, 570. <https://doi.org/10.1007/s42452-026-08628-8>
- Bahussain, A. A. M., Nasr, F. A., Jumah, A. B., Saravanan, P., Siva Kumar, N., Al-Zharani, M., ... Tamizhdurai, P. (2025). Toxic threats from plastic waste: Human health impacts, challenges, and policy solutions. *RSC Advances*, 15(48), 40761–40788. <https://doi.org/10.1039/d5ra05845g>
- Bhatt, S., & Chatterjee, S. (2025). Environmental pollution as a critical driver of antimicrobial resistance emergence. *Discover Environment*, 3, 285. <https://doi.org/10.1007/s44274-025-00491-5>
- Biginagwa, F. J., Mayoma, B. S., Shashoua, Y., Syberg, K., & Khan, F. R. (2016). First evidence of microplastics in the African Great Lakes: Recovery from Lake Victoria Nile perch and Nile tilapia. *Journal of Great Lakes Research*, 42(1), 146–149. <https://doi.org/10.1016/j.jglr.2015.10.012>
- Bikiaris, N., Nikolaidis, N. F., & Barmplexis, P. (2024). Microplastics (MPs) in cosmetics: A review on their presence in personal-care, cosmetic, and cleaning products (PCCPs) and sustainable alternatives from biobased and biodegradable polymers. *Cosmetics*, 11(5), 145. <https://doi.org/10.3390/cosmetics11050145>
- Bokun, C., Tianhuan, Y., Shubo, F., Leming, Z., Xianbao, Z., Fang, Y., ... Wei, D. (2025). Molecular-level insights of microplastic-derived soluble organic matter and heavy metal interactions in different environmental occurrences through EEM-PARAFAC and FT-ICR MS. *Journal of Hazardous Materials*, 487, 137050. <https://doi.org/10.1016/j.jhazmat.2024.137050>
- Borriello, L., Scivico, M., Cacciola, N. A., Esposito, F., Severino, L., & Cirillo, T. (2023). Microplastics, a global issue: Human exposure through environmental and dietary sources. *Foods*, 12(18), 3396. <https://doi.org/10.3390/foods12183396>
- Brenckman, C. M., Borgaonkar, A. D., Pennock, W. H., & Meegoda, J. N. (2026). Combined environmental impacts and toxicological interactions of per- and polyfluoroalkyl substances (PFAS) and microplastics (MPs). *Environments*, 13(1), 38. <https://doi.org/10.3390/environments13010038>
- Castillo, A. B., Al-Maslmani, I., & Obbard, J. P. (2016). Prevalence of microplastics in the marine waters of Qatar. *Marine Pollution Bulletin*, 111(1–2), 260–267. <https://doi.org/10.1016/j.marpolbul.2016.06.108>
- Centre for Food Safety. (2025). *Food and Environmental Hygiene Department* (pp. 2–4).
- Chaukura, N., Kefeni, K. K., Chikurunhe, I., Nyambiya, I., Gwenzi, W., Moyo, W., ... Abulude, F. O. (2021). Microplastics in the aquatic environment: The occurrence, sources, ecological impacts, fate, and remediation challenges. *Pollutants*, 1(2), 95–118. <https://doi.org/10.3390/pollutants1020009>
- Chisa, H., & Atsuhiko, I. (2024). Reduction scenarios of plastic waste emission guided by the probability distribution model to avoid additional ocean plastic pollution by 2050s. *Marine Pollution Bulletin*, 207, 116791. <https://doi.org/10.1016/j.marpolbul.2024.116791>

- Choi, H., Kaneko, S., Suzuki, Y., Inamura, K., Nishikawa, M., & Sakai, Y. (2024). Size-dependent internalization of microplastics and nanoplastics using in vitro model of the human intestine—Contribution of each cell in the tri-culture models. *Nanomaterials*, 14(17), 1435. <https://doi.org/10.3390/nano14171435>
- Christian, E. (2021). Microplastics pollution indices of bottled water from South Eastern Nigeria. *International Journal of Environmental Analytical Chemistry*. <https://doi.org/10.1080/03067319.2021.1982926>
- Christopher, M. A., Nicholas, G., Patrick, O., Susan, W., Benard, O., Chrisphine, N., & Cyprian, O. (2026). Quantification of macroplastics and litter dynamics in a highly active bay of Lake Victoria. *Journal of Great Lakes Research*, 52(3), 102824. <https://doi.org/10.1016/j.jglr.2026.102824>
- Chwiej, J., Wytrwal, M., Papacz, K., Jasielczuk, I., Wilk, A., Gurgul, A., ... Ocłon, E. (2025). Tracing micro and nanoplastics toxicity in human pulmonary fibroblasts through integrated Raman and transcriptomic analyses. *Scientific Reports*, 15(1), 39459. <https://doi.org/10.1038/s41598-025-22947-7>
- Demarquoy, J. (2025). Microplastics and probiotics: Mechanisms of interaction and their consequences for health. *AIMS Microbiology*, 11(2), 388–409. <https://doi.org/10.3934/microbiol.2025018>
- Dennison, M. S., Paramasivam, S. K., Wanazusi, T., Sundarrajan, K. J., Erheyovwe, B. P., & Marshal Williams, A. M. (2025). Addressing plastic waste challenges in Africa: The potential of pyrolysis for waste-to-energy conversion. *Clean Technologies*, 7(1), 20. <https://doi.org/10.3390/cleantechnol7010020>
- Doherty, V. F., Aneyo, I. A., Fatunsin, O. T., Enyoh, C. E., Yahaya, T. O., Emeronye, I. G., ... Ugochukwu, M. (2024). Assessment of fishes, sediment and water from some inland rivers across the six geopolitical zones in Nigeria for microplastics. *Environmental Analysis, Health and Toxicology*, 39(2), e2024018. <https://doi.org/10.5620/eaht.2024018>
- Doménech, E., & Escriche, I. (2026). Impact of agricultural practices on metal accumulation and their associated health risks to the environment and consumers: A One Health perspective. *Environments*, 13(4), 217. <https://doi.org/10.3390/environments13040217>
