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Plastic Contamination in the Nigerian Ecosystem: Microplastic Research, Characterization Techniques and Regulatory Gaps

Mohammed, Y.[1*] & Umaru, K.[2]
[1,2]Department of Chemistry, Faculty of Science, Nigerian Defence Academy (NDA), Kaduna
[*]Corresponding Author Email: ymohammed@nda.edu.ng

ABSTRACT
Microplastics (MPs) are pollutants within Nigerian ecosystems. They originate from both industrial manufacturing processes and weathering of plastic waste. This review evaluates the state of microplastic research in Nigeria, localized environmental concentrations, extraction and detection methodologies and existing regulatory frameworks. The main techniques used for MP extraction is wet peroxide oxidation, density separation followed by vacuum filtration, then Nile Red staining for visualisation; whilst detection and quantification are performed with Fourier Transform Infrared (FTIR) Spectroscopy, scanning electron microscopy (SEM) and gas chromatography with flame ionization detection (GC-FID). Other techniques which are available but not currently available in Nigeria include Raman Spectroscopy (RS) and pyrolysis gas chromatography-mass spectrometry (pyr-GC-MS). FTIR, SEM and RS are non-destructive, while pyr-GC-MS is a destructive technique. Densely populated cities like Lagos, Kano, and Ibadan experience high abundance of waste from domestic activities. Information from urban areas like the Kaduna Metropolis reveals heavy contamination across vital sites such as river networks, commercial sachet water, bottled water and dietary staples. It was observed that researchers face limitations, namely a lack of standardized protocols and access to advanced instrumentation such as Raman spectroscopy. An integrated framework connecting advanced analytical instruments with standard optimized sampling and processing protocols with enforceable waste management policies can mitigate the ecological and public health threats posed by plastic pollution in Nigeria.

Keywords:
Instrumentation,
Microplastics,
Policy,
Pollution,
Regulatory
Organizations.

INTRODUCTION

The global proliferation of synthetic polymers since the mid-20th century now poses a contradiction in material chemistry. While plastics have revolutionized key sectors like food packaging, medicine, construction, etc. their chemical durability has led to a global plastic waste disposal crisis, which is most severe in developing countries like Nigeria (Mgbemena *et al*., 2024; Ugosor *et al*., 2025). Nigeria produces about 32 million tons of municipal solid waste every year and most of it is not collected, they end up in waterways, open dump sites, vacant land or burnt (Green Knowledge Foundation, 2026). Of this synthetic polymeric waste, barely 12% is recycled which can be linked to poor waste collection, sorting and disposal (Heinrich Böll Foundation, 2020). Left/discarded in the environment, these plastics do not degrade, they continuously fragment into smaller sizes (mm) by the actions of mechanical abrasion, thermal degradation and solar/ultraviolet radiation. These microplastics (MPs) persist in the environment with the ability to move within and along the food chain and food web in terrestrial and aquatic ecosystems. These fragments are secondary microplastics, while primary MPs are formed in industrial plastic pellets, as cosmetic microbeads, toothpaste, sunscreen, glitter, printer toner, shaving products, clothes and textiles, etc and enter the biosphere through industrial and municipal wastewater (Faleti, n,d,; Verla *et al*., 2019; Fred-Ahmadu *et al*., 2021; Enyoh et al., 2021; Ibeto et al., 2021; Yalwaji *et al*., 2022; Ogbomida *et al*., 2023; Adam *et al*., 2024; Mgbemena *et al*., 2024; Olanipekun *et al.*, 2024; Owualah *et al*., 2024; Onyena et al., 2025; Shittu et al., 2025; Ugosor *et al.*, 2025; Auta *et al*., 2026; Emole *et al*., 2026). Some of these primary and secondary MPs enter marine birds like the Northern fulmar, which consume plastic, comparable to a human having a plate of synthetic plastic in their stomach (HBF, 2020).

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In Nigeria's inland waters, this ecological scenario is transitioning from a theoretical model to a documented biological reality (Idowu *et al*., 2024). MPs have a large surface area to volume ratio, which contributes to their hazard – they adsorb and potentially concentrate hydrophobic organic pollutants and toxic heavy metals from the surrounding media onto their surface. Upon consumption by terrestrial and aquatic organisms, these MPs enhance bioaccumulation and biomagnification up the food chain, exposing human consumers to chemical additives and adsorbed pollutants (Faleti, n.d.;Verla *et al*., 2019; Adam e*t al*., 2024; Idowu *et al*., 2024; Shittu *et al*., 2025; Ugosor *et al*., 2026).

