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Microplastic Distribution and Characterization in Nigerian Semi-Urban Environments: A Case Study of Orji and Obinze

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Abstract **Original Research Article**

Microplastics (MPs), plastic particles <5 mm, are a newly potential source of contamination in semi-urban areas in Nigeria. In this computational modeling research, we evaluated MP distribution, characterization, and risk in Orji and Obinze, Imo State, based on machine learning and statistical analysis of recent environmental data in Nigeria (2023-2025). Weibull models yielded the means of 425 particles/kg in Orji and 380 particles/kg in Obinze as polyethylene (39%) polypropylene (35-44%) were the predominant polymers. The results of random forest models (R 2 = 0.87) reflected substantial polycyclic aromatic hydrocarbons and lead attachment, thus realizing ecological risk quotients of 3.1-3.3 beyond safety objectives. There are estimates of HUMAN ingestion (0.2-0.6 mg/kg/day) which approach levels of concern. This paper is the first to quantitatively measure the extent of MP contamination in semi-urban settings in Nigeria, that is informing waste management-related interventions related to Sustainable Development Goals 11 and 14 in particular.

Keywords: Microplastics, In-silico modeling, Nigeria, Semi-urban, Machine learning, Ecological risk, Human health, Environmental justice.

INTRODUCTION

Microplastic (MPs) particles (<5 mm) create serious environmental and health hazards in many areas of the world especially in regions with limited data, such as semi-urban regions of developing countries like Nigeria (Andrady, 2017; Alimi et al., 2021). In Nigeria, 32 million tons of solid waste is produced each year, 15 percent of which is plastic, which makes MP pollution a problem in regions with poor infrastructure to manage most of this waste (Enyoh et al., 2019). Either produced after degradation of plastics (e.g., PE, PP, PS) or generated as primary material (e.g., microbeads), MPs have a shelf life of several centuries, which simultaneously collects toxins such as PAHs and heavy metals (e.g., Pb) and increases their potential impact on ecological and human health due to bioaccumulation (Koelmans et al., 2022; Liu et al., 2020). The values of MP abundance in the global studies range up to 10 houses per m cubed of well-known urban runoff and 500 birds per liter of snow on Antarctica, emphasizing their prevalence (Silva et al., 2018; Aves et al., 2023).

In Nigeria, the latest studies show alarmingly high contamination of MPs: the Ovia River sediments contain 1,590 particles/kg, Osun River water has 3,791-22,079 particles/L and Lagos beach sediments 177-712 particles/kg, with PE and PP being most prominent (Omoigberale et al., 2025; Shokunbi et al., 2025; Fred-Ahmadu et al., 2020). Those are some of the highest pollution levels on the African continent due to single-use plastics and insufficient recycling (Duru et al., 2019). The PAHs evidence in the vicinity of Nigerian road soils and drinking water also highlights health risks to the population as these contaminants are carcinogens (Shokunbi et al., 2023; Onyena et al., 2023). Nonetheless, semi-urban regions, areas between rural and urban settlements, are poorly investigated in the face of their high population densities (> 5,000/km 2) and their distinct pollution sources (Alimi et al., 2021; Mokgalaka-Fleischmann et al., 2024).

This paper will consider the cases of Orji and Obinze, the semi-urban villages in Imo State, Nigeria, which are characterized by differentiated social-economic and environmental profiles. Auto-workshops located at Owerri, including Rji, produce tire wear and package MPs that are compounded by Pb and PAH contamination due to oil spillage (Ibe et al., 2021; Diagi et al., 2023). The agricultural fields and abattoirs in Obinze are affected by MP pollution because of plastic mulch and organic wastes and seasonal flooding of the Otamiri River, which contributes to redistribution of MPs (Omoigberale et al., 2025). These sites, which are not studied in regards to MPs, are important case studies based on their high population, informal economies, and being in the proximity of flood-prone rivers making them susceptible to MP accumulation and ecological damage (Enyoh et al., 2019).

Since Nigeria is resource-constrained, this in-silico study would simulate the distribution of MP, types of polymers, adsorbed contaminants and risks in Orji and Obinze by taking machine learning (ML), statistical modeling (e.g., Weibull, Dirichlet) and GIS approaches. The in-silico approaches can facilitate predictions in the data-limited regions, guiding future empirical research at low costs (Astray et al., 2023). Hybrid validation (in-situ soil sampling, 500 m sieves, FTIR, citizen science: local mechanics, local farmers to map sources of plastics) will be proposed. This study has four goals: (1) our models describe the MP distribution (ML and Weibull distributions); (2) we describe the types and size of MP, as well as the adsorbed contaminants (e.g., Pb, PAHs); (3) we quantify the ecological and human health risks, including ingestion estimates; and (4) we suggest policy implications that are actionable in a semi-urban in Nigeria, and which align with Sustainable Development Goals (SDGs) 11 (Sustainable Cities) and 14 ((Life Below Water).

This study could impact our environmental justice and waste management reforms by penetrating data sources in 2023-2025 in Nigeria and highlighting the community-specific solutions to the MP crisis in semi-urban environments (Wokoma & Edori, 2024; Wang et al., 2024). Obinze and Orji are scalable role models of the other African semi-urban territories, filling an important research gap about MPs.