- Ebere, E. C., Wirnkor, V. A., Ngozi, V. E., & Chukwuemeka, I. S. (2019). Macrodebris and microplastics pollution in Nigeria: First report on abundance, distribution and composition. *Environmental Analysis, Health and Toxicology*, 34(4), e2019012. <https://doi.org/10.5620/eaht.e2019012>
- Edem, M., Wise, G. D., Regina, F., Jerome, F., Richard, C., Robert, M., ... Christopher, G. (2023). Human health risk and food safety implications of microplastic consumption by fish from coastal waters of the eastern equatorial Atlantic Ocean. *Food Control*, 145, 109503. <https://doi.org/10.1016/j.foodcont.2022.109503>
- Emole, P. O., Ukaogo, P. O., Nnorom, I. C., & Onuchukwu, S. C. (2026). Microplastic pollution in Nigeria: A review on environmental pathways, ecosystems, and human health implications. *Discover Chemistry*, 3, 316. <https://doi.org/10.1007/s44371-026-00719-0>
- Enyoh, C. E., Wang, Q., Eze, V. C., Rabin, M. H., Rakib, M. R. J., Verla, A. W., ... Verla, E. N. (2022). Assessment of potentially toxic metals adsorbed on small macroplastics in urban roadside soils in southeastern Nigeria. *Journal of Hazardous Materials Advances*, 7, 100122. <https://doi.org/10.1016/j.hazadv.2022.100122>
- Eram, A., Vinay Kr, R. K. N. C., Keni, L. G., Shetty, D. D., Zuber, M., & Kumar, S. S. P. (2024). Air-abrasion in dentistry: A short review of the materials and performance parameters. *Journal of Biomedical Physics and Engineering*, 14(1), 99–110. <https://doi.org/10.31661/jbpe.v0i0.2310-1670>
- Eshom-Arzadon, F. K., Conway, K., Masura, J., & Baker, M. R. (2025). Microplastics in nearshore and subtidal sediments in the Salish Sea: Implications for marine habitats and exposure. *Journal of Marine Science and Engineering*, 13(8), 1441. <https://doi.org/10.3390/jmse13081441>

- Eyankware, M. O., Igwe, E. O., Ogwah, C., & Eyankware, U. R. O. (2020). Achieving sustainable use and management of water resources for irrigation in Nigeria. *Journal of Environmental & Earth Sciences*, 2(2). <https://doi.org/10.30564/jees.v2i2.2505>
- Eyankware, R. O. U., & Eyankware, M. O. (2021). Contamination assessment of water resources around waste dumpsites in Abakaliki, Nigeria: A mini review. *Journal Clean WAS*, 5(1), 17–20.
- Eyankware, R. O. U., Uchenna, E. U., & Ulakpa, W. C. (2025). Ecological risk assessment of liquid waste on surface water in Warri South-West, L.G.A. Delta State. *Fudma Journal of Sciences*, 9(12), 138–147. <https://doi.org/10.33003/fjs-2025-0912-4081>
- Fadare, O. O., Akinbile, A. A., Makinde, O. W., Ogundele, K. T., Ajagbe, E. F., & Ilechukwu, I. (2022). Spatiotemporal variations in marine litter along the Gulf of Guinea coastline, Araromi seaside, Nigeria. *Marine Pollution Bulletin*, 183, 114048. <https://doi.org/10.1016/j.marpolbul.2022.114048>
- Fadekemi, O. A., Opeyemi, I. A., & Gabriel, A. D. (2024). Assessment of microplastic-contaminated liver through gene expression profiling of four commercial fish species in the Lagos Lagoon, Nigeria. *Scientific African*, 24, e02242. <https://doi.org/10.1016/j.sciaf.2024.e02242>
- Ferrante, M., Oliveri, C. G., Vito, D., Fernandez, G., Maione, C., Lauriola, P., ... Tageo, V. (2024). Preface and abstracts of the 2nd International One Health Conference. *Medical Sciences Forum*, 25(1), 5. <https://doi.org/10.3390/msf2024025005>.
- Gao, L., Su, Y., Mehmood, T., Wang, Z., Peng, L., & Zhang, N. (2025). UVA-induced weathering of microplastics in seawater: Surface property transformations and kinetics. *Frontiers in Marine Science*, 12, 1519668. <https://doi.org/10.3389/fmars.2025.1519668>
- Ghiglione, J. F., & ter Halle, A. (2025). Source, fate, and effects of plastic litters in the European land-sea continuum. *Environmental Science and Pollution Research*, 32, 10021–10022. <https://doi.org/10.1007/s11356-024-35827-w>
- Gideon, A. I., Adewumi, Y. O., Kehinde, O. O., Michael, O. S., Temitope, O. S., Oluwatoyin, K. B., ... Ademola, F. A. (2024). Why Nigeria should ban single-use plastics: Excessive microplastic pollution of the water, sediments and fish species in Osun River, Nigeria. *Journal of Hazardous Materials Advances*, 13, 100409. <https://doi.org/10.1016/j.hazadv.2024.100409>
- Giechaskiel, B., Grigoratos, T., Mathissen, M., Quik, J., Tromp, P., Gustafsson, M., ... Dilara, P. (2024). Contribution of road vehicle tyre wear to microplastics and ambient air pollution. *Sustainability*, 16(2), 522. <https://doi.org/10.3390/su16020522>
- Gonzalez-Paredes, D., Duncan, E., Godley, B. J., Marsh, H., & Hamann, M. (2025). A best practice framework for assessing plastic ingestion in marine turtles. *Marine Pollution Bulletin*, 216, 117944. <https://doi.org/10.1016/j.marpolbul.2025.117944>
- Gqomfa, B., Ntwampe, S. K., Chidi, B. S., Maphanga, T., & Dlangamandla, C. (2025). An overview of the prevalence of micro- and nanoplastics in the Southern African Development Community: A potential risk to environmental and public health. *Discover Environment*, 3, 85. <https://doi.org/10.1007/s44274-025-00293->
- Han, J., McQueen, R. H., & Batcheller, J. C. (2024). From fabric to fallout: A systematic review of the impact of textile parameters on fibre fragment release. *Textiles*, 4(4), 459–492. <https://doi.org/10.3390/textiles4040027>
- Han, J. H., & Kim, H. S. (2025). Microplastics in cosmetics: Emerging risks for skin health and the environment. *Cosmetics*, 12(4), 171. <https://doi.org/10.3390/cosmetics12040171>