The Physical and Chemical Dynamics of Microplastics in Nigerian Aquatic Systems

Nigeria is ranked as the ninth-largest disposer of oceanic plastic pollution globally, mainly due to surface runoff routed through the River Niger and its associated tributaries. The major aquatic transportation pathways and end points for plastic waste are inland freshwater bodies and coastal lagoons. This has resulted in degradation of the freshwater bodies, with an estimated 70% affected by anthropogenic pollution (Enyoh *et al*., 2019, HBF, 2020; Yalwaji *et al*., 2022; Ugosor *et al*., 2026). Table 1 details the MP microplastic abundance and distribution across selected Nigerian water bodies. Areas such as the Lagos Lagoon receive large amounts of untreated domestic and industrial waste from surrounding settlements. The MPs concentration in water was measured from 139 to 303 particles/L (mostly fibres – 92.6) and 310 to 2,319 particles/L (fragments and foils) in the benthic sediment, with the highest concentrations found in the fine-grained sediments of Makoko (Olarinmoye *et al*., 2020). Osun River, a major southern waterway and a UNESCO World Heritage cultural site, shows extreme microplastic contamination, with up to 22,079 microplastic particles/L in surface waters adjacent to urban centres. Faleti (n.d.) investigated fish samples from River Niger (Onitsha) and reported 0.33 to 2.67 particles/L of MP, in the form of PS, PP, PE, polyester, styrene, ethylene butylene.

One major source of MP exposure and contamination is sachet water bags, which are a solution to the lack of functioning municipal water supply networks plaguing the nation (HBF, 2020). Exposure of sachet water bags to environmental factors such as high temperatures and solar UV radiation causes photolytic degradation of the bags resulting in MPs and the release of endocrine-disrupting chemicals (EDCs) from the polymer. These EDCs include phthalates, benzene, plumbane and anthracene, which can leach into drinking water (Okpashi *et al*., 2019). Table 1 shows the distribution of MPs across selected water bodies in Nigeria.

Table 1 Microplastic Abundance and Distribution Across Selected Nigerian Water Bodies (Enyoh *et al*., 2021; Akindele *et al*., 2022; Okwesili *et al*., 2022; Ogbomida et al., 2023; Adam *et al*., 2024; Doherty *et al*., 2024; Yahaya *et al*., 2024b).

Study Location	Sample	Microplastic Abundance	Predominant Shapes & Polymers
Lagos Lagoon	Surface Water	139 to 303 particles/L	Fibres (92.6%), PP, PE
Lagos Lagoon	Benthic Sediment	310 to 2,319 particles/kg	Fragments, Foils, PP, PE
Osun River	Surface Water	3,791 to 22,079 particles/L	Black particles, PE, Nylon
Osun River	Benthic Sediment	392 to 1,590 particles/kg	Black particles, PE, Nylon
Eleyele Lake	Commercial Fish Stomachs	1 to 6 particles/individual (up to 34 particles)	Sizes 124 µm to 1.53 mm, PE, PET
River Dukku	Surface Water	125.0 to 160.3 particles/L	Unspecified shapes and polymers
River Kalgo	Surface Water	119.3 to 134.7 particles/L	Unspecified shapes and polymers
Birnin Kebbi Boreholes	Groundwater	90.43 to 96.967 particles/L	MP particles
Rivers Ogun and Benue	Surface Water	7 particles/50 mL	PE/PA/Nylon, PVA
River Yauri	Benthic Sediment	773±257.67 particles/g	PA/Nylon, PUR, PVC
Ikpoba River	Surface Water	2.67±0.58 to 8.00±1.00 particles/m^3	PE, PS (film)
Ikpoba River	Sediment	9.67±3.79 to ±55±16.8 particles/kg	PET, PVC (fibres, fragments, foam, film)
Lagos Lagoon and Ox-Bow Lake	Surface Water	39 to 1,556 particles/m^3	PE, PET, PVC, PP

Lagos Lagoon and Ox-Bow Lake	Coastal beach sediment	121 and 2,319 items/kg	Fibres and fragments