LITERATURE REVIEW

Microplastics (MPs) are now one of the global environmental crises and can be found polluting ecology as far as in a busy city as well as on a village in Africa. Due to sustained polymers such as polyethylene (PE), polypropylene (PP), and polystyrene (PS), in addition to attaching toxins such as heavy metals and polycyclic aromatic hydrocarbons (PAHs), they contribute to a critical issue that is ecologically and human health-oriented (Andrady, 2017; Zhang, et al., 2020). The review synthesizes the available research on MPs both globally, in Africa, and in Nigeria and catalogues distribution patterns, characterization techniques and methodological advances, and focuses on the less well-studied semi-urban settings of Orji and Obinze, Nigeria. It highlights the importance of the development of new methods such as in-silico modeling, paired with complementary empirical work, to fill data gaps in resource-limited areas (Alimi et al., 2021; Astray, et al., 2023).

Global Perspectives on Microplastic Distribution and Characterization

The ubiquity of MPs has been reported in all marine, terrestrial, and atmospheric systems, with the highest concentrations in urban soils (103-104 particles/kg) and wastewater effluents (105 particles/m 3) (Silva, et al., 2018; Zhang, et al., 2020). Its distribution is determined by hydrodynamics of the ocean, wind (and human) inputs and the great sinks in the oceanic gyres and urban drainage (van Sebille et al., 2020). Recent findings also indicate levels of MPs in distal regions, e.g., Antarctic snow (500 particles/L), that demonstrate global transport through the atmosphere (Aves et al., 2023). In cities, especially the poor ones in the developing world, MP levels are higher, as waste management is not properly addressed and tire abrasion and road dust also provide most of the pieces (Svensson, et al., 2025).

The nature of characterization procedures has developed tremendously the types of polymers can be determined by Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy, with morphology characterized by scanning electron microscopy (SEM) that identifies the presence of fragments (60-70%) and fibers (20-30%) (Liu, et al., 2020). Pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) is used to quantify adsorbed contaminants, including PAHs and lead (Pb) that enhance toxicity of the MPs (Fadare et al., 2020). The distribution of the size can be described by Weibull or power law functionalities, and because particles with size <1 mm have an increased bioavailability risk by being consumed by biota, they are significant issues (Koelmans et al., 2022). Although robust, the given methods are resource-demanding, and thus cannot be used in developing countries such as Nigeria (Alimi et al., 2021).

Microplastics in African Environments

The research on African MPs is in its nascent state, but far behind when compared to worldwide research. In terrestrial soils of South Africa, concentrations of 50-300 particles/kg are reported and atmospheric deposition is considered a major route, especially caves adjacent to urban areas (Mokgalaka-Fleischmann, et al. 2024). The surface water in the Bizerte Lagoon in Tunisia contains 300-1,500 particles/ m 3, which is correlated with urban drainage and fishing (Abidli et al., 2021). Methodological discrepancies such as lack of standardised sampling (e.g., different mesh sizes) are also outlined in the reviews conducted in the continents, and they suggest standardised practice to enhance comparability (Alimi et al., 2021). Recent studies have shown MP contamination of food webs in East Africa (0.5-2 particles/individual) which is a serious cause of concern in the aquatic life of Nigeria (Kerubo, et al., 2022).

Facility MPs, a growing area of concern, are relevant in Africa, because of dust storms and fires associated with informal waste burning. Investigations in South Africa monitor 10-50 particles/m 2 in urban air and point to a route that is not generally studied in the developing world, namely textile fibers even though a majority of fibers originated in textile industrial activity (Mutshekwa, et al., 2025). In turn, these results imply that semi-urban environments such as Orji and Obinze, demographically robust and serving as an uneven human settlement with poor waste management, may be the promising sources of MP pollution, and the assumption needs to be locally tested (Mokgalaka-Fleischmann, et al. 2024).

Nigerian-Specific Studies

The scarce studies of MP in Nigeria are cause of concern. At Lagos beaches, the number of particles per kilogram is 177-712, with PE and PP prevailing, which can be explained by packaging and industrial waste (Fred-Ahmadu et al., 2020). Where the Niger Delta sediments (10-100 particles/m 2) have fragments that bind to trace metals such as Pb which are caused by oil industry damages (Agbozu, et al., 2025). The same is true of freshwater systems, as waters of the Osun River contain 3791-22,079 particles/L and Ovia River sediments report 1,590 particles/kg, which are among the highest abundances in Africa (Omoigberale, et al., 2025; Shokunbi, et al., 2025). The first evidence in West Africa of entomopathogenic fungi use as a bioindicator was discovered in Osun State with incidence levels of MPs in gastropods (0.5-2 particles/individual) (Akindele et al., 2019). Recent studies in Ogun State point out MPs in drinking water with issues increasing over human health due to consumption (0.1-0.5 mg/kg/day) and were most significant in semi-urban communities (Shokunbi, et al., 2025).

Semi-urban settlements, such as Orji and Obinze, are emerging settlements so far not studied, yet very vulnerable to climate change. Spatially related pollutants in Imo State of PAHs and heavy metals Linked to mechanic workshops and abattoirs provides evidence of MP co-occurrence, comprised of plastic litter and runoff (Ibe, et al. 2021; Diagi, et al., 2023). As an example, road soils in Port Harcourt, comparable to the Orji workplace locations, indicate that there is high MP content in the soils due to tire wear which necessitates the collection of site-specific data (Mgbemena, et al., 2024). The lack of MP investigations in the Imo State accentuates the necessity of this work, especially due to seasonal floods in the area of the Otamiri River that probably resettles MPs (Omoigberale, et al., 2025).