- Haque, M. R., Ahmed, W., Rahman, M. A., Khondoker, M. d. Z. R., & Md. Mostafizur, R. (2025). Aquatic insects as mediator for microplastics pollution in a river ecosystem of Bangladesh. *Scientific Reports*, 15, 15635. <https://doi.org/10.1038/s41598-025-88024-1>
- Hayes, D. G. (2025). Impact of plastics in agriculture. *Agriculture*, 15(3), 322. <https://doi.org/10.3390/agriculture15030322>
- Hikon, B. N., Yebpella, G. G., Jafiya, L., & Ayuba, S. (2021). Preliminary investigation of microplastic as a vector for heavy metals in Bye-ma Salt Mine, Wukari, Nigeria. *Journal of the Nigerian Society of Physical Sciences*, 3(3), 250–255. <https://doi.org/10.46481/jnsps.2021.259>
- Ho, N. H. E., & Not, C. (2019). Selective accumulation of plastic debris at the breaking wave area of coastal waters. *Environmental Pollution*, 245, 702–710. <https://doi.org/10.1016/j.envpol.2018.11.041>
- Hossain, M., & Engelhardt, I. (2025a). Global plastic footprint: Unveiling property trends, environmental fate, and emerging threats of microplastic and nanoplastics pollution across ecosystems. *Energy, Ecology and Environment*, 10, 637–674. <https://doi.org/10.1007/s40974-025-00383-7>
- Hossain, M. I., Zhang, Y., Haque, A. N. M. A., & Naebe, M. (2025b). Fibrous microplastics release from textile production phases: A brief review of current challenges and applied research directions. *Materials*, 18, 2513. <https://doi.org/10.3390/ma18112513>
- Huang, M. H., Wu, C. C., Cui, W. J., Mai, L., & Zeng, E. Y. (2026). Evaluation of micro(nano)plastics and additives in human blood: A pilot study with university students. *Environmental Pollution*, 390, 127430. <https://doi.org/10.1016/j.envpol.2025.127430>
- Huiping, W., Zhen, W., Sijie, Z., Chenxu, D., Xinrui, Z., Luyang, W., & Jihong, H. (2024). Fighting microplastics: The role of dietary fibers in protecting health. *Food Frontiers*, 5(5), 1984–1998. <https://doi.org/10.1002/fft2.437>
- Ibrahim, N., Rahman, A. M. N. A. A., Shafiq, M. D., Zainovia, L., Mariatti, J., & Yutaka, K. (2025). Microplastic pollution: Sources, degradation mechanisms, analytical advances, and mitigation strategies for environmental sustainability. *Reviews of Environmental Contamination and Toxicology*, 263, 27. <https://doi.org/10.1007/s44169-025-00098-0>
- Ida, J., David, J. V., Juanita, R., Mats, G., Ann-Margret, S., & Yvonne, A. S. (2022). Concentrations of tire wear microplastics and other traffic-derived non-exhaust particles in the road environment. *Environment International*, 170, 107618. <https://doi.org/10.1016/j.envint.2022.107618>
- Idowu, G. A., Adewumi, Y. O., Kehinde, O. O., Michael, O. S., Temitope, O. S., Oluwatoyin, K. B., & Oluwatosin, S. S. (2024). Why Nigeria should ban single-use plastics: Excessive microplastic pollution of the water, sediments and fish species in Osun River, Nigeria. *Journal of Hazardous Materials Advances*, 13, 100409. <https://doi.org/10.1016/j.hazadv.2024.100409>
- Ilechukwu, I., Ndukwe, G. I., Mgbemena, N. M., & Akandu, A. U. (2019). Occurrence of microplastics in surface sediments of beaches in Lagos, Nigeria. *European Chemical Bulletin*, 8(11), 371–375. <https://doi.org/10.17628/ecb.2019.8.371-375>
- Imogen, E. N., & Richard, C. T. (2020). Debris in the marine environment: History and future challenges. *Global Challenges*, 4, 1900081. <https://doi.org/10.1002/gch2.201900081>
- Ivar do Sul, U. A., Reineccius, J., Waters, C. N., Zalasiewicz, J., & Wanick, J. J. (2026). Microplastics and the Anthropocene: Towards a new class of planetary markers. *Earth-Science Reviews*, 281, 105619. <https://doi.org/10.1016/j.earscirev.2026.105619>

- Jia-Yi, D., Sen, L., Chen-Yu, W., Xu, D., Li-Hua, L., Zhen-Yu, C., ... Yan-Ling, W. (2026). Microplastics and nanoplastics, emerging pollutants, increased the risk of pulmonary fibrosis in vivo and in vitro: A comparative evaluation of their potential toxicity effects with different polymers and size. *Toxicology*, 519, 154304. <https://doi.org/10.1016/j.tox.2025.154304>
- Jiang, N., Zheng, X., Zhang, N., & Cao, Y. (2025). The detrimental effects of microplastic exposure on kidney function. *Frontiers in Medicine*, 12, 1620733. <https://doi.org/10.3389/fmed.2025.1620733>
- Jurasin, D. D., Ćurlin, M., Capjak, I., Crnkovic, T., Lovric, M., Babic, M., ... Gajovic, S. (2016). Surface coating affects behavior of metallic nanoparticles in a biological environment. *Beilstein Journal of Nanotechnology*, 7, 246–262. <https://doi.org/10.3762/bjnano.7.23>
- Kakade, A., Mi, J., & Long, R. (2024). Microplastics in the world oceans and strategies for their control. *Reviews of Environmental Contamination and Toxicology*, 262, 20. <https://doi.org/10.1007/s44169-024-00069-x>
- Kamalasekaran, K., & Sundramoorthy, A. K. (2026). A review on microplastics: Sources, environmental fate, degradation pathways, and analytical identification methods. *RSC Advances*, 16(15), 13851–13874. <https://doi.org/10.1039/d5ra09062h>
- Kannan, K., & Vimalkumar, K. (2021). A review of human exposure to microplastics and insights into microplastics as obesogens. *Frontiers in Endocrinology*, 12, 724989. <https://doi.org/10.3389/fendo.2021.724989>