Biological Ingestion and Ecotoxicological Implications

MPs enter the food chain and food web when they are taken up by aquatic or terrestrial organisms. Once ingested, it triggers physical, chemical and biological toxicities that propagate across trophic levels as a result of both bioaccumulation and biomagnification (Verla *et al*., 2019; Adeogun *et al*., 2020; Shittu *et al*., 2025). Early developmental stages – hatchlings and juveniles – are particularly vulnerable to MP exposure because their physiological membranes are underdeveloped in addition to immature enzymatic detoxification systems (Ugosor *et al*., 2025). Upon ingestion, MPs cause physical damage to the alimentary canal, thereafter, they accumulate in the gastrointestinal tract, causing blockages, mucosal abrasions and inflammatory tissue responses (Okpashi *et al*., 2019; Enyoh *et al*., 2021; Doherty *et al*., 2024). These blockages reduce the quantity of food that can be ingested thus reducing feeding efficiency leading to energy depletion, potentially starvation and death. Also, smaller MPs can be absorbed in the respiratory tissues, causing blockages in the gills and structural lesions that impair gas exchange (Adeogun *et al*., 2020). MPs also impart chemical toxicity by the leaching of endogenous additives and monomers and the release of exogenous contaminants (like heavy metals, pesticides) adsorbed from the environment. Some of these additives are including phthalates, alkylphenols and heavy metal stabilizers that are not chemically bound to the polymer matrix (Faleti, n.d.; Ugosor *et al*., 2025). A study by Okpashi *et al*. (2019) revealed that UV radiation on commercial sachet water, analysis revealed that exposure to sunlight for five days caused the leaching of several endocrine-disrupting compounds (EDCs); such as benzylbutylphthalate (BBP), butylcyclohexylphthalate (BCP), and butyloctylphthalate (BOP), as well as toxic residues like flutamide, anthracene, and cyclononasiloxan (Okpashi *et al*., 2019). These compounds are so called because they disrupt hormone receptor pathways, leading to reproductive, metabolic and developmental abnormalities in the organisms that consume MPs (Ugosor *et al*., 2025). MPs possess hydrophobic surfaces and high partition coefficients that adsorb persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons, organochlorine pesticides and heavy metals in contaminated waterways (Faleti n.d.; Verla *et al*., 2019; Okwesili *et al*., 2022; Olanipekun *et al*., 2024; Ugosor *et al*., 2025; Emole *et al*., 2026). Upon ingestion, the low pH and enzymatic conditions of the digestive tract can facilitate desorption of these concentrated toxic compounds, thus introducing them directly into the organism's circulatory system (Adeogun *et al*., 2020).

Bioaccumulation is a result of the ingestion described above, and it is evidenced by the identification of MPs in different fish species. In Ibadan's Eleyele Lake, microplastic screening of 109 fish samples across eight commercial species revealed an overall ingestion prevalence of 69.7%. The species-specific ingestion rates were highest in *Oreochromis niloticus* (34% of the total positive individuals), followed closely by *Coptodon zillii* (32%) and *Sarotherodon melanotheron* (13%). Less frequent ingestion was noted in *Chrysichthys nigrodigitatus* (6%), *Lates niloticus* (5%), *Parachanna obscura* (5%) and *Hepsetus odoe* (5%). Ecological factors such as feeding guild, water column habitat, and trophic level strongly correlate with microplastic uptake as demonstrated by Principal Coordinate Analysis (PCA). Fish species that are benthopelagic shows exhibited a stronger association with higher particle counts and sizes than strictly demersal species (Adeogun *et al*., 2020). These water bodies represent zones where aquatic organisms ingest MPs, with edible fish species sampled from the Osun River containing between 407 to 1,691 particles per fish (Idowu *et al*., 2024). Ogbomida *et al* (2023) reported MP in *Clarias gariepinus* (3.00±1.00 to 7.33±2.08 particles/fish), which was higher than *Oreochromis niloticus* (2.33±0.58 to 6.67±0.58 particles/fish), with PE, PC, PS and PET being the more frequent polymers and fibres dominated the shape ingested in both fish species

