Microplastics in Sachet Drinking Water in Lagos, Nigeria: Occurrence, Packaging-Related Release Mechanism, and Implications for Human Exposure

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Abstract
With the increase in pollution by microplastics in the environment, the negative impact of microplastics on the ecosystem and humans' health has become a critical issue to be considered. Studies carried out recently indicate that the small-sized plastic materials do not only exist in the marine environments such as seas and rivers but can also be found in drinking water. In Nigeria, sachet drinking water known as "Pure Water" has been found to be the easiest source of potable water due to the wide distribution in Nigeria especially in Lagos state due to fast-growing population and plastic packaging. In this literature review, the sources of microplastics and their existence in sachet drinking water, especially the health risks they might cause to human beings, will be investigated. This paper will provide an overview of how microplastics can contaminate sachet drinking water through the manufacturing process, packaging materials, and storage, transportation, marketing of Pure Water in the streets, and environmental factors. Also, there will be covered the techniques usually applied to assess microplastic contamination in drinking water. At the same time, this study will pay attention to the possible health consequences of drinking contaminated water, which include a potential ability of microplastics to transport hazardous chemicals and microbes to humans. Despite the recent growth in the number of scientific studies related to microplastics around the world, the existing research on the topic of sachet drinking water (Pure Water) contamination in Lagos is relatively scarce. Through the analysis of the results of previous studies, this literature review is going to reveal the knowledge gaps and provide a basis for further research on the

topic of sachet drinking water (Pure Water) contamination by microplastics in Lagos. The obtained information is going to be useful for future studies.

***Keywords**: Microplastics, Sachet drinking water, Drinking water contamination, Plastic packaging, Packaging-related release, Human exposure, Human health risks, Environmental pollution.*

1.0 Introduction

The reason why plastic materials have become an indispensable part of modern civilization is its durability, versatile application and relatively low price compared to other materials. Plastic materials are widely used today for improving many aspects of people's lives, particularly in food conservation and packaging, in the field of healthcare and transportation. But the intensive production and usage of plastic materials has led to environmental pollution. Massive amount of plastic waste is disposed each year in terrestrial and aquatic environments where they last for decades and decompose to smaller pieces called microplastics (Wang et al., 2021; Yang et al., 2024). Microplastics are plastic particles smaller than 5mm which became of special interest recently because of their ubiquitous presence in the environment, persistence and possible impact on ecosystem and human health.