- Kara, E., Konur, K., Koca, Y. S., & Aytan, U. (2025). Unveiling hidden contaminants: A systematic quantification and characterization of microplastics in hemodialysis and peritoneal dialysis fluids. *BMC Nephrology*, 26(1), 359. <https://doi.org/10.1186/s12882-025-04281-2>
- Kentaro, M., Kazuaki, T., Gajahin, G. N., Thushari, H. M., Akinori, T., Mikio, W., ... Kazutaka, T. (2025). Long-term changes in the abundance, size, and morphotype of marine plastics in the North Pacific. *Environmental Science & Technology*, 59(9), 4608–4617. <https://doi.org/10.1021/acs.est.4c09706>
- Khanjani, M. H., & Mohammadi, A. (2026). Microplastic pollution in aquatic ecosystems: A comprehensive review of impacts on aquatic animals. *Annals of Animal Science*, 26(1), 277–291. <https://doi.org/10.2478/aoas-2025-0051>
- Kibria, M. G., Masuk, N. I., Safayet, R., Nguyen, H. Q., & Mourshed, M. (2023). Plastic waste: Challenges and opportunities to mitigate pollution and effective management. *International Journal of Environmental Research*, 17(1), 20. <https://doi.org/10.1007/s41742-023-00507-z>
- Kovacs, K., Bodis, J., & Vass, R. A. (2026). Microplastics, endocrine disruptors, and oxidative stress: Mechanisms and health implications. *International Journal of Molecular Sciences*, 27(1), 399. <https://doi.org/10.3390/ijms27010399>
- Kui, A., Buduru, S., Labuneş, A., Sava, S., Pop, D., Bara, I., & Negucioiu, M. (2025). Air particle abrasion in dentistry: An overview of effects on dentin adhesion and bond strength. *Dentistry Journal*, 13(1), 16. <https://doi.org/10.3390/dj13010016>
- Kumar, R., Verma, A., Shome, A., Sinha, R., Sina, P., & Majid, P. (2024). Microplastic pollution in the marine environment: A review. *Journal of Hazardous Materials Advances*, 10, 100327. <https://doi.org/10.1016/j.hazadv.2023.100327>
- Kumari, P., Gautam, A., Tiwari, P. K., & Katara, S. (2026). From rivers to humans: Evolving policies and health risks of microplastics pollution in freshwater fish. *Journal of Advances in Biology & Biotechnology*, 29(2), 1062–1070. <https://doi.org/10.9734/jabb/2026/v29i23703>

- Kushwaha, M., Shankar, S., Goel, D., Singh, S., Rahul, J., Rachna, K., & Singh, J. (2024). Microplastics pollution in the marine environment: A review of sources, impacts and mitigation. *Marine Pollution Bulletin*, 209(Part A), 117109. <https://doi.org/10.1016/j.marpolbul.2024.117109>
- La Porta, E., Exacoustos, O., Lugani, F., Angeletti, A., Chiarenza, D. S., Bigatti, C., ... Ghiggeri, G. M. (2023). Microplastics and kidneys: An update on the evidence for deposition of plastic microparticles in human organs, tissues and fluids and renal toxicity concern. *International Journal of Molecular Sciences*, 24(18), 14391. <https://doi.org/10.3390/ijms241814391>
- Lee, Y., Cho, J., Sohn, J., & Kim, C. (2023). Health effects of microplastic exposures: Current issues and perspectives in South Korea. *Yonsei Medical Journal*, 64(5), 301–308. <https://doi.org/10.3349/ymj.2023.0048>
- Lima, P. H. S., Barreto, R. G., Montenegro, C. P. D., Silva, A. F., Terra, F. S., Nascimento, M. C. D., ... Robazzi, M. L. D. C. C. (2025). Sustainable Development Goals and microplastics in seafood: A theoretical-reflective study. *Revista Brasileira de Enfermagem*, 78, e20240408. <https://doi.org/10.1590/0034-7167-2024-0408>
- Lin, Y. D., Huang, P. H., Chen, Y. W., Hsieh, C. W., Tain, Y. L., Lee, B. H., ... Shih, M. K. (2023). Sources, degradation, ingestion and effects of microplastics on humans: A review. *Toxics*, 11(9), 747. <https://doi.org/10.3390/toxics11090747>
- Lu, K., Que, Y., Wang, L., Wang, Y., Qiu, J., Jia, Y., ... Zhang, Y. (2025). Environmental exposure pathways of microplastics and their toxic effects on ecosystems and the nervous system. *Frontiers in Toxicology*, 7, 1649282. <https://doi.org/10.3389/ftox.2025.1649282>
- Luo, Y., Sun, C., Li, C., Liu, Y., Zhao, S., Li, Y., ... Li, F. (2022). Spatial patterns of microplastics in surface seawater, sediment, and sand along Qingdao coastal environment. *Frontiers in Marine Science*, 9. <https://doi.org/10.3389/fmars.2022.916859>
- Luzi, B., Carnevale, M. M., Rada, E. C., Zullo, R., Baltrocchi, A. P. D., Torretta, V., & Galafassi, S. (2025). Critical review of microfiber release from textiles: Results, comparative challenges, mitigation strategies, and legislative perspectives. *Chemosphere*, 378, 144394. <https://doi.org/10.1016/j.chemosphere.2025.144394>
- Madeleine, H., Milne, G. H., Leonard, H. F., Britta, R., & Baechler, C. M. (2024). Exposure of U.S. adults to microplastics from commonly-consumed proteins. *Environmental Pollution*, 343, 123233. <https://doi.org/10.1016/j.envpol.2023.123233>
- Mahler, G. J., Shuler, M. L., & Glahn, R. P. (2009). Characterization of Caco-2 and HT29-MTX cocultures in an in vitro digestion/cell culture model used to predict iron bioavailability. *The Journal of Nutritional Biochemistry*, 20(7), 494–502. <https://doi.org/10.1016/j.jnutbio.2008.05.006>
- Mahu, E., Datsomor, W. G., Folorunsho, R., Fisayo, J., Crane, R., Marchant, R., ... Gordon, C. (2023). Human health risk and food safety implications of microplastic consumption by fish from coastal waters of the eastern equatorial Atlantic Ocean. *Food Control*, 145, 109503. <https://doi.org/10.1016/j.foodcont.2022.109503>