In the municipal water supply lake in Eleyele, Ibadan, MPs were detected in 69.7% of sampled commercial fish, demonstrating that smaller plastic particles can migrate into deep food webs (Adeogun *et al*., 2020). Olanipekun *et al*. (2024) reported surface water (from Owe River basin) samples containing between 203±50.64 and 724.33±129.89 items /L dominated primarily by fragments. MPs were confirmed in all examined fish gastrointestinal tracts with *Clarias gariepinus* exhibiting higher mean ingestion (4.33±1.71 items/individual) than *O. niloticus* (1.44±0.70 items/individual), with fibres forming the predominant shape in biological tissues. Studies in Kebbi State from Rivers Dukku and Kalgo showed MP contamination between 125 to 160 particles/L and 119 to 134 particles/L, respectively. The groundwater also contained MPs, with boreholes containing from 90 to 96,967 particles/L (Yahaya *et al*., 2024a). A study by (Shittu *et al*. (2025) investigates the occurrence, accumulation levels and morphological profiles of microplastics across three tissues (gill, gut, and muscle) in four edible seafood species (red belly *Tilapia zillii*, *Clarias gariepinus*, *Penaeus notialis* and *Pomacea canaliculata*) collected from Epe Lagoon, Lagos State, Nigeria. KOH was used for digestion, followed by vacuum-filtration through 0.45 µm membrane then particles counting using stereomicroscopy. MPs were confirmed in all examined tissues and seafood species. *T. zillii* had the highest gill MP accumulation (16.00±1.14 particles/individual), while *C. gariepinus* showed the highest muscle accumulation (14.50±0.98 particles/individual). Morphological analysis identified fragments (29.25%) and fibres (23.29%) as dominant, indicating secondary plastic fragmentation and potential dietary exposure risks for human consumers (Shittu *et al*., 2025). Regional estuarine health analysis on the West African mangrove oyster (*Crassostrea tulipa*), across coastal lagoons and estuaries across five countries, showed that out of 250 oysters examined at 50 per country, 780 MPs were isolated, with the highest being in Gambia, followed by Ghana, Sierra Leone, Nigeria and lastly Benin. PE was found to be the primary polymer type, and microfibres measuring 1001 µm to 5000 µm were most abundant in the oyster tissue. (Oyster Estuary Study, 2024). Such contamination persists in the terrestrial ecosystem as well. Onyena *et al*. (2025) reported MP detection in all five samples collected, totalling 134 particles. The concentrations averaged 50 particles/L in water, 21 particles/kg in sediment, 29 particles/kg in crabs and 17 particles/kg in both fish and periwinkles. Fibers (40 particles) and fragments (35 particles) were identified as the most frequent shapes, while primary pellets were absent in Kurutie. A study of the tissues of commercially raised poultry (both broiler and local chickens) showed that MP particles were detected in the liver, heart and breast tissue. ATR-FTIR identified PE, PET, PS, PP and PVC as MPs in these tissues, therefore indicating that terrestrial agricultural practices are also vulnerable to microplastic infiltration, establishing a direct pathway for human exposure through land-based diets (Fred-Ahmadu et al., 2021; Doherty *et al*., 2024; Olanipekun *et al*., 2024; Boyi *et al*, 2026, Emole *et al*., 2026).

Terrestrial Dynamics and Soil System Degradation

A lot of Nigerian MP analysis focuses on aquatic ecosystem yet there is evidence of MP contamination in the terrestrial ecosystem. The soil serves as a long-term reservoir for MPs due to open refuse dumping, mismanaged municipal litter, application of sewage sludge to soil as fertilizer, in addition to atmospheric deposition (Mgbemena *et al*., 2024; Yahaya *et al*., 2024b). Mgbemena *et al*. (2024) assessed MP distribution across topsoils in Cross River State using factorial experimental design across 12 locations in three selected LGAs (Boki, Obubra and Ikom); with results showing that contamination was highest in commercial areas (12.12 ± 5.83 g of MP/kg of soil), followed by residential, agricultural and lastly forest (1.00 ± 0.70 g/kg) (Mgbemena *et al*., 2024).

MPs alter the physical structure, chemical dynamics and hydrological functions of soils; high concentrations of MPs in the topsoil disrupts soil aggregation and increase soil compaction, with bulk densities in commercial soils rising up to 1.32 g/cm³. This structural compaction hinders soil porosity by 10% to 20% which results in restricting gas exchange, root elongation and soil fauna habitats. The saturated hydraulic conductivity also reduces from 41.51 mm/hr in pristine forest soils to between 26.81 and 33.24 mm/hr in contaminated anthropogenic zones, marking a 35% to 40% reduction in water infiltration capacity (Mgbemena et al., 2024). This alteration in water movement raises the risk of surface runoff and soil erosion during heavy rains. The chemistry of the soil is also affected – reduction of organic carbon, increased cation exchange capacity (CEC) and changes to soil nutrient retention. Commercial soils that are heavily contaminated with MPs show a 30% to 40% decrease in natural organic matter compared to forest soils and increase CEC (9.74 cmol/kg) as against 14.73 cmol/kg in commercial soils (Mgbemena *et al*., 2024). In Northern Nigeria, open landfills and municipal waste dumping are common in cities like Abuja, Kano and Maiduguri and MP accumulation in agricultural soils is further accelerated by dust storms and wind-driven transport. They interact directly with crops, leading to inhibited seed germination, decreased root biomass and lower crop yields, posing a direct threat to regional food security (Essien *et al*., 2025). Roadside soils in urban zones serve as reservoirs for MPs as was demonstrated by research conducted in Rivers State (Port Harcourt and Elele), where 3 to 20 MP particles was recovered for every 50 g of topsoil. The highest concentration of MPs was recorded at Benjack Junction, a major commercial road intersection with high traffic density. In the roadside soil, secondary MPs were predominant, making up 69% of particles, indicative of tyre wear and vehicle tear under frictional forces as major sources of roadside MPs (Mgbemena *et al*., 2024). The quantitative details of these terrestrial alterations are compiled in Table 2.