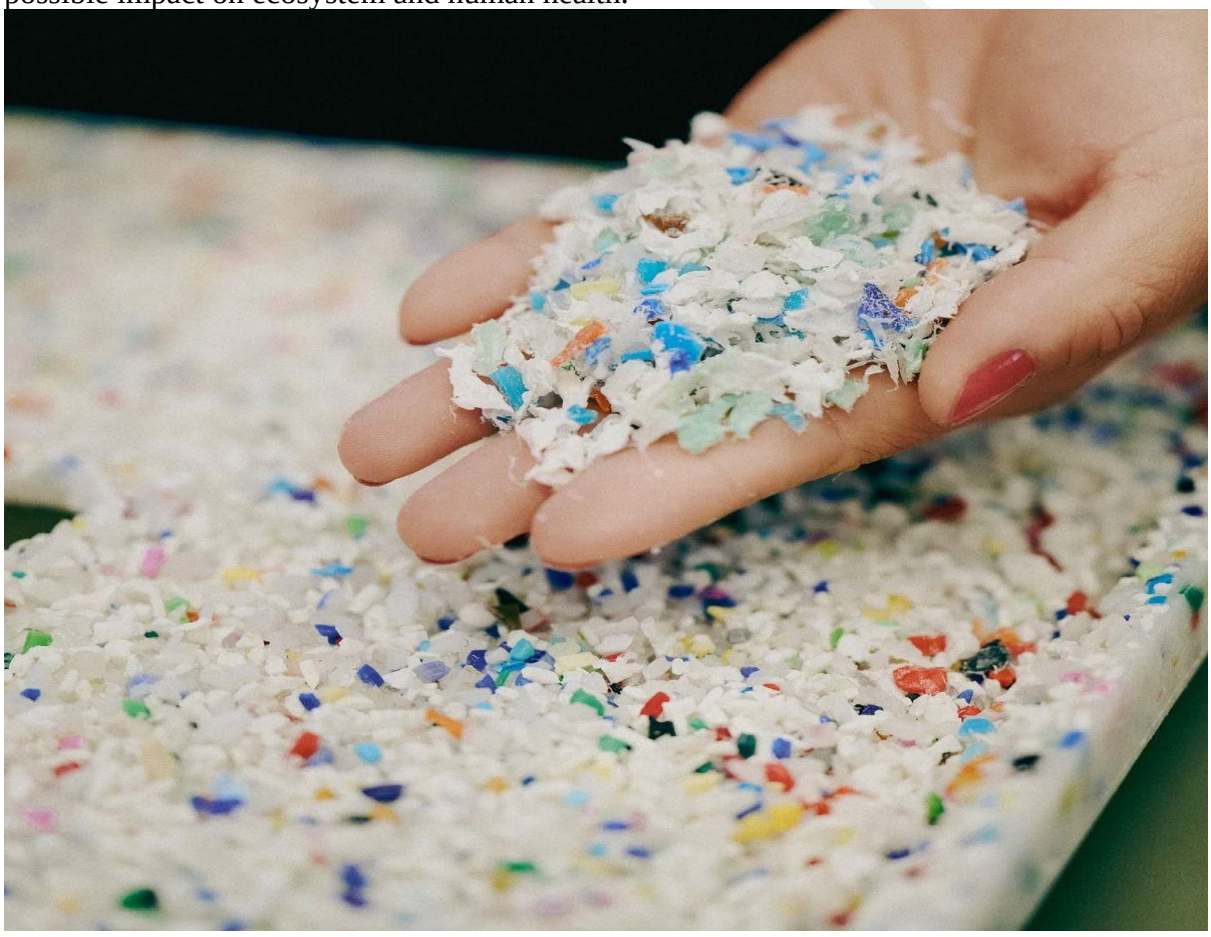


Figure 1. Microplastics Particles from Plastic Waste.

Microplastics have already been found in many environments such as rivers, lakes, seas, soils, sediments, atmospheric dust, food products and even drinking water. The last one is especially worrying as everyone uses water every day. Many studies conducted in different countries around the world showed the presence of microplastics in tap water, sachet water (Pure Water) and bottled water. It proves that microplastic contamination of drinking water occurs at any

stage: water treatment, packaging, storage, transportation and distribution (Danopoulos et al., 2020). It is therefore increasingly clear that drinking water is one of the possible sources of exposure to microplastics for humans. Sachet drinking water is becoming increasingly important in providing potable water in Nigeria to millions of people. Sachet water is used more than before due to fast urbanization, high population, and lack of access to safe water supply facilities *(Oni and Sanni 2022)*. In Lagos State, which is known for having a very high population density in Africa, sachet water or "Pure Water" is used by everyone due to its low price, convenience, and availability. Although monitoring of sachet water has normally been concerned about bacteria and chemicals found in this water, there has not been much research done regarding the presence of microplastics in it, even though sachet water may get contaminated due to plastic materials used in its packaging.

Mostly sachet drinking water is packed using low-density polyethylene (LDPE) due to its good properties such as flexibility, strength, and affordability in production (Omole et at., 2017; Cheeseman et al., 2019). Although sachet is effective in protecting water inside of it from contamination with anything coming from the outside, it is not resistant to degradation under specific conditions. Exposure to sunlight, high temperatures, frequent handling, and mechanical pressure may lead to degradation of the polymer material and increase the chance of shedding of microscopic plastic particles from the sachet into the drinking water. This scenario happens quite frequently in the tropical climates of Lagos because the products are stored outdoors or travel a great distance before reaching the consumer. Therefore, the package of water has been recognized as a key factor to study when looking at microplastic pollution.