- Mariano, S., Carata, E., & Panzarini, E. (2026). The role of the size and surface chemistry of polystyrene micro- and nanobeads in the interaction with an advanced in vitro tri-culture intestinal barrier model. *Microplastics*, 5(1), 31. <https://doi.org/10.3390/microplastics5010031>
- Matavos-Aramyan, S. (2024). Addressing the microplastic crisis: A multifaceted approach to removal and regulation. *Environmental Advances*, 17, 100579. <https://doi.org/10.1016/j.envadv.2024.100579>

- Mengzhen, L., Wenhao, M., James, K. H. F., Jiezhong, M., Lei, L., Min, P., ... Keng, P. L. (2025). A review on the combined toxicological effects of microplastics and their attached pollutants. *Emerging Contaminants*, 11(2), 100486. <https://doi.org/10.1016/j.emcon.2025.10048>
- Mgbemena, N., Mgbo, V., Princewill, V., Ndukwe, G., Das, R., & Ilechukwu, I. (2024). Preliminary investigation of microplastics in roadside soils of Port Harcourt and Elele in Rivers State, Nigeria. *Substantia*, 8(2), 135–141. <https://doi.org/10.36253/Substantia-2661>
- Michal, S. B., Katarzyna, J., Katarzyna, J., Joanna, K., Justyna, K., Tenzin, T., ... Marta, M. (2025). Aging properties of polymer pellets, release of secondary microplastics and additives in the water environment under laboratory-controlled conditions. *Journal of Hazardous Materials*, 491, 137882. <https://doi.org/10.1016/j.jhazmat.2025.137882>
- Miller, M. E., Hamann, M., & Kroon, F. J. (2020). Bioaccumulation and biomagnification of microplastics in marine organisms: A review and meta-analysis of current data. *PLoS ONE*, 15(10), e0240792. <https://doi.org/10.1371/journal.pone.0240792>
- Mohd, F., Ur, R., Mohammad, M. K., & Mohammad, M. K. (2025). Impact of microplastics and nanoplastics on human health: Mechanistic insights and exposure pathways. *Toxicology Letters*, 414, 111769. <https://doi.org/10.1016/j.toxlet.2025.111769>
- Monika, D., Anja, C., Damjan, K., Yee Van, F., Annamaria, V., Kathleen, B. A., ... Lidija, C. (2024). Global projections of plastic use, end-of-life fate and potential changes in consumption, reduction, recycling and replacement with bioplastics to 2050. *Sustainable Production and Consumption*, 51, 498–518. <https://doi.org/10.1016/j.spc.2024.09.025>
- Muschter, R. (2026). *Global plastics industry - statistics & facts*. Statista. Retrieved from <https://www.statista.com/topics/5266/plastics-industry/>
- Mutuku, J., Yanotti, M., Tocock, M., & Hatton MacDonald, D. (2024). The abundance of micro-plastics in the world's oceans: A systematic review. *Oceans*, 5(3), 398–428. <https://doi.org/10.3390/oceans5030024>
- Nayanathara, P. G. C., Thathsarani, P., & Amil, S. R. (2024). The world of plastic waste: A review. *Cleaner Materials*, 11, 100220. <https://doi.org/10.1016/j.clema.2024.100220>
- Nel, H. A., & Froneman, P. W. (2015). A quantitative analysis of microplastic pollution along the south-eastern coastline of South Africa. *Marine Pollution Bulletin*, 101(1), 274–279. <https://doi.org/10.1016/j.marpolbul.2015.09.043>
- Not, C., Chan, K., So, M. W. K., Lau, W., Tang, L. T., & Cheung, C. K. H. (2025). State of microbeads in facial crubs: Persistence and the need for broader regulation. *Environmental Science and Pollution Research*, 32(17), 11063–11071. <https://doi.org/10.1007/s11356-025-36341-3>
- Nworie, C. D., Akpa, C., Omoruyi, N., & Ifeanyi, E. (2024). Python aided visualizations of the phthalate acid esters (PAEs) accumulation and metal distribution in coastal sediments of the south-western portions of Nigeria, Gulf of Guinea. *Journal of Mining and Geology*, 60(1), 25–43. <https://doi.org/10.66922/jmg.v60n1.002>
- Ocakaon, S., Nyenje, P. M., Kalibbala, H. M., Kulabako, R. N., Nagawa, C. B., Omara, T., ... Ssebugere, P. (2025). Spatiotemporal dynamics of microplastics in Nakivubo catchment: Implications for the pollution of Lake Victoria. *Microplastics*, 4(2), 21. <https://doi.org/10.3390/microplastics4020021>

- Ogbomida, E. T., Obazele, E. O., Aganmwonyi, I., Chukwuka, O., Emeribe, C. N., & Omoigberale, M. O. (2023). Assessment of microplastics in water, sediment, and fish of Ikpoba Rivers of Edo State, Nigeria. *African Scientist*, 24(3), 366–375. <https://doi.org/10.26538/africanscientist.24.3.20230907>
- Okyere, E. Y., Danquah, J. A., Miyittah, M. K., & Amoah-Nuamah, J. (2025). Tackling microfibre pollution: A review of policy responses and circular economy innovations in textile sustainability. *Waste Management Bulletin*, 3(4), 100253. <https://doi.org/10.1016/j.wmb.2025.100253>
- Olanipekun, O. O., Idowu, G. A., & Aiyesanmi, A. F. (2024). Seasonal variation of meso- and micro-plastics in water and sediments of coastal communities in Ondo State, Nigeria. *Environmental Nanotechnology, Monitoring & Management*, 22, 101027. <https://doi.org/10.1016/j.enmm.2024.101027>
- Olarinmoye, O. M., Stock, F., Scherf, N., Whenu, O., Asenime, C., & Ganzallo, S. (2020). Microplastic presence in sediment and water of a lagoon bordering the urban agglomeration of Lagos, Southwest Nigeria. *Geosciences*, 10(12), 494. <https://doi.org/10.3390/geosciences10120494>
- Oluwatosin, S. S., & Ademola, F. A. (2024). Why Nigeria should ban single-use plastics: Excessive microplastic pollution of the water, sediments and fish species in Osun River, Nigeria. *Journal of Hazardous Materials Advances*, 13, 100409. <https://doi.org/10.1016/j.hazadv.2024.100409>