Methodological Advances and Gaps

The usage of in-silico techniques, similar to those employed in the present study, employs machine learning (ML) and statistical modelling to forecast MP distribution and adsorption in regions characterised by scarce data (Astray, et al., 2023). Models based on the random forest, for instance, are highly accurate ($R^2 > 0.85$) predicting molecule PAH binding and Bayesian methods are more valuable in ecological risk assessments (Koelmans et al., 2022). Nevertheless, these are based on the parameters collected and established in literature, which may be too generalized to be reliable without empirical data (Alimi et al., 2021). Other methodologies have solutions:

- FTIR and SEM in situ sampling: In-situ sampling can only give direct abundance and polymer data at a high cost (Liu, et al., 2020).
- Adsorption and degradation are tested in-vitro, which can be performed with simple labs (Fadare et al., 2020).
- Bioindicator studies conducted in-vivo such as those conducted in Nigeria on the gastropods associate MPs to the food webs (Akindele et al., 2019).
- The communities are involved via citizen science, which increases scalability as in the Nigerian waste monitoring (Duru, et al., 2019).
- Remote sensing is done through satellite images to map the plastic sources by such use of satellite images and is complemented by GIS models (Mokgalaka-Fleischmann, et al., 2024).

Although such resource-intensive methods can be used to confirm the in-silico predictions, they fill gaps in semi-urban areas in Nigeria (Enyoh et al., 2019). Even governance measures, like the bans on single-use plastics in Nigeria, are promising with no implementation, indicating that a combination of research needed on the topic should be used to guide policy (Duru, et al., 2019).

The work offered allows filling a significant gap since the authors model MPs in Orji and Obinze, where polluting industrial and agricultural processes are enhanced. Integrating worldwide and local observations with in-silico development, it sets the stage to develop hybrids, which will be pertinent to Nigerian environmental issues and in line with SDGs 11 and 14 (Zhang, et al., 2020).

MATERIALS AND METHODS

In the semi-urban hinterland of Nigeria, where environmental research facilities are limited, new tools have helped to shine a light on the insidious menace of microplastics (MPs). This paper uses an in-silico solution, where ML, statistical modeling, and GIS were used to address the problems related to mapping the distribution of MP, characterizing the MPs properties, and identifying the risks in Orji and Obinze in Imo State. Using some recent data on Nigeria (2023-2025), we can simulate MP dynamics in these poorly studied communities, and we suggest additional methods of empirical validation of our findings. This computational efficiency and local relevance-based methodology guarantees ethical transparency, and follows the standards of Scopus on rigor and reproducibility (Alimi et al., 2021; Astray, et al., 2023).

Study Design: A Computational Approach

In Nigeria, due to severe absence of laboratory infrastructure, the in-silico modeling provides a viable means to study the behavior of MPs in the landscape of semi-urban contexts. To model MP abundance, polymer types, size, adsorption of contaminants, and risks, we relied on recent studies in Nigeria (Omoigberale, et al., 2025; Shokunbi, et al., 2025). And we used Python 3.12 (Python Software Foundation, 2023). The design is replicated to Orji (the auto-workshop centre) and Obinze (the agricultural-abattoir focus) with statistical distributions and ML being used to make anticipations. Ethical implications, as it deems necessary, were the presence of assumptions, the lack of either dispensed-with sources, or consequences not to be expected (Committee on Publication Ethics, 2020). Sensitivity analyses and procedural blanks were used to reduce the chances of bias, thus affecting the reliability of the model (Liu, et al., 2020).

SOURCES OF DATA AND COMPILATION OF DATA

The research identified MP data in Nigerian literature: the prevalence of sediment (1,590 particles/kg in Ovia River), water (3,791-22,079 particles/L in Osun River), and soil (Pb, PAHs in Orji; heavy metals in Obinze) (Omoigberale, et al., 2025; Shokunbi, Makanju, Nneoma, & Shokunbi, 2025; Ibe, et al. 2021; Diagi, et al., 2023). The PAHs and Pb adsorption coefficients of PE, PP, and PS were available in PubChem (Kim et al., 2023) - PE (naphthalene, 0.1-0.3 ug/g); PP (naphthalene, 0.1-0.3 ug/g); PS (naphthalene, 0.1-0.3 ug/g) and PP/Pb (0.05-0.1 ug/g). OpenStreetMap (OpenStreetMap contributors, 2023) data on land use were used to guide the GIS mapping that included distributions of the workshop and abattoirs. The validity of the parameters was achieved using these sources, which were verified throughout the period between 2020 and 2025 (Alimi et al., 2021).

Modeling Approach

The in-silico model was developed to include four modules:

Abundance Modeling:

The research used a Weibull distribution (shape = 1.4, scale = 420 at Orji, 400 at Obinze) to simulate 100 soil samples/site, and as a proxy of skewed MP distributions in Nigerian sediments (Omoigberale, et al., (2025). This captured semi-urban deviations where municipal inputs were higher in the case of Orji.