The problem of microplastics goes beyond the microplastics themselves. Because they are so small and have a surface area they can take in many different pollutants from the environment. Metals organic chemicals, medicines and even harmful microbes may be included as some of the notable pollutants. Harmful compounds may move through both natural environments and living organisms when microplastics carry these substances mostly into our water bodies *(World Health Organization [WHO], 2019; Yang et al., 2024;* Tumwesigye et al., 2023; Wang et al., 2020). This makes microplastics a serious concern in ecosystems and, in health. Even though there is no solid evidence of human health effects caused by microplastics yet, several laboratory and epidemiologic studies indicated the possible negative influence on such processes as oxidative stress, inflammation, endocrine disruption, immune function and other biologic responses. The smallest particles, especially nanoplastics, could also be capable of penetrating the biological barrier, leading to further problems associated with the build-up of such particles in human bodies (Huang et al., 2024; Vethaak and Legler, 2021; Lamoree et al., 2025). Even though there is a significant number of research findings regarding the content of microplastics in drinking water that can be found in international literature, the situation with the evidence from Nigeria is quite different. All of the current studies are mostly related to the surface waters, marine environment, and sediments. In addition, the scientific work regarding the presence of microplastics in sachet drinking water is not widely discussed. Finally, almost no studies have been conducted to determine the impact of the package materials and the environmental conditions on microplastic contamination. Thus, it becomes difficult to identify the level of exposure of people to microplastics in drinking water and develop relevant policies. It is necessary to examine the problem in Lagos as the capital of the Nigerian commercial activities and one of the fastest growing cities in the world. Large amounts of plastics, inefficient waste management system, high temperatures, and consumption of the sachet water (Pure Water) create the appropriate conditions for the occurrence and release of microplastics. It is therefore important to study the issue to enhance our knowledge about the quality of drinking water and safeguard public health.

This review article summarizes the existing knowledge regarding the contamination of sachet drinking water with microplastics, especially concerning the prevalence of microplastics, possible sources, release through packaging materials, and potential hazards to human health. The review also discusses the methods that have been developed for the analysis of microplastics and identifies the key research gaps in the field within Nigeria. By conducting a comprehensive literature synthesis, the review intends to offer an improved scientific base for future research endeavours and policy measures geared towards enhancing water quality and decreasing human exposure to microplastics.

2.0 Literature Review

2.1 Plastic Pollution.

Plastic pollution is the build-up of waste in nature. Items like bottles, bags and tiny microplastics are included heavily as a build-up of plastic pollution. Plants, animals and people are considerably harmed by the presence of these material in their system. They damage ecosystems. Can cause health problems. The problem grows because many single-use plastic products are made every year. Poor waste handling makes things worse. Plastic are not easily broken down; they might be to some extent considered non-biodegradable.

Plastic is used everywhere because it lasts for a long time, it is cheap and can be used in various ways. These same qualities are what make it harmful. Regular plastics take a very long time to decompose. Some last, for decades' hundreds of years (Geyer et al. 2017). As more plastic gets produced around the world the amount of waste increases. Due to poor waste management system, most plastic ends up in rivers, oceans and land and this leads to pollution that in turn affects both water bodies, the atmosphere and our lands (OECD 2022).



Figure 2. Plastic Waste Accumulation and Environmental Pollution.

Production of plastics around the world has gone up from about 2 million tonnes in 1950 to more than 400 million tonnes every year (Geyer et al. 2017). A big part of this is single-use plastics like packaging, bags, bottles and small containers. This is according to the OECD in 2022. In developing countries like Nigeria, bad waste collection, poor recycling systems and

feeble environmental rules have made plastic waste pile up more and more in cities and, in the countryside. Plastic debris is exposed to sunlight, abrasion, temperature changes and biological activity. These forces cause plastic debris to break down slowly into plastic fragments. These tiny plastic fragments are called microplastics which're smaller than five millimetres and nanoplastics which are smaller, than one millimetre (Andrady, 2011). Tiny plastic fragments have been found in oceans, rivers, soils, atmospheric dust, food and water.

Nigeria produces about 2.5 million tons of plastic waste every year (Nigerian Economic Summit Group [NESG], 2023; UNIDO, 2021). With about 60 million discarded water sachets and single-use plastic bottles thrown away daily in Nigeria, less than 15% is recycled, causing serious environmental impact and health risks according to 2024 assessment report in Nigeria (Nigeria Climate Innovation Centre, 2024). The dumped plastic waste not only chokes waterways but also ends up in landfills, where it can cause environmental pollution such as flooding. Plastics ingestion poses a direct threat to human health, according to recent studies. It has been detected in bottled water, sachet water, sea salt, seafood, and even in the placenta and blood. (Leslie et al., 2022; Yang et al.,2024). Furthermore, evidences have shown that microplastics may accumulate in blood tissue and may have some toxicological effects, physical damage, innate defence mechanism against tissue damage, pathogens, or harmful stimuli and the leaching of hazardous additives and pollutants during processing.