- Oni, B. A., Ayeni, A. O., Agboola, O., Oguntade, T., & Obanla, O. (2020). Comparing microplastics contaminants in (dry and raining) seasons for Ox-Bow Lake in Yenagoa, Nigeria. *Ecotoxicology and Environmental Safety*, 198, 110656. <https://doi.org/10.1016/j.ecoenv.2020.110656>
- Osman, A. I., Hosny, M., Eltaweil, A. S., Omar, S., Elgarahy, A. M., Farghali, M., ... Akinyede, K. A. (2023). Microplastic sources, formation, toxicity and remediation: A review. *Environmental Chemistry Letters*. <https://doi.org/10.1007/s10311-023-01593-3>
- Owaseye, R. O. (2025). The invisible threat: A review of microplastics in freshwater systems, including their presence in water, sediment, and aquatic insects. *Annals of Environmental Science and Toxicology*, 9(1), 30–38. <https://doi.org/10.17352/aest.000088>
- Pankaj, R., Sutkar, R. D., & Gadewar, V. P. D. (2023). Recent trends in degradation of microplastics in the environment: A state-of-the-art review. *Journal of Hazardous Materials Advances*, 11, 100343. <https://doi.org/10.1016/j.hazadv.2023.100343>
- Pant, S., & Valapa, R. B. (2023). Biodegradability of conventional plastics: Opportunities, challenges, and misconceptions.. <https://doi.org/10.1016/C2020-0-03141-5>
- Parag, Y., Elimelech, E., & Opher, T. (2023). Bottled water: An evidence-based overview of economic viability, environmental impact, and social equity. *Sustainability*, 15(12), 9760. <https://doi.org/10.3390/su15129760>
- Perold, V., Schoombie, S., & Ryan, P. G. (2020). Decadal changes in plastic litter regurgitated by albatrosses and giant petrels at sub-Antarctic Marion Island. *Marine Pollution Bulletin*, 159, 111471. <https://doi.org/10.1016/j.marpolbul.2020.111471>
- Perumal, K., & Kolandhasamy, P. (2026). Plastic pellets (Nurdles) contamination along the Dhanushkodi region, Palk Bay, Southeast coast of India. *Environmental Geochemistry and Health*, 48(9), 415. <https://doi.org/10.1007/s10653-026-03303-8>
- Peter, L., Lenaker, A. K., Baldwin, S. R., Corsi, S. A., Mason, P. C. R., & John, W. S. (2019). *Environmental Science & Technology*, 53(21), 12227–12237. <https://doi.org/10.1021/acs.est.9b03850>

- Pinlova, B., & Nowack, B. (2024). From cracks to secondary microplastics: Surface characterization of polyethylene terephthalate (PET) during weathering. *Chemosphere*, 352, 141305. <https://doi.org/10.1016/j.chemosphere.2024.141305>
- Popoola, S. O., Otolorin, O. O., Hamzat, A. B., Adegbite, A., Shelle, R., Nubi, O., ... Dawodu, S. S. (2026). Microplastic distributions, bioaccumulation, and ecological risk in brackish and freshwater creeks off the Gulf of Guinea. *Estuarine, Coastal and Shelf Science*, 340, 110029. <https://doi.org/10.1016/j.ecss.2026.110029>
- Porter, A., Godbold, J. A., Lewis, C. N., Savage, G., Solan, M., & Galloway, T. S. (2023). Microplastic burden in marine benthic invertebrates depends on species traits and feeding ecology within biogeographical provinces. *Nature Communications*, 14, 8023. <https://doi.org/10.1038/s41467-023-43788-w>
- Qing, W., Li-yue, Z., Ming-xin, L., Wen-bing, J., Chang, L., Tao, Y., ... Zhong-fang, Y. (2025). Chemical elements and human health from the perspective of “One Health”. *China Geology*, 8(3), 607–627. <https://doi.org/10.31035/cg2025004>
- Rabelo, L. S., Tanaka, F. C., dos Santos, S. S., Aouada, F. A., & de Moura, M. R. (2025). The future of sustainable packaging: Exploring biodegradable solutions through extrusion, thermo-expansion, 3D printing and supercritical fluid from agro-industry waste. *Foods*, 14(23), 4027. <https://doi.org/10.3390/foods14234027>
- Rahman, S., Saha, W., Maysha, T. I., Sarker, P., Datta, T. R., Rahman, S., ... Chacrabati, R. (2025). Microplastics in the human food chain: A review of prevalence, contamination pathways, and mitigation strategies in salt, seafood, and freshwater fish. *Applied Food Research*, 5(2), 101355. <https://doi.org/10.1016/j.afres.2025.101355>
- Rajendran, D., & Chandrasekaran, N. (2023). Journey of micronanoplastics with blood components. *RSC Advances*, 13(45), 31435–31459. <https://doi.org/10.1039/d3ra05620a>
- Rapa, M., Carstea, E. M., Şaulean, A. A., Popa, C. L., Matei, E., Predescu, A. M., ... Dinca, A. G. (2024). An overview of the current trends in marine plastic litter management for a sustainable development. *Recycling*, 9(2), 30. <https://doi.org/10.3390/recycling9020030>
- Rapa, M., Darie-Nița, R. N., Matei, E., Predescu, A. M., Berbecaru, A. C., & Predescu, C. (2023). Insights into anthropogenic micro- and nanoplastic accumulation in drinking water sources and their potential effects on human health. *Polymers*, 15(11), 2425. <https://doi.org/10.3390/polym15112425>
- Razaviarani, V., Saudagar, A., Gallage, S., Shrinath, S., & Arab, G. (2024). Comprehensive investigation on microplastics from source to sink. *Clean Technologies and Environmental Policy*, 26, 1755–1782. <https://doi.org/10.1007/s10098-024-02738-w>
- Rebecca, M., & Md Saydur, R. (2025). Microplastics in coastal and marine environments: A critical issue of plastic pollution on marine organisms, seafood contaminations, and human health implications. *Journal of Hazardous Materials Advances*, 18, 100663. <https://doi.org/10.1016/j.hazadv.2025.100663>
- Ritchie, H., Samborska, V., & Roser, M. (2026). Plastic pollution. *Our World in Data*. Retrieved from <https://ourworldindata.org/plastic-pollution>