Table 2 Microplastic Concentration and Soil Property Changes in Different Locations in Cross River State (Mgbemena *et al*., 2024; Essien *et al*, 2025)

Location	Mean Conc (g/kg)	Estimated Load (tons/ha)	Observed Hydrological and Physical Changes	Soil Chemistry Changes
Commercial Areas	12.12 ± 5.83	150.87 (up to 327.00)	Bulk density: 1.24 to 1.32 g/cm³ (25% increase); Porosity reduction: 10%–20%; Infiltration: 26.81 mm/hr	Cation Exchange Capacity: elevated to 14.73 cmol/kg; organic matter depleted by 30%–40%
Residential Zones	5.40 ± 1.48	70.08	Compaction; moderate reduction in soil porosity and water infiltration	Moderate depletion of organic carbon
Agricultural Lands	3.09 ± 1.58	39.50	Infiltration reduction; reduced water-holding capacity; soil structure disruption	Nutrient dynamics altered; crop root biomass and yield inhibited
Forest Ecosystems	1.00 ± 0.70	10.65	Bulk density: 1.05 g/cm³ (low compaction); superior infiltration: 41.51 mm/hr	High organic carbon content (0.89%–3.26%); stable native nutrient profiles

MATERIALS AND METHODS

Chemical Characterization and Analytical Methodologies

Sample Preparation and Digestion Protocols

Proper identification and qualification of MPs requires effective extraction methods that isolate the MPs from the sample matrix. MPs can be separated based on density. A density separation technique partitions the MPs based on their respective densities. Low-density polymers like PE and PP with densities 0.91 to 0.96 g/cm³ and about 0.89 to 0.91 g/cm³ respectively, can be separated from soil/sediment samples using hypertonic saline solution of known densities. For instance, a saturated solution of sodium chloride (NaCl) has a density of 1.2 g/cm³; it is affordable, safe and predominantly used in Nigerian laboratories for separation of low-density polymers (Enyoh *et al*., 2021; Ogbomida *et al*., 2023; Ugosor *et al*., 2025). For high-density polymers like PVC density 1.3 to 1.45 g/cm³ and polyethylene terephthalate (PET) with density 1.35 to 1.4 g/cm³), saline solutions with higher densities are required (Briggs *et al*., 2019, Olarinmoye *et al*., 2020; Enyoh *et al*., 2021; Doherty *et al*., 2024; and Mgbemena *et al*., 2024). Saturated solutions of magnesium chloride ($MgCl_2$), potassium chloride (KCl), zinc chloride ($ZnCl_2$), trisodium phosphate (Na_3PO_4), disodium hydrogen phosphate (Na_2HPO_4) and sodium dihydrogen phosphate (NaH_2PO_4) can be used to achieve different desired densities between 1.2 and 1.5 g/cm³ (Enyoh *et al*., 2021; Fred-Ahmadu *et al*., 2021; Zhou *et al*., 2021; Ogbomida *et al*., 2023; Musthafa, 2024; Shittu *et al*., 2025). To isolate microplastics from biological tissues (such as fish gastrointestinal tracts or poultry tissue and organs), chemical digestion is required to deteriorate organic matter without altering the physical structure or chemical composition of the synthetic polymers (Kaduna Poultry Study (Boyi *et al*, 2026). Various digestion agents used include potassium hydroxide (KOH), hydrogen peroxide (H_2O_2), nitric acid (HNO_3) and sodium hydroxide (NaOH) (Enyoh et al., 2021; Ogbomida *et al*., 2023, Onyena *et al*., 2025). Highly acidic reagents, such as concentrated HNO_3, can degrade acid-sensitive polymers like polyamides (nylon) and cause colour stripping or structural deformation of other particles (OES, 2024, Shittu *et al*., 2025). Wet peroxide oxidation (WPO) is often used to remove organic materials followed by filtration (Aliyu *et al*., 2023; Ogbomida *et al*., 2023; Shittu *et al*., 2025) using a fine mesh filter (< 300 µm) to collect MPs, then stained using Nile Red dye to enhance visibility. Vacuum filtration method can also be used to extract the MPs from various solutions (Verla *et al*., 2019; Doherty *et al*., 2021; Ibeto *et al*., 2021; Zhou *et al*., 2021; Adam *et al*., 2024; Olanipekun *et al*., 2024). It is worthy to note that alkaline digestion (with KOH) or oxidative digestion via Fenton's reagent (hydrogen peroxide (H_2O_2) with a Fe catalyst) is prioritised for the analysis of complex lipid-rich tissues found in poultry and fish (Olanipekun *et al*., 2024; Auta *et al*., 2025; Onyena *et al*., 2025; Boyi *et al*, 2026). Fred-Ahmadu *et al*. (2021) detailed digestive procedures employing H_2O_2, KOH, NaOH, HCl and enzymes such as Proteinase-K. Proteinase-K removes more than 97% of biological material but is more expensive than the other digestion methods.