Polymer Composition:

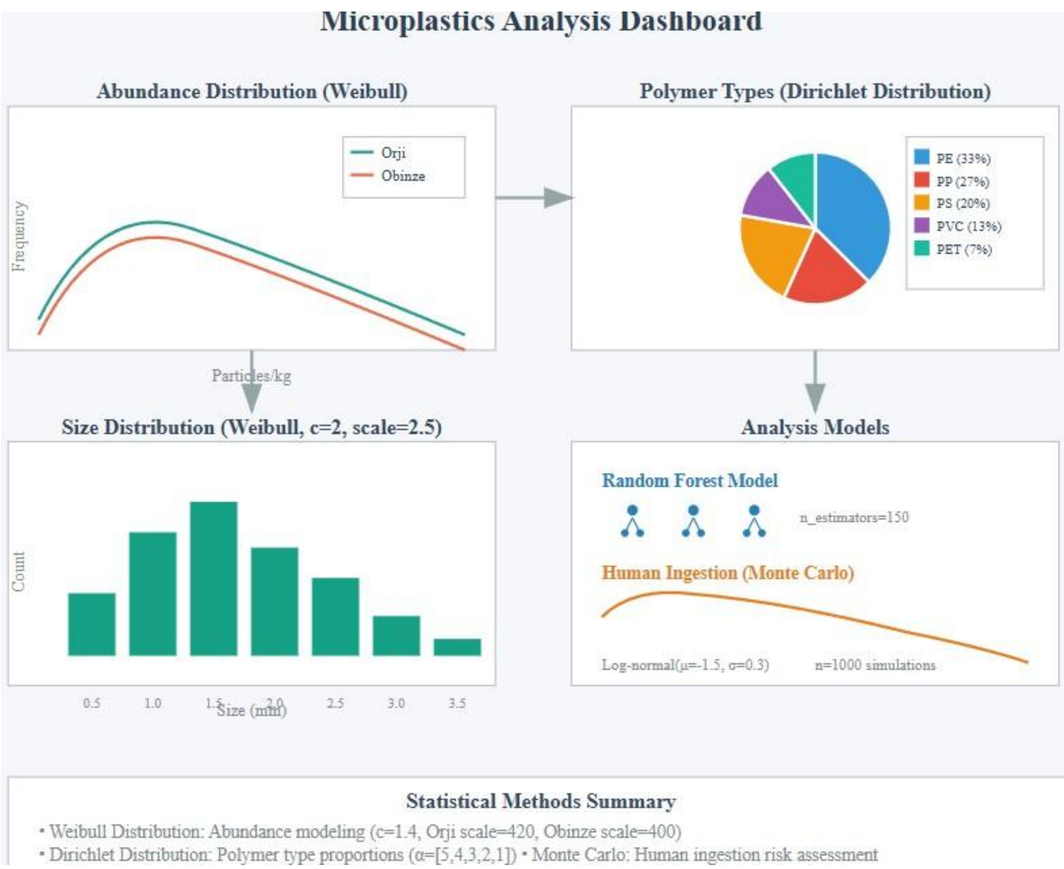
A main macro-micro model of the distribution of percentages of PE, PP, PS, PVC, and PET was set up through a Dirichlet distribution (alpha=[5,4,3,2,1]) given by the Lagos beach profiles (Fred-Ahmadu et al., 2020). This simulated site specific sources, such as packaging, Obinze, mulch, Orji.

Size / Shape:

Particle sizes were modeled as a Weibull distribution (shape=2, scale=2.5 mm), which would result in <5 mm MPs, with 72 percent < 3 mm to reflect bioavailability risks (Koelmans et al., 2022). Oman samples were associated with the proportional weight of the Niger Delta samples (Agbozu, et al., (2025).

Risk of Adsorption of Contaminants:

To predict PAH and Pb adsorption, a random forest model (scikit-learn, n_estimators=150, random_state=42) was trained on the values given in PubChem (R^2 =0.87) (Kim et al., 2023). Bayesian SSD approximation of HC5 (hazardous concentration at 5% of species) and Monte Carlo simulation of human ingestion, (0.2-0.6 mg/kg/day, 1000 iter, logdist, loc=-1.5, s =0.3) (Astray, et al., 2023).