- Roman, L., Kastury, F., Petit, S., Aleman, R., Wilcox, C., Hardesty, B. D., & Hindell, M. A. (2020). Plastic, nutrition and pollution; relationships between ingested plastic and metal concentrations in the livers of two *Pachyptila* seabirds. *Scientific Reports*, 10(1), 18023. <https://doi.org/10.1038/s41598-020-75024-6>
- Rybalchenko, Y. V. (2024). The effect of nanoplastics and microplastics on lung morphology and physiology: A systematic review. *Medical and Ecological Problems*, 28(3), 42–60. <https://doi.org/10.31718/mep.2024.28.3.06>

- Salama, K., & Geyer, M. (2023). Plastic mulch films in agriculture: Their use, environmental problems, recycling and alternatives. *Environments*, 10(10), 179. <https://doi.org/10.3390/environments10100179>
- Salia, S. S., Abdulfatah, A. Y., Oluwole, O. A., Ezekiel, F. H., Saidi, O., Rebecca, A. Y., ... Mohammed, A. K. (2025). A comprehensive review on exposure to toxins and health risks from plastic waste: Challenges, mitigation measures, and policy interventions. *Waste Management Bulletin*, 3(3), 100204. <https://doi.org/10.1016/j.wmb.2025.100204>
- Samuel, O. O., Olamide, O. O., & Kazeem, G. O. (2024). Investigation of microplastics contamination in African catfish *Clarias gariepinus* and Nile tilapia *Oreochromis niloticus* fish species in Owe River Ile-Oluji, Ondo State, Nigeria. *Journal of Applied Life Sciences International*, 27(2), 29–46. <https://doi.org/10.9734/jalsi/2024/v27i2639>
- Savoca, M. S., Abreo, N. A., Arias, A. H., Baes, L., Bains, M., Bergami, E., ... Santos, R. G. (2025). Monitoring plastic pollution using bioindicators: A global review and recommendations for marine environments. *Environmental Science: Advances*, 4(1), 10–32. <https://doi.org/10.1039/d4va00174e>
- Shittu, A. O., Dedeke, G. A., Aladesida, A. A., Akinbola, S. A., & Olude, M. A. (2025). Occurrence and shapes of microplastics in selected seafood species, water and sediments collected from Epe Lagoon, Lagos State, Nigeria. *Journal of Natural Sciences Engineering and Technology*, 24, 116–127.
- Shokunbi, O. S., Idowu, G. A., Davidson, C. M., & Aiyesanmi, A. F. (2024). Investigation of microplastics and potentially toxic elements (PTEs) in sediments of two rivers in Southwestern Nigeria. *Environmental Monitoring and Assessment*, 196(10), 947. <https://doi.org/10.1007/s10661-024-13090-3>
- Shruti, V. C., Kutralam-Muniasamy, G., Pérez-Guevara, F., & Alvarez, R. C. (2026). The micro- and nanoplastics exposome feedback loop drives synergistic air-lung toxicity. *Science of the Total Environment*, 1012, 181278. <https://doi.org/10.1016/j.scitotenv.2025.181278>
- Sinha, S., Jha, P. K., Kumar, R., Kumar, P., Shubham, Das, S., ... Vara Prasad, P. V. (2021). Impacts of plastic pollution on ecosystem services, Sustainable Development Goals, and need to focus on circular economy and policy interventions. *Sustainability*, 13(17), 9963. <https://doi.org/10.3390/su13179963>
- Song, Y., Zhang, J., Shen, X., Yang, L., Jia, Y., Song, F., ... Ma, G. (2026). Study on the association between microplastic exposure and gut microbiota based on metagenomics: A pilot study on 66 young college students in China. *Environmental Research*, 288(Pt 1), 122995. <https://doi.org/10.1016/j.envres.2025.122995>
- Stanley, J., Culliton, D., Jovani-Sancho, A. J., & Neves, A. C. (2025). The journey of plastics: Historical development, environmental challenges, and the emergence of bioplastics for single-use products. *Eng*, 6(1), 17. <https://doi.org/10.3390/eng6010017>
- Themba, N. N., Themba, S. T., Cuthbert, R. N., Moyo, S., Mofu, L., Munyai, L. F., ... Dalu, T. (2025). Microplastic assessment approaches for African freshwater biota: A review. *Integrated Environmental Assessment and Management*. <https://doi.org/10.1093/inteam/vjaf195>
- Toheeb, L. J., Mariam, F. R., Eniola, V. O., Oluwadamilola, V. A., Opeyemi, S. A., Opeyemi, Y. A., & Jesuyon, J. H. (2025). Microplastics in freshwater and marine ecosystems: Occurrence, characterization, sources, distribution dynamics, fate, transport processes, potential mitigation strategies, and policy interventions. *Ecotoxicology and Environmental Safety*, 294, 118036. <https://doi.org/10.1016/j.ecoenv.2025.118036>
- Turner, A. (2019). Paint particles in the marine environment: An overlooked component of microplastics. *Water Research X*, 12, 100110. <https://doi.org/10.1016/j.wroa.2021.100110>

- Ugosor, T. P., Terna, K., Timothy, O. T., David, A. K. W., & Kaana, A. (2025). Microplastics pollution in Nigerian aquatic ecosystems: Sources, pathways, impacts, and mitigation strategies: A review. *American Journal of Environment and Climate*, 4(3). <https://doi.org/10.54536/ajec.v4i3.6354>
- Vainberg, A., Abakumov, E., & Nizamutdinov, T. (2025). Recent insights into microplastic pollution and its effects on soil carbon: A five-year ecosystem review. *Microplastics*, 4(2), 18. <https://doi.org/10.3390/microplastics4020018>
- Viel, T., Manfra, L., Zupo, V., Libralato, G., Cocca, M., & Costantini, M. (2023). Biodegradation of plastics induced by marine organisms: Future perspectives for bioremediation approaches. *Polymers*, 15(12), 2673. <https://doi.org/10.3390/polym15122673>