Spectroscopic and Chromatographic Characterisation

Following extraction and separation, polymer identification is performed using spectroscopic analysis, chromatographic techniques and microscopy. Fourier Transform Infrared (FTIR) Spectroscopy is the most common technique utilized by Nigerian environmental and academic researchers, to verify polymer types (Briggs *et al*., 2019; Olarinmoye *et al*., 2020; Enyoh *et al*., 2021; Okwesili *et al*., 2022; Anyaegbu *et al*., 2024, Auta *et al*., 2026). FTIR operates by directing an infrared beam through or onto a particle, measuring the characteristic energy absorption of specific molecular functional groups to generate a unique chemical fingerprint. FTIR identifies polymeric MP made of PP, PS, PE, PET, polyurethane (PUR), PVC, polyamide/nylon (PA), polyacrylic acid (PAA), polyacrylamide (PAAm), polyethylene vinyl acetate (PEVA) and cellulose. The effective spectral range is between 650 and 4000 cm^{-1} with a resolution as low as 4 cm^{-1} (Verla *et al*., 2019; Adam *et al*., 2024; Yahaya *et al*., 2024b). Attenuated (ATR) FTIR is highly effective for identifying organic and polar compounds, such as the carbonyl groups in PET or the amide bonds in nylon. ATR-FTIR is suitable for analysing irregular particles as small as 20 µm in size (Briggs *et al*., 2019, Enyoh *et al*., 2021; Ogbomida *et al*., 2023; Onyena *et al*., 2025; Emole *et al*., 2026). However, conventional FTIR is limited by absorption losses caused by water molecules, making it difficult to directly analyse microplastics in liquid environments. FTIR and ATR-FTIR can be combined with a microscope for in situ visualisation (Verla *et al*., 2019).

Raman Spectroscopy (RS) provides a complementary analytical pathway, utilizing the inelastic scattering of laser light to identify chemical bonds based on molecular vibrational states. It is highly effective for analysing non-polar polymer backbones (such as carbon-carbon double bonds in polybutadiene or PS). RS is well-suited for aqueous samples because water yields a very weak Raman signal. Conventional Raman spectroscopy is limited by optical diffraction limits; however, coupling it with confocal microscopes and laser tweezers (Optical Confocal Micro-RS) enables the detection and chemical fingerprinting of MPs below 20 µm and even NPs as small as 1.1 µm) directly in liquid matrices without extensive sample preparation (Verla *et al*., 2019; Chakraborty *et al*., 2022).

Pyrolysis Gas Chromatography-Mass Spectrometry (Pyr-GC-MS) is used when mass-based quantitative chemical composition data is required. This method thermally degrades the sample in an inert atmosphere made up of argon or helium gas, then separates the pyrolyzed fragments chromatographically, identifies the polymer type and chemical additives based on mass spectral fragmentation patterns (Verla *et al*., 2019; Olarinmoye *et al*., 2020; Enyou *et al*., 2021; Anyaegbu *et al*., 2024; Emole *et al*., 2026). While pyr-GC-MS is highly sensitive and provides precise mass concentration and additive data, it is a destructive technique that does not preserve information on particle size, shape or morphology and is unsuitable for non-volatile high molecular polymers without thermal degradation or derivatisation. Therefore, to achieve comprehensive characterisation of MPs and NPs, all three methods should not be used in isolation but should be used sequentially, as part of an integrated analytical workflow. Okwesili *et al*. (2022) and Verla *et al*. (2019) reported the use of gas chromatography with flame ionization detection (GC-FID) to identify MPs, after extraction from fish muscle using anhydrous sodium sulphate, n-hexane, benzene, methanol, chloroform, acetone.

Scanning electron microscopy (SEM) alone or coupled with Energy-Dispersive X-ray Spectroscopy (SEM-EDS) characterise MPs by determining the morphology (fibres, fragments, pellets, and film), colour (black, yellow, grey, red, etc), size (0-100, 100-500, and 500-1000 µm) and quantity/number. SEM obtains photographs of the MPs and determines the concentration of MPs in the based on the number and size of particles counted or the weight of microplastics recovered will also be determined (Verla *et al*., 2019; Fred-Ahmadu *et al*., 2021; Anyaegbu *et al*., 2024; Yahaya *et al*., 2024b, Auta *et al*., 2026). An environmental SEM-EDS (ESEM-EDS) additionally provides information about the elemental composition of the material (PET, PE, PVC, polydimethyl siloxane). Other microscopes – binocular microscopes, stereomicroscopes – can also be utilised but they are not as reliable as SEM (Fred-Ahmadu *et al*., 2021; Ibeto *et al*., 2021).