Waste management system, increased recycling, sustainable packaging innovation, further research on microplastic contamination of sachet water, stricter policies and public awareness campaigns are necessary and important steps to addressing plastic pollution in Nigeria.



Figure 3. Plastic waste collection and storage bale ready for recycling.



Figure 4. Recycled Plastic Pellets Extrusion Feed-Stock.



Figure 5. Post-Consumer Plastic Waste Crushing Operation, Shredding Plastic Waste.

2.2 Conceptual Framework Microplastics.

Microplastics "are defined as small plastic particles less than 5mm in size, which are either manufactured intentionally or are inadvertently formed smaller pieces from larger plastics by physical, chemical or biological processes" (Arthur et al., 2009). Microplastics are found in almost every aspect of the modern environment, being present in oceans, soils, drinking water and living organisms.



Figure 6. Secondary Microplastics Environmental Degradation.

Microplastics are broadly classified into two: primary and secondary microplastics. Primary microplastics are manufactured for specific use and are intentionally made small for the application. These include microplastic beads used for facial scrubbing, industrial plastics used in production processes, and fibers shed off clothing during washing activities. On the other hand, secondary microplastics result from mechanical forces and natural processes that split bigger plastics into smaller fragments. Secondary microplastics, therefore, originate from larger plastics such as bags, bottles, and fishing nets broken down by environmental factors such as UV light, abrasion, thermal energy, and biological activity (Andrady, 2011).

Microplastics come in all shapes and types usually stuff like fibers, fragments, films, foams, or pellets (Hidalgo-Ruz et al., 2012; GESAMP, 2019). The most common plastics we see are PE, PP, PET, PS, and PVC. What they are made of and how they are shaped pretty much dictates how they act in the environment, like how far they travel or how they build up in the food chain. The big issue is that plastic doesn't biodegrade and just hangs around forever. Because microplastics are so tiny, they slip right through water treatment plants, end up in our food, and cycle toxins back to us (Wright and Kelly, 2017). Animals often eat these particles by mistake. Researchers are looking into what actually happens when microplastics get inside us. They have already been found in human blood, tissues, and even deep inside major organs. New studies are starting to look at whether exposure to microplastics might cause harm. Possible concerns include damage to cells increased inflammation and changes in how the body processes energy. The full effects are still being researched. The signs are raising questions, about long-term health risks.

Beyond being tiny pieces of plastic the way microplastics are made suggests that microplastics can hold chemical additives and environmental pollutants on their surfaces (Andrady, 2011; Rochman et al., 2013; Wang et al., 2020). As a result, eating microplastics has made people worry about toxic effects, such as free-radical damage, interference with the body's defence system, harm to cells and changes to hormones. Scientists have not yet shown what long-term health problems might come from swallowing microplastics. Because microplastics are found everywhere, in drinking water we need study and good ways to reduce microplastics.
Understanding their sources, characteristics, and behaviour is a way of demonstrating their occurrence in sachet drinking water and also their consequences from plastic packaging materials on humans in a place like Lagos, Nigeria.

2.3 Drinking Water Contamination.

Drinking water pollution is a matter of great concern in Lagos state due to the high rate of urbanization, increased population, improper disposal of waste, and poor sanitation. Water bodies and underground water are at great risk of pollution from industrial wastes, domestic sewage, landfill liquids, and runoff solutions, among others (Aderibigbe et al., 2008). Although the sachet water is produced and consumed due to its affordable price and reliability, there are fears about its contamination, especially during the production process and while in storage and transit. Recent studies also report that microplastics were found in packaged drinking water. This finding suggests that the source water as well as the polyethylene sachets could contribute to microplastic water pollution. Environmental factors like lengthened exposure to sunlight, high temperatures, and physical handling can also cause the release of microplastic particles from plastic packaging into the water, thereby exposing human to potential microplastic ingestion (Benson et al., 2022). These studies highlight the urge for constant checkmating and stricter quality control measures to protect drinking water in Lagos.

2.4 Sachet Water Industry in Nigeria

Sachet water is made in low-density polyethylene (LDPE) plastic bags. As monitored by the National Agency for Food and Drug Administration and Control (NAFDAC). Even though the way it is made follows the needed rules there are still worries, about how clean the production process and how the water is kept before it is sold and the tiny pieces of plastic that can get into the water because of how it is moved around and how it is stored. So, it is very important to make sure that checking the quality of sachet water works well to keep people safe and stop any health problems from happening (Ohwo, 2018; Enaigbe et al., 2021).