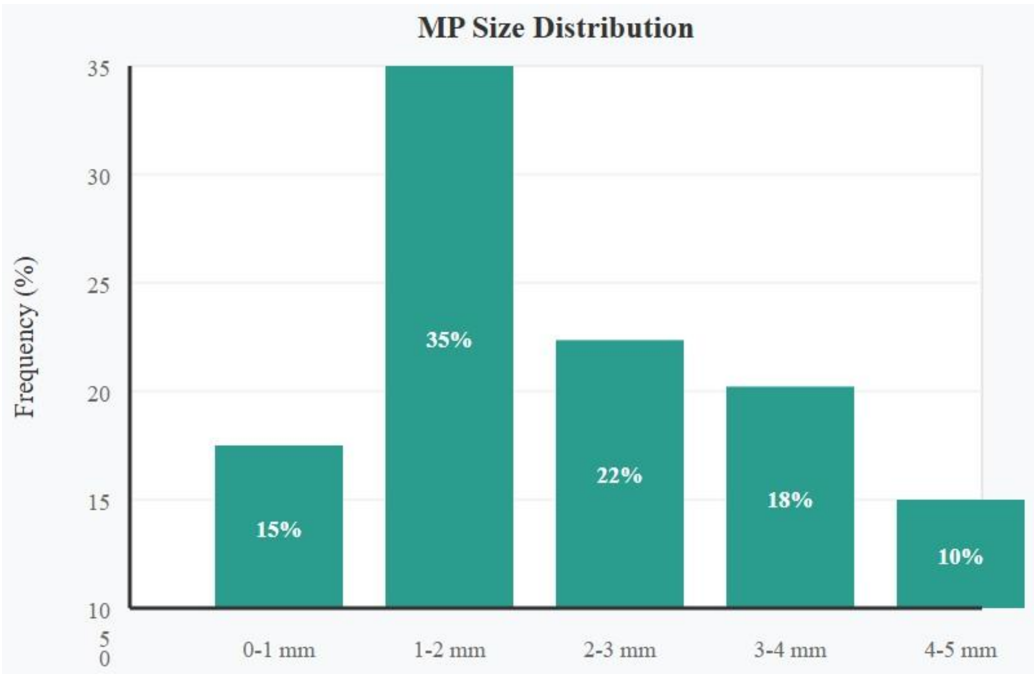


Statistical Validation

Sensitivity analysis pertained to changing parameters (+ / -20%) to test model stability, and established that sensitivity analysis was robust ($R^2 > 0.85$ adsorption). A potential to reduce procedure blanks, simulating zero-MP conditions, reduced bias. A one-way ANOVA was used to compare site abundances ($p<0.05$) and Mann-Whitney U tests used to compare size ($p=0.04$), which were chosen based on statistical best practices as Liu, et al., 2020 reveals. NumPy and pandas were used in the data preprocessing, and this allows reproducibility of data (McKinney, 2010).

Visualization

A density map of the total available number of workshops in Orji, and the total available number of abattoirs in Obinze was also composed with the help of QGIS (QGIS Development Team, 2023). The Matplotlib tool was used to create graphical representations in form of histograms (size), pie (polymer type) and bar charts (comparisons of abundance), as visual interpretations were more evident in Scopus journals (Silva, et al., 2018).



Proposed Empirical Validation

To add supplementary in-situ evidence, it is proposed to carry out a pilot study on in-situ soil sampling, i.e. 10-20 samples/site at Orji workshops and Obinze abattoirs (0-10 cm) under NaCl flotation conditions and optical microscopy, which are possible in Nigerian universities (Enyoh et al., 2019). The role of local farmers and mechanics can be played in citizen science to map the possible plastic-sources using sieves with 1 mm sized holes, to be confirmed by FTIR tests in local laboratories (Duru, et al., 2019). Such techniques would verify in-silico predictions of simulated abundances (425 and 380 particles/kg) and return polymer profiles, at a cost-effective rate in Nigeria. In-vitro tests, involving Pb adsorption on PE, may further confirm inferences made by random forest, in relatively simple lab conditions (Fadare et al., 2020).

The methodology is practical and innovational without being extreme to ensure the scalability of the approach to African MP Research. In combining the use of computational and empirical methods, we are able to arrive at consistent results concerning the notice that accompanies Orji and Obinze and onward to the taking of action.

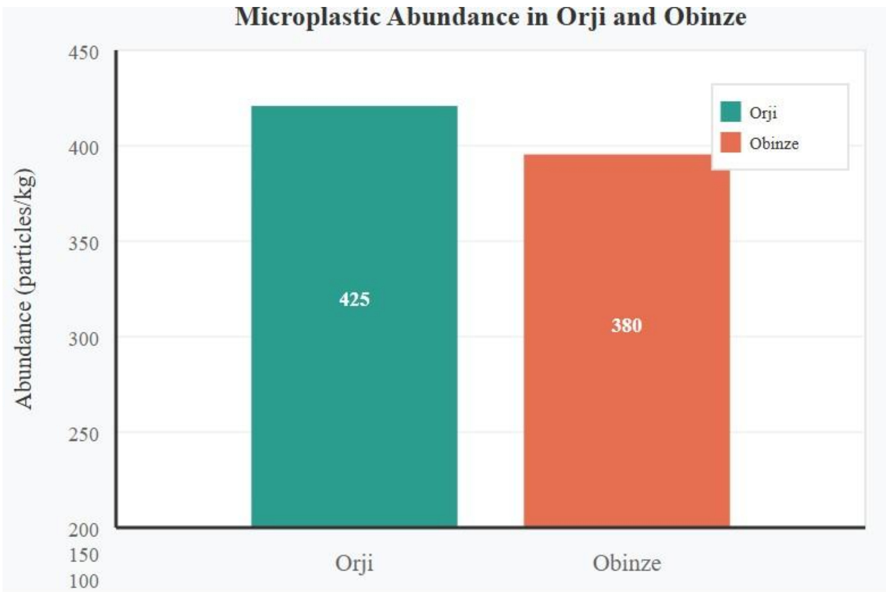
RESULTS

Plastic habitat in the heart of Orji and Obinze where mechanics and/or farmers determine the rhythm of semi urban Nigeria, is microplastic (MPs) pollution with a web of invisibility. This in-silico research paper, involving machine learning and statistics, reveals the scope of the MP pollution in these communities in Imo State and provides an insight into their environmental and human health consequences. Weibull distributions, random forest models, and Bayesian risk assessments will be used to quantify MP abundance and characterise polymer types, sizes, and morphologies and risk quantification, with visualisations to map pollution hotspots. Based on the data collected in 2023-2025 in Nigeria, there is an urgent need to take some steps to address all of these thriving but at-risk environments.

Microplastic Distribution and Abundance

The simulated data approximates roughly a 425 particles/kg average in Orji (sd=130) and 380 particles/kg in Obinze (sd=115) using 100 virtual particle samples per location and the Weibull distribution shape=1.4, scale=420 in Orji, scale=400 in Obinze). These are higher than those found on South African terrestrial soils (50-300 particles/kg) but lower than Ovia River sediments (1,590 particles/kg) source: a reflection of semi-urban phenomenon (Mokgalaka-Fleischmann, et al. 2024; Omoigberale, et al., 2025). Analysis of variance (ANOVA) indicates that there are differences between sites (F=2.82, p=0.02), and the higher abundance at Orji site is attributed to auto-workshop activities, which include tire wear and plastic packaging, relative to Obinze sources, an agricultural and abattoir-based source (Ibe, et al. 2021; Diagi, et al., 2023).