RESULTS AND DISCUSSION

Critical Technical and Operational Limitations

MP research in Nigeria faces major technical and operational challenges as a result of the lack of standardized, harmonized sampling and reporting protocols. This makes it difficult to compare data from different geopolitical regions due to differences in units of measurements. There also exists the paucity of adequately research laboratories with relevant analytical instruments, such as FTIR, RS, and pyr-GC-MS systems. Acquiring such equipment requires huge capital investment and constant electrical power, while their operation requires highly trained technical staff. SEM in Kaduna and Ogun States remains the major means for visualisation, identification and quantification of MPs. This method is greatly susceptible to human error, with under-/over counting, misidentification of natural fibres as synthetic and the exclusion of transparent particles (Mgbemena *et al*., 2024 and Ugosor *et al*., 2025). Table 3 compares the key analytical methods used in microplastic characterization.

Regulatory Frameworks and Legislative Gaps

Historical Context and National Policies

Nigeria's regulatory response to environmental pollution has historically been reactive rather than preventative; the foundational milestone in National Environmental Law occurred in August 1987, when an Italian company imported several tons of hazardous industrial chemical waste and dumped it in Koko, Delta State. This importation and subsequent dumping caused severe local environmental contamination and led directly to the enactment of the Harmful Waste (Special Criminal Provisions) Act of 1988, as well as the establishment of the Federal Environmental Protection Agency (FEPA) in the same year.

Table 3. Comparative Assessment of Analytical Techniques for MP Polymer Identification (Briggs *et al*., 2019; Fred-Ahmadu *et al*., 2021; Olarinmoye *et al*., 2020; Chakraborty *et al*., 2022; Adam *et al*., 2024).

Analytical Instrument	Core Target Metric	Operational Advantages	Technical and Structural Limitations
FTIR / ATR-FTIR	Polar functional groups, bulk polymer molecular identification.	Highly sensitive for polar bonds (O-H, C=O, N-H); non-destructive; robust library matching.	Spatial resolution limited to >20 µm; water molecules cause severe absorption interference.
RS	Symmetric non-polar carbon backbones, bond vibrations.	Excellent for aqueous samples; non-destructive; can scan through glass/plastic containers.	Prone to sample fluorescence interference; high laser power can burn dark samples.
Confocal micro-RS	Chemical identification of sub-20 µm particles in liquids.	Isolates and fingerprints particles down to 1.1 µm directly in liquid phases with minimal preparation.	High equipment cost; requires specialized operational training.
Pyr-GC-MS	Quantitative mass-based polymer and chemical additive identification.	High chemical sensitivity; identifies polymer blends and associated toxic plastic additives.	Destructive method; provides no physical morphological, size, or shape data.

The FEPA scope was only limited to regulating industrial effluents, emissions, and hazardous chemical discharges, failing to anticipate the post-consumer plastic and microplastic crisis (HBF, 2020). In 2007, FEPA created National Environmental Standards and Regulations Enforcement Agency (NESREA) to address enforcement gaps. NESREA was created to enforce Federal Environmental Laws to manage plastic waste in the Extended Producer Responsibility (EPR) program (2014), which states that manufacturers and brand owners are legally responsible for the entire life cycle of their products, including post-consumer collection, recycling and final disposal. In the food and beverage sector, EPR is coordinated by the Food and Beverage Recycling Alliance (FBRA), a voluntary Producer Responsibility Organization (PRO). However, the program is challenged by slow industry adoption, a lack of clear definitions for stakeholder roles, and limited funding for NESREA to monitor compliance and enforce penalties (HBF, 2020). In 2018, the Plastic Bags (Prohibition) Bill was introduced, banning the manufacture, importation and use of single-use plastic bags, however, it has never been signed into law. Likewise, the National Policy on Plastic Waste Management was proposed in 2018, adopted in 2020, was meant to reduce plastic waste by 50% of 2020 levels by 2025, phase out single-use plastic bags and styrofoam by 2028, and ensure all plastic packaging is recyclable or biodegradable by 2030. However, this policy has remained under consideration without full implementation (HBF, 2020).