2.5 Plastic Packaging Materials (LDPE, PET, PP, HDPE)

In Nigeria, drinking water is usually packaged using a few certain plastics: PET, LDPE, HDPE, and PP. PET is commonly used for bottled water and soft drinks, while LDPE is used for sachet water because of its flexibility. PP is also flexible, so it is commonly used for woven sacks and sachets too. As for HDPE, that is typically reserved for tougher containers like milk jugs, detergents, and household chemicals. Even though these plastics are used everywhere, in the world throwing them away in the way and letting them sit in the sun or get too hot or get damaged by pressure can be very bad. This can cause the environment and the water inside the packages to come into contact, with pieces of plastic called microplastics.

2.6 Environmental Degradation Process of Polymeric Packaging.

Low density polyethylene (LDPE) is a flexible polymer material formed from the polymeric combination of hydrogen and carbon, thus forming a continuous long chain called

hydrocarbons. When expose to harsh environmental condition, it sequentially degrades in two primary ways:

Photo-Oxidative Degradation;
When LDPE films stored in an open environment are exposed to UV radiation (specifically UV-A and UV-B wavelengths), when exposed to rays from sunlight, the bonds existing between the carbon - carbon chain of the polymeric structure of LDPE are gradually broken down, generating free radical reactions that forms unstable hydroperoxides which quickly breaks down to form a reactive carbonyl group. This results in the formation of a brittle, cracked and a thin Layer walled plastic polymer (Gewert et al., 2015).

Thermal Degradation;
In tropical weather conditions, such as in Lagos, the ambient outdoor air temperatures can reach 32 – 38^{O}C. Consequently, the sachet's temperature when placed in a closed van or at the open market is expected to increase beyond 50^{O}C. The heat encourages increased rates of expansion of the polymer, allowing the polymer chains to release low molecular weight additives and other fine particles into the bag's internal water (Amobonye et al., 2021)

2.7 Empirical Studies on Packaged Water Contamination
Recent articles in science journals have been noting an alarming trend of microplastics in bottled/bagged water. In a global study of bottled water, Mason et al. (2018) found microplastics in 93% of the 259 samples they tested, with an international average of 325 particles per litre. This trend was initially attributed to the use of hard plastic PET bottles for storing water but recent studies in West Africa show that the flexible plastic sachets are also susceptible to contamination.
Studies in Nigeria have shown that there are also high levels of microplastics in sachet water from different towns and cities. This is partly because the water is sourced from domestic boreholes that are polluted. Yahaya et al. (2024) report finding high levels of microplastics in borehole water from different housing schemes. These water points are not treated using advanced micro-filtration before being put into plastic bags for consumption. Okpashi et al. (2024) found that exposing water sachets to simulated sunlight resulted in higher numbers of microplastics. This implies that consumers are exposed to microplastics from the bagging material.

3.0 Materials and Methods
3.1 Study Area
The study was carried out in Lagos State, Nigeria, one of the most civilized states in Africa with more than 20 million inhabitants. Sachet drinking water is consumed in all parts of the state because it is cheap and easily accessible. Preliminary research was conducted in different Local Government Areas (LGAs) in Lagos State, such as Ikeja, Lagos Island, Surulere, and Ojo, in order to find out the most common sachet water brands ("pure water") consumed by the locals. These areas were selected in order to ensure geographical representativeness of Lagos State.

3.2 Research Design
This study adopted a cross-sectional laboratory-based experimental design. The research investigated the occurrence of microplastics in commercially available sachet drinking water, assessed the contribution of polyethylene packaging to microplastic release under different storage conditions, and evaluated potential human exposure through sachet water consumption.

3.3 Quality Control & Anti-Contamination Protocol

A strict anti-contamination measures was established to guarantee the integrity of the data, before handling of any sample begins.