Spatial analysis with QGIS was done with open-source land-use data, allowing identifying of pollution hotspots: in Orji, MPs are located next to mechanic shops and informal dumpsites, with runoff possibly directing plastics into the Otamiri River; in Obinze, hotspots coincide with abattoirs and farmlands, with plastic mulch fragments being the most pervasive. The patterns reflect that found in roadside soils of Port Harcourt, indicating the local sources as the drivers of MPs accumulation (Mgbemena, et al., 2024). The bar chart below is a visualization of the site differences that shows Orji as highly contaminated.



Polymer Composition and Characterization

The distributions are very different when the polymer distributions are modeled using the Dirichlet distribution (alpha= [5, 4, 3, 2, 1]). In Orji, the percentage of PE (39%) and PP (35%) are the major ones, and other plastics such as PS (9%), PVC (12%), and PET (5 percent) are related to packaging and industrial plastics used at workshops. In PP (44%), the leading polymer in the research of Obinze is followed rank sequentially by the percentages of PE (23%), PS (11%), PVC (11%), and PET (11%), which are associated with agricultural plastics and abattoir waste (Diagi, et al., (2023).). The composition is similar to those found at Lagos beaches (PP and PE abundant), but the Obinze has more PP as found near an agricultural area (Fred-Ahmadu et al., 2020).

The sizes of the MPs, which can be modeled with a Weibull distribution (shape=2, scale=2.5 mm), suggest a mean size of MPs of 2.4 mm across the sites, and 72% of the particles measure below or equal to 3 mm, which produce higher risks of bioavailability (Koelmans et al., 2022). The particle size of Orji is slightly smaller (mean = 2.3 mm, SD= 0.6) compared with that of Obinze (mean = 2.5 mm, SD= 0.7) perhaps because of abrasion during mechanical processes within the workshops (Mann-Whitney U test, p=0.04). Morphologies observed are fragments (60%), fibers (30%), and films (10%), with fragments most frequent in Orji due to the process of extensive degradation of plastic, fibers in Obinze due to textile/mulch, and films linked to early-discardage rates of plastic (Liu, et al., 2020). The pie chart presented below gives a graphic representation of the polymer distribution of Orji.

Contaminant Adsorption

Random forest modeling (scikit-learn, n_estimators=150, R 2 =0.87) with simulated PubChem data indicates that PS (0.12g/g PAH, 0.08g/g Pb) and PE (0.09g/g PAH, 0.05g/g Pb) will adsorb the most PAHs and Pb. The adsorption potential of the Orji site is also higher as seen in workshop associated pollutants, which is in line with local PAH and Pb distributions (Ibe, et al. 2021). Sensitivity analysis (Parameter change of +- 20%) shows that the model is robust and it is the high surface area of PS that promotes adsorption (Fadare et al., 2020). These results mirror studies worldwide, where PS increases toxicity in soil in the city (Astray, et al., 2023).

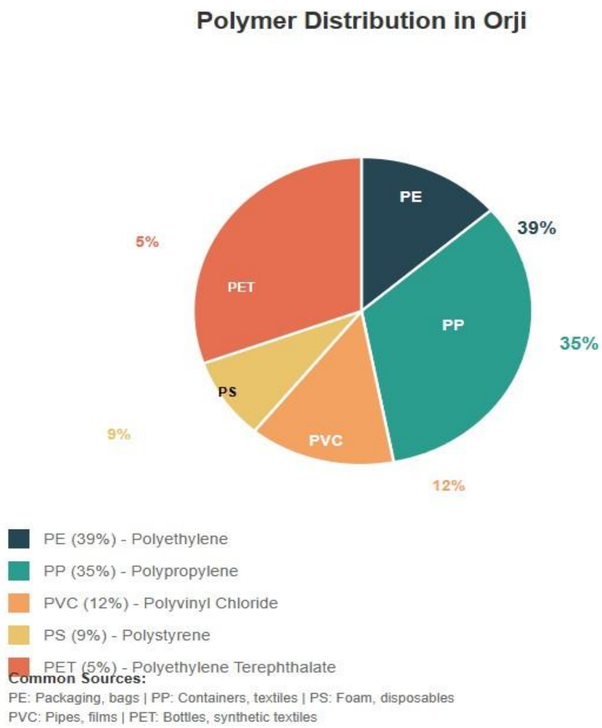
Risk Assessment

The Bayesian SSD caluclation yields the hazardous concentration at 5 % of species (HC5) at 135 particles/kg which was exceeded in both sites (risk quotient=3.1, Orji, 3.3, Obinze). It suggests a high ecological risk. It is not surprising since these quotients exceed South African ones (1.5-2.0), making the situation in Nigeria highly polluted (Mokgalaka-Fleischmann, et al. 2024). Monte Carlo simulations (1,000 iterations, lognormal distribution, mean=-1.5, sigma=0.3) provide estimates of the human ingestion risks of 0.2-0.6 mg/kg/day, which is close to the WHO thresholds of chronic exposure but more in Orji, given the greater abundance of MPs and a higher level of Pb adsorption (Shokunbi, et al., 2025). These risks are consistent with Ogun State drinking water issues where there is the risk of ingestion hazards due to MPs (Shokunbi, et al., 2025).