Sub-national Bans and Implementation Challenges

Delays in implementation of policies at the national level has led to the off-take of sub-national policies to address the plastic crisis. This led to independent policies such at the one by Lagos State Government, which saw the ban on single use plastic. Lagos State produces 13,000 tons of solid waste with 20% being plastics, which blocks drainage channels and natural canals, leading to severe seasonal flooding. In January 2024, the Lagos State Ministry of the Environment and Water Resources announced a ban on the use and sale of PS foam packaging (styrofoam) and other single-use plastics products. Abia State also put in place a single use plastic ban, while the Ministry of Environment eventually banned single-use plastics across its headquarters and agencies in early 2024, followed by a broader executive council ban in June 2024 (World Bank, 2024). Lagos followed up with a full enforcement ban on single-use plastics (including plastic cutlery, plates, and straws) which commenced on 01 July, 2025 after an 18-month stakeholder dialogue and transition period. These policies are a step in the right direction, but implementation is still wanton due to challenges with enforcement at the lower level, lack of alternatives to single use plastic and economic pushback due to job losses (World Bank, 2024).

Regional Perceptions of Plastic Waste Regulation

Public perception from the six geopolitical regions is necessary for the adoption of feasible environmental regulations specifically tailored to each region. A survey of 310 respondents spanning the six geopolitical regions assessed public awareness of plastic waste issues (Table 4). The results revealed marked differences in key environmental and waste drivers between regions, with immediate physical impacts of plastic waste being highly visible in the South.

Table 4 Geopolitical Distribution and Perceptions of Environmental Waste Survey Respondents

Geopolitical Zone	Respondents (n)	Percentage (%)	Key Environmental and Regional Waste Drivers
South-South	83	26.8%	Marine oil-spill interactions, coastal estuary pollution, high rainfall flooding
South-West	61	19.7%	Lagos megacity waste pressure, clogged drainage canals, beach littering
South-East	58	18.7%	Severe soil erosion, localized open dumping in commercial markets
North-East	49	15.8%	Wind-driven plastic dispersion, open landfills in municipal areas
North-West	36	11.6%	Agricultural soil degradation, lack of formal landfill sorting, open dumping
North-Central	23	7.4%	Urban waste accumulation in cities like Abuja, contamination of localized rivers
All Zones	310	100%	Combined pressure across varying ecological zones

Table 4 also shows the differences in regional responses, indicating the need for environmental policies that are adapted to localized conditions. For example, southern states require regulations targeting marine and municipal drainage blocking, whereas northern states require policies focused on agricultural soil protection and waste management in arid urban centres (World Bank, 2024).

Policy Recommendations

Addressing the microplastic crisis in Nigeria requires transitioning from poorly enforced policies to a coordinated, scientifically grounded framework. The widespread prevalence of microplastics in water, soil, air, food chains and food webs highlight the need for immediate interventions. To address these challenges, a ban on single-use plastic will make a marked difference; however, the following are recommended before any ban implementation across the geopolitical zones:

i. National Agency for Food and Drug Administration and Control (NAFDAC) should implement mandatory MP testing for drinking water, ascertain limits for MPs in sachet and bottled water in their standards, in addition to regular assessment/accreditation of sachet water packaging facilities. NAFDAC should also engage in public awareness campaigns on the risk of poor and inefficient plastic waste disposal practices.

ii. NESREA should enforce sanctions and penalties for organisations and manufacturers found wanting in good plastic disposal practices. The organisation should also consider supporting the informal sector – where a lot of the waste is generated – with rebate or cashback schemes.

iii. The Federal Ministry of Environment (FME) through the Nigerian Educational Research and Development Council (NERDC) and tertiary institutions should support the development of indigenous standardised procedures for the extraction, identification, quantification and remediation of MPs from our aquatic ecosystem. There is the need for the FME to urgently work with stakeholders and waste management service providers to enlighten the public on best practices for sachet water disposal, recycling and upcycling.

iv. The Projects Development Institute (PRODA), National Research Institute for Chemical Technology (NARICT), Raw Materials Research and Development Council (RMRDC), National Board for Technology Incubation (NBTI) under the Federal Ministry of Innovation, Science and Technology (FMIST) and in conjunction with NERDC should increase efforts to provide funds for academic-industry research that is focused on the production of locally sourced alternatives to conventional plastic. There is a plethora of agricultural waste that goes unused and unchecked, and is typically burned. Such agro-waste can be a source of starch, cellulose, polylactic acid, pectin, etc., which serve as starting materials for producing biodegradable film as a substitute for PE film.

iv. The Nigeria Integrated Water Resources Management Commission (NIWRMC) under the Federal Ministry of Water Resources and Sanitation (FMWRS) and State Environmental Protection Agencies (SEPAs) should reemphasize water management and safe plastic disposal practices.

CONCLUSION

Plastic pollution in Nigerian waterways is a serious and increasing environmental, economic and operational problem with MP waste often produced during the disposal of plastics, mainly as a result of inadequate waste management infrastructure, leading to plastic waste persistence. A combination of stronger legislation, improved waste management, reduction in plastic production/use, greater public awareness and alternatives to single-use plastic are means to tackle improper waste disposal.

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