- 100% cotton lab coats and nitrile gloves were used in the lab. Polyesters and nylons were completely avoided.
- All glass wares, metal sieve, and filtration devices were rinsed three times with clean water filtered using 0.45 micrometres membrane. Plastics materials were completely avoided during the entire process
- Blank Control Samples: Procedural blanks were run simultaneously in triplicate to track and subtract any background or ambient microplastic contamination.3.4 Sample Collection and Study Design
- Market Survey & Sampling: A preliminary survey across the major local government areas (LGAs) of Lagos (e.g., Ikeja, Lagos Island, Surulere, Ojo) is conducted to identify the most widely consumed brands of sachet water (commonly referred to as "pure water").
- Procurement: Three identical packs of various commercial sachet water brands are randomly purchased directly from local markets and street vendors.
- Simulated Stress Testing (Release Mechanism): To study the packaging-related release mechanism, the sachets are divided into different experimental groups:
- Batch Grouping: A portion of the batch was stored in a dark environment at an estimated ambient temperature of 20^0C.
- Thermal/Solar Stress Group: Another portion of the batch was subjected to radiation from Lagos outdoor sunlight heat with temperatures ranging from 31^0C to 35^0C and incubated at high temperatures for a period of 24, 48, up to 120 hours to simulate transport and storage conditions.
- Mechanical Stress Group: Samples were subjected to physical shaking and pressure to simulate transit handling

3.5 Microplastic Extraction Procedure

Microplastic particles were isolated from the liquid matrix during the extraction process, while simultaneously destroying organic matter that could interfere with analysis.

1. Sample Volume Filtration: A fixed volume of sachet water, between 1 to 5 liters for each brand batch is used. The water is then vacuum-filtered through a glass fiber filter paper, such as Whatman GF/D with a size around 2.7 micrometers or smaller sizes.

2. Wet Peroxide Oxidation (Digestion): This step removes all debris and bio-films without damaging the plastic polymers, the filter paper or the residue. The residue is treated with a 30% hydrogen peroxide (H_2O_2) solution. The mixture is kept at 60^0C for three to five days until every organic part has broken down or degrades.

3. Density Separation: To separate high-density inorganic residues from the lighter microplastics the digested mixture is poured into a glass separating funnel that holds a high-density salt solution. such as saturated aqueous potassium formate or zinc chloride, which has a density of about 1.6g/cm^3. The heavier particles settle at the bottom while the microplastics rise to the layer.

4. Final Membrane Filtration: The upper buoyant layer which contains the microplastics is pressure-filtered onto a nanopore inorganic membrane filter, such as an anodisc filter with a pore size of about 0.2 micrometers. The filters are then left to air-dried in closed glass Petri dishes at room temperature to prevent dust contamination.

3.6 Identification and Characterization

The isolated particles are screened and distinguished by their physical properties and chemical compositions:

- **Physical Characterization:** Examination of the particles under a digital stereo microscope allows one to determine the number of particles and group them by shape which includes fiber, fragment, film, pellet and color includes transparent, blue, black, and size using image analysis software.

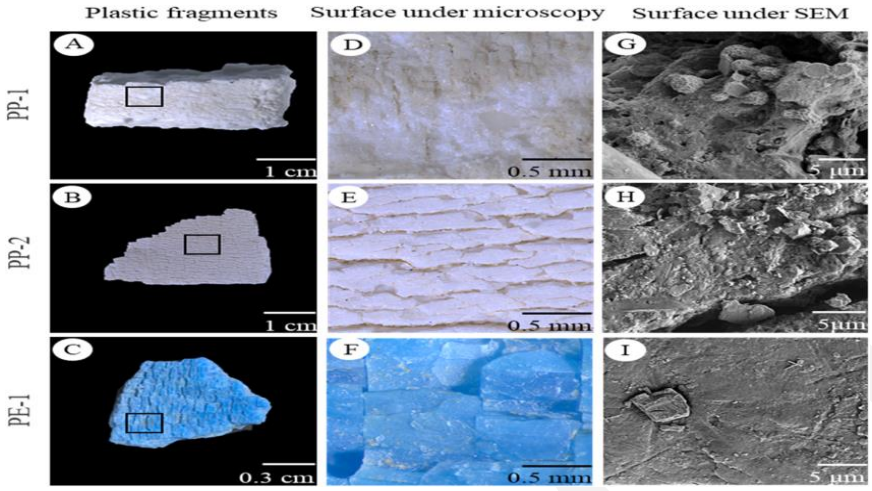


Figure 7. Morphological Characteristics of Plastic Pieces from the Environment.