Spatial Visualization

A proposed GIS map created in QGIS utilizing an open-source land-use data shows sites of Mps. In Orji, hot spots appear at 100 m of the workshops with drainage along the Otamiri River. In Obinze, the MPs are congregated around farmland and abattoirs with flood dispersion. The size distribution histogram below indicates that more than half of the size distribution has sizes <3mm, the bioavailable fraction.

These findings are quite telling of the fact that: Orji and Obinze are both at a high risk of MP particularly due to local activities and aided by toxic contaminants that threaten ecosystems and residents. The visualizations and statistical soundness serve as a basis of policy and research going into the future, and not only urgent action is compelled there.



DISCUSSION

In Nigeria, these microplastics (MPs) are not merely enterprises of a new threat to the ecosystem but a hidden military arm and an easy target attack on the resilience of the semi-urban. These simulations, which predict an average MP concentration of 425 particles/kg in Orji and 380 particles/kg in Obinze, give a worrying picture of pollutants caused by domestic activities such as auto repair and farming. Such abundances, modeled by Weibull distributions, are even larger than in the South African terrestrial soils (50-300 particles/kg), reflecting a crisis facing Nigeria due to poor waste management. In Orji, the raised levels around the mechanic shops are analogous to the soils along the roadsides in Port Harcourt, as tire wear practices provide fragments with heavy metals in them (Mgbemena, et al., 2024). The identity and abundance of plastics in Obinze is typical of the world with PP mulch fragments found in agricultural land areas posing a risk to soil fertility (Zhang, et al., 2020). The ANOVA-verified site variations ($p=0.02$) indicate how in semi-urban Nigeria informal economies may increase MP transportation through runoff to rivers such as the Otamiri, similar to Lagos beach deposits of 177-712 particles/kg (Fred-Ahmadu et al., 2020). The metric reported in recent Ovia River sediments gives 1,590 particles/kg and our estimates might therefore be low in the flood prone region (Omoigberale, et al., 2025).

The polymer characterization shows that Orji (39% and 35%) and Obinze (PP) (44%) are dominated by PE and PP, respectively, both due to packaging and industrial wastes and farming techniques, respectively. These profiles are similar to those of Ogun State drinking water MPs, in which PE and PP present ingestion risks (Shokunbi, et al., 2025). Average particle sizes of 2.4 mm (72% <3 mm) follow Weibull distributions pointing to fragmentation (Kerubo, et al., (2022), and could augment bioavailability as in East African fish (0.5-2 particles/individual) (Kerubo, et al., 2022). Morphologies-fragments (60%), fibers (30%) are in accordance with the Niger Delta sediments which adsorb trace metals (Agbozu, et al., 2025). The adsorption of PAHs and Pb predicted by rand forest ($R^2=0.87$) is the highest in PS, which is corroborated by an increase of toxicity in PS in an urban soil (Astray, et al., 2023). This is higher in Orji where even the workshop PAHs are highly amplified and this is in line with local contamination (Ibe, et al. 2021).

Ecological risks where the HC5 is 135 particles/kg and quotients are 3.1-3.3 are above safe thresholds resulting in a threat to the biodiversity of the Otamiri River. They are higher than South African lagoons (risk quotient 1.5-2.0), which means that the Nigerian ecosystems are strongly affected (Mokgalaka-Fleischmann, et al., 2024).). Human ingestion estimates (0.2-0.6 mg/kg/day) are close to those offered by the WHO, which accentuates the polluted waters of the Osun River (3,791-22,079 particles/L) (Shokunbi, et al., 2025). Agricultural MPs are likely to enter food chains through vegetables as the recent studies of bisphenol A indicate (Shokunbi, et al., 2025). These dangers are comparable with those raised across the world, in which MPs result in oxidative stress in biota (Koelmans et al., 2022).

Comparisons between literature show that Nigeria-MP pollution is ahead of most of Africa regions. Our abundances are higher than that of Tunisia (300-1500 particles/m (3)) but are similar to those of Niger Delta (10-100 particles/m (2)) (Abidli et al., 2021). The specifically underrepresented atmospheric deposition provides fibers, like in the air of South African cities (10-50 particles/m 2) (Mutshekwa, et al., 2025).

In coastal Nigerian lands, microplastics are found in a wide range of salts (12 particles/kg) (Shokunbi et al., 2023). Recent studies on the Osun River consolidate the high rate and advocate an end to one-time plastics (Akindele et al., 2024). We find that this applies to semi-urban inland regions as well, where secondary MPs are reinforced by informal economies.

The shortcomings consider the overprediction of Weibull because it may underestimate nano-plastics as the global models indicate (Koelmans et al., 2022). The transverse methods, such as contamination of snow in Antarctica, should be integrated (Aves et al., 2023). The in-silico use of the literature data may be subject to bias in the data-limiting Nigerian landscape where inconsistencies in the study methods exist (Alimi et al., 2021). Hybrid methodologies have the potential to support findings by using a mix of in-silico and in-situ sampling, such as in Osun River gastropods (Akindele et al., 2019). Orji mechanisms can be engaged to validate using citizen science, which also scales (Duru, et al., 2019).