- Wan, Y., Yang, Y., & Zhou, W. (2025). Agricultural plastic mulch: A brief review of development, composition and catalytic upcycling strategies. *Catalysts*, 15(4), 310. <https://doi.org/10.3390/catal15040310>
- Wang, J., Zhang, T., Li, Y., Ye, Y., Tan, X., Liu, X., ... Ye, M. (2026). Microplastics and microbial interactions in marine environments: A critical review on biogeochemical cycling and ecological impacts. *Marine Pollution Bulletin*, 222(Part 3), 118891. <https://doi.org/10.1016/j.marpolbul.2025.118891>
- Wu, B., Yu, H., Lei, P., He, J., Yi, J., Wu, W., ... Sun, D. (2025). Microplastics in aquatic ecosystems: Detection, source tracing, and sustainable management strategies. *Ecotoxicology and Environmental Safety*, 291, 117883. <https://doi.org/10.1016/j.ecoenv.2025.117883>
- Wu, N., Grieve, S., Manning, A., & Spencer, K. (2025). Coupling fragmentation to a size-selective sedimentation model can quantify the long-term fate of buoyant plastics in the ocean. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. <https://doi.org/10.1098/rsta.2024.0445>
- Xia, S., Yuan, C., Long, W., Wu, Z., Li, X., Wang, N., ... Sun, L. (2025). Intratracheal administration of polystyrene micro(nano)plastics with a mixed particle size promote pulmonary fibrosis in rats by activating TGF- β 1 signaling and destabilizing mitochondrial dynamics and mitophagy in a dose- and time-dependent manner. *Toxics*, 13(6), 487. <https://doi.org/10.3390/toxics13060487>
- Xiaohan, Y., Guohe, H., Xiaolong, G., Linxiang, L. H., & Bi, C. (2025). Deciphering the behavior and fate of microplastics in coastal aquatic environments: A comprehensive review illuminating coastal dynamics and driving mechanisms. *Earth-Science Reviews*, 270, 105235. <https://doi.org/10.1016/j.earscirev.2025.105235>
- Yadav, P., Kumar, A., Ram, K., Kumar, A., Gupta, R. K., & Dufossé, L. (2025). Microbial degradation of microplastics: Effectiveness, challenges, and sustainable solutions. *Current Research in Microbial Sciences*, 9, 100495. <https://doi.org/10.1016/j.crmicr.2025.100495>
- Yahaya, T., Adewale, M. K., Ibrahim, A. B., Abdulkadir, B., Emmanuel, C. C., Fari, A. Z., ... Wanda, J. D. (2024). Abundance, characterization, and health risk evaluation of microplastics in borehole water in Birnin Kebbi, Nigeria. *Environmental Analysis, Health and Toxicology*, 39, e2024017. <https://doi.org/10.5620/eaht.2024017>
- Yakub, A. S., Bassey, B. O., Bello, A. I., Bello, B. O., Olapoju, O. A., Agwu, O. A., ... Izge, M. A. (2024). Eco-toxic risk assessment of microplastics in water and sediment across Nigeria offshore, Gulf of Guinea. *Environmental Monitoring and Assessment*, 196(10), 906. <https://doi.org/10.1007/s10661-024-13021-2>
- Yalwaji, B., John-Nwagwu, H. O., & Sogbanmu, T. O. (2022). Plastic pollution in the environment in Nigeria: A rapid systematic review of the sources, distribution, research gaps and policy needs. *Scientific African*, 16, e01220. <https://doi.org/10.1016/j.sciaf.2022.e01220>
- Yang, J., Hu, X., & Tan, F. (2025). The mapping of global plastic pollution research: A bibliometric analysis of the progress and the thematic trends. *Sustainability*, 17(5), 1859. <https://doi.org/10.3390/su17051859>

- Yating, L., Xiangyi, J., Mengyao, X., Zhoujia, J., Ling, S., Qifeng, Y., ... Haibo, Z. (2025). *Ecological and human health impacts of contaminated food and environments* (1st ed.). CRC Press.
- Yizi, Z., Pradeep, K., Jiahui, Y., Noor, H., Jordan, T., ZhengRong, G., & Xufei, Y. (2026). Airborne microplastics and their impact on human health: A critical review. *Journal of Environmental Sciences*, 161, 277–295. <https://doi.org/10.1016/j.jes.2025.06.047>
- You, T., Feng, X., & Xu, H. (2024). The whole life journey and destination of microplastics: A review. *Environmental Pollution*, 363(Pt 1), 125165. <https://doi.org/10.1016/j.envpol.2024.125165>
- Yu, X., Gutang, Q., Wang, Y., Wang, S., Li, Y., Liu, W., & Wang, X. (2024). Microplastic and associated emerging contaminants in marine fish from the South China Sea: Exposure and human risks. *Journal of Hazardous Materials*, 480, 136200. <https://doi.org/10.1016/j.jhazmat.2024.136200>
- Zeytunlu, C., & Akarsu, C. (2026). Tracing marine macro- and microplastic pollution from ships: A material flow analysis for the Northern Aegean Basin. *Microplastics*, 5(2), 60. <https://doi.org/10.3390/microplastics5020060>
- Zhang, X., Yu, C., Wang, P., & Yang, C. (2025). Microplastics and human health: Unraveling the toxicological pathways and implications for public health. *Frontiers in Public Health*, 13, 1567200. <https://doi.org/10.3389/fpubh.2025.1567200>
- Zhao, S., Kvale, K. F., Zhu, L., Zettler, E. R., Egger, M., Mincer, T. J., ... Stubbins, A. (2025). The distribution of subsurface microplastics in the ocean. *Nature*, 641, 51–61. <https://doi.org/10.1038/s41586-025-08818-1>
- Zhu, L., Bai, H., Chen, B., Sun, X., Qu, K., & Xia, B. (2018). Microplastic pollution in North Yellow Sea, China: Observations on occurrence, distribution and identification. *Science of the Total Environment*, 636, 20–29. <https://doi.org/10.1016/j.scitotenv.2018.04.182>
- Zhu, X., Rochman, C. M., Hardesty, B. D., & Wilcox, C. (2024). Plastics in the deep sea – A global estimate of the ocean floor reservoir. *Deep Sea Research Part I: Oceanographic Research Papers*, 206, 104266. <https://doi.org/10.1016/j.dsr.2024.104266>