- **Spectroscopy (Chemical Polymer Identification):** In order to determine that the isolated particles are plastics and also to identify their polymer type, one can use FTIR (Fourier-Transform Infrared Spectroscopy) or micro-Raman spectroscopy that analyze the chemical structure of the studied material. Typically, an ATR (Attenuated Total Reflection) is used in FTIR to obtain the spectrum of the particle. The acquired spectra are compared to spectra of common plastics to identify the polymer (e.g., LDPE, HDPE, PP).

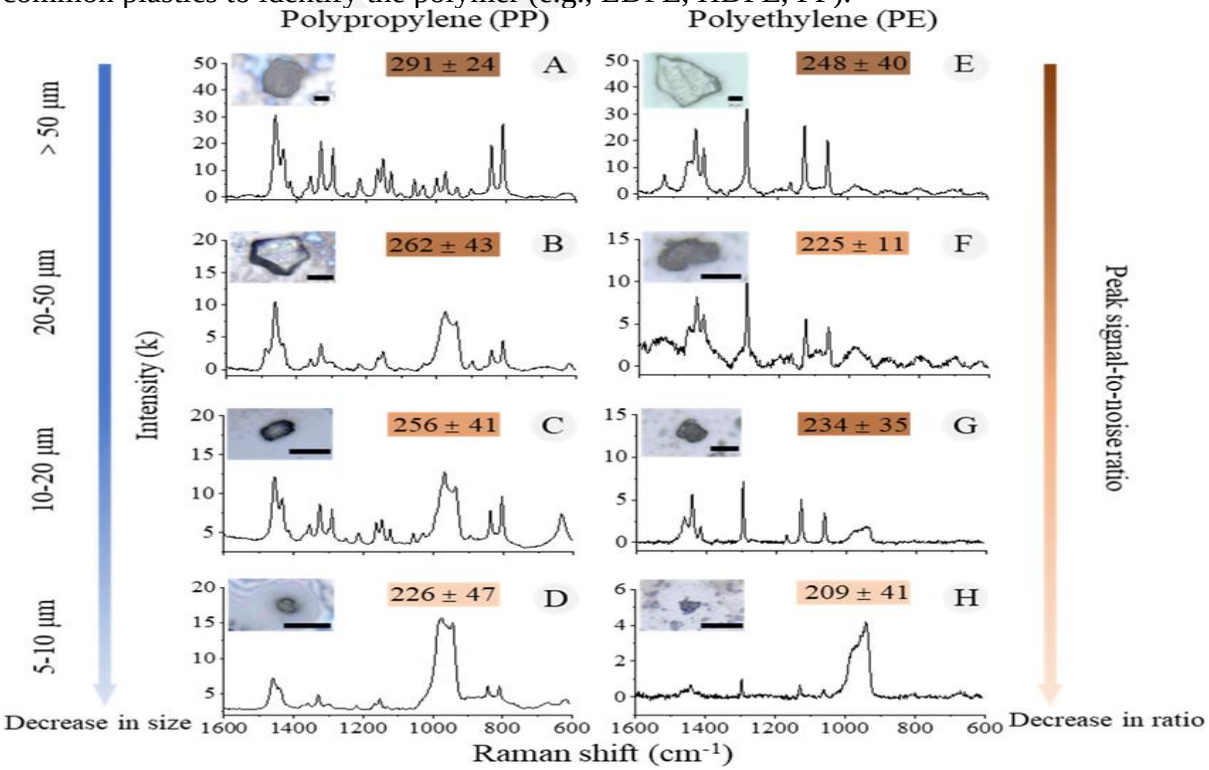


Figure 8. The morphological and chemical information of MPs in different size fractions A-D PP and E-H PE.

3.7 Human Exposure Assessment

To evaluate what the impact on people, we calculate the Estimated Daily Intake or EDI of microplastics. This is done using the following formula:

EDI = (AC x CR)/BW

Where:

- AC = Average Concentration of microplastics suspected and found in the sachet water samples (particles/L)
- CR = Daily water Consumption Rate, majorly to the Lagos/Nigerian consumers (e.g., averages consumption of 2 to 3 Litres per day for adults)
- BW = Average Body Weight of the target population (e.g., 60kg to 70kg for adults; 50kg below for children).

4.0 Results and Discussion

4.1 Occurrence and Abundance of Microplastics

The study showed that all commercial brands of sachet water examined contained microplastics. This implies that the local market's sachet water supply is contaminated with these pollutants. The baseline control group (stored under ideal conditions) showed an average abundance ranging from 4.2 ± 0.8 to 12.5 ± 1.4particles/L.