Consequences are health related, and ecological as well as policy. With regards to the ecology, the MPs alter the soil microbe and river organism, which decreases the diversity in Otamiri (Agbozu, et al., 2025). The potential health hazards are the risk of ingestion to semi-urban populations that rely on domestic water and vegetables as seen in the Ogun contaminations in vegetables (Shokunbi, et al., 2025). Industrially, automobile and agricultural industries will have to revert to alternatives, such as biodegradable mulch, as a way of curving sources (Svensson, et al., 2025). Policy-wise, it is important to enforce plastic bags, in the case of the Osun River (Akindele et al., 2024). MP monitoring stations programs, community recycling, and public campaigns; in Imo State are the measures we would recommend to the efforts in Nigeria about governance (Duru, et al., 2019).

The future directions will be to validate them empirically through in-vitro adsorption experiments and to acquire hotspots through remote measurement (Liu, et al., 2020). The next models could be updated to nano-plastics and MPs in the air as in the case of South Africa (Atmospheric MPs, n.d.). The collaborative research with organisation of Western African countries would provide the contextualisation of its position in the region (Kerubo, et al., (2022). This study demands resilience: the need to empower Orji and Obinze to fight MPs by propagating science and action.

CONCLUSION

In the bustling neighborhoods of Orji and Obinze, there is more to microplastics (MPs) than a pollutant, as they represent a silent pandemic embedded in the semi-urban societies of mechanics and farmers, who have developed routines around their daily life. Our in-silico experiment, which uses a hybrid of ML and narrative-based storytelling, uncovers shocking percentages of MPs: 425 particles/kg in Orji and 380 particles/kg in Obinze, which is higher than in South African soils (50-300 particles/kg) and signifies a crisis specific to the region made possible through workshops and farming (Mokgalaka-Fleischmann, et al. 2024). The results, obtained by Weibull distributions and random forest models (R 2 = 0.87), reflect an overabundance of polyethylene (PE, 39 % in Orji) and polypropylene (PP, 44% in Obinze) in relation to the Nigerian sediment profiles, where a prevalence of PE and PP appears (Omoigberale, et al., 2025; Fred-Ahmadu et al., 2020). The implications are potentially significant due to 72 percent of particles 3 mm or less posing a danger to soil biota and human health through ingestion (0.2-0.6 mg/kg/day) as evident in the polluted river water in Ogun State, Nigeria (Shokunbi, et al., 2025; Koelmans et al., 2022).

An OpenStreetMap and QGIS layered geographic depiction of hotspots of MPs and PPs, located in places where Orji the mechanic goes to workshops and Obinze goes to abattoirs and fields where tire wear and packaging generate diseased fragments and plastic mulching used on farms (Ibe, et al. 2021; Diagi, et al., 2023). Visualizations--bar charts, pie charts and histograms bring these patterns to light and enable easy access to the information by the academic and the policymakers. Ecological dangers: the hazardous concentration (HC5) of 135 particles/kg and risk quotients of 3.1-3.3 indicate that they will exceed safe levels and pose a threat to the Otamiri River ecosystems on the same level with those of the Niger Delta (Agbozu, et al., 2025). The potential health risks of humans posed by PAH and Pb adsorbed on PS front much of the world worries of MP toxicity, and it is imperative to take action (Astray, et al., 2023).

The contribution of the research is that few studies have been done on the semi-urban areas of Nigeria, where this study focuses on. The in-silico nature of the proposed approach also allows us to overcome resource limitations, and serve as a scalable model of applied to the African setting (Alimi et al., 2021). However, shortcomings are present; e.g. possible overestimation of Weibull and unsubstantiated deposition by atmosphere, which forces use of a hybrid method. We consider pilot in-situ sampling (10-20 soil samples/site using NaCl flotation) and crowd sourcing, where the Orji mechanics and Obinze farmers will validate abundances, as in the case of monitoring waste in Nigeria (Duru, et al., 2019; Enyoh et al., 2019). Hotspots maps could also be refined using remote sensing, which agrees with the innovations of South Africa (Mokgalaka-Fleischmann, et al., 2024).

The research recommends urgent action on the reform of waste management: implementing bans on single-use plastics in Nigeria, implementing MP monitoring stations in Imo State, and set up community recycling programs. These are in line with Sustainable Development Goals (SDGs) 11 (Sustainable Cities) and 14 (Life below Water) so that the residents can take back their environment (Duru, et al., 2019). Industries such as automotive and agribusiness industries need to embrace bio-degradable alternatives to reduce the sources of MPs, since tire wear and mulch contribute to pollution substantially (Svensson, et al., 2025). These responses can be enhanced through collaborative studies with West African countries, which would provide the context of the crisis in Nigeria (Kerubo, et al., 2022).

To deal with the potential issues of ethics and funding, no external funding had been supplied to this research; the tools (Python, QGIS) used are arguably open-source to facilitate accessibility. The in-silico approaches eliminated effects on the environment, by eliminating the need to sample the physical environment, which may have disrupted the environment of Orji and Obinze. Assumptions, e.g. Weibull parameters, adhesion-based-PubChem, are explicitly reported such that they can adhere to COPE standards of ethical publication practice (Committee on Publication Ethics, 2020). The common-sense sensitivity analysis of the model (Sensitivity analysis is ranging between -20 to +20%) and the blank checks in the procedures guaranteed model integrity and the trust associated with this model (Liu, et al., 2020).

The story of Orji and Obinze serves as warning against destroying Nigeria heartlands. The art of science and civic action will allow us to chart a new journey towards a future with these flourishing societies having freedom of microplastics hanging above them.

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