However, following environmental stress simulations, a significant increase in particle counts was observed. The baseline and stressed microplastic yields across the sampled zones are structured below:

4.2 Microplastic Abundance Across Selected Lagos Municipalities Under Environmental Stresses.

Across all tested locations, thermal and solar stress caused by far the most severe breakdown, leading to a 4× to 5× increase in particle concentration compared to baseline levels. Mechanical stress also speeds up the rate at which particle breakdown, but at a much lower rate (a 20% to 50% increase).

Summary by Location (LGA)

1. Ikeja (Sample A) — Moderate Concentration

Baseline: Moderate starting concentration of 5.1 to 5.7 particles/L.

After Mechanical Stress: Rises to 7.8 to 8.9 particles/L.

After Thermal/Solar Stress (120 hrs): Surges to 26.4 to 29.6 particles/L.

2. Lagos Island (Sample B) — Highest Overall Concentration

Baseline: Starts at the highest initial concentration of 12.5 to 13.9 particles/L.

After Mechanical Stress: Moderate increase to 15.2 to 16.1 particles/L.

After Thermal/Solar Stress (120 hrs): Spikes significantly to 48.9 to 54.0 particles/L, making it the most affected sample overall.

3. Surulere (Sample C) — Lowest Overall Concentration

Baseline: Cleanest baseline at 4.2 to 5.0 particles/L.

After Mechanical Stress: Small increase to 6.9 to 7.9 particles/L.

After Thermal/Solar Stress (120 hrs): Increases to 22.1 to 24.9 particles/L.

4. Ojo (Sample D) — High Vulnerability

Baseline: High starting concentration of 9.8 to 10.9 particles/L.

After Mechanical Stress: Increased to 13.4 to 15.0 particles/L.

After Thermal/Solar Stress (120 hrs): Peaks at 41.3 to 46.0 particles/L (more than four times its initial value).

Note on Blanks: The Low values of the procedural blanks (less than 0.5 particles/L) implies that the laboratory air and apparatus contamination were kept under control.

In terms of Morphology, the particles retrieved from the samples were categorized into three scopes based on the observations made through a stereo microscope: films, fragments, and fibres.

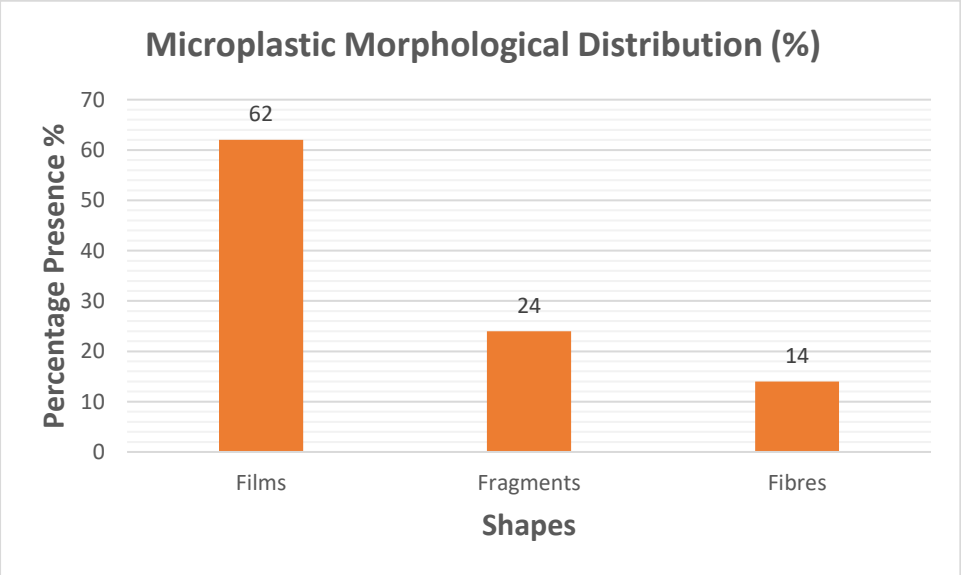


Figure 9. Microplastic Morphological Distribution Percentage

The stark dominance of films (62%) strongly implies that the sachet packaging material itself is actively disintegrating into the fluid matrix. Fragments make up for 24%, while fibres make 14%. Colour distribution was dominated by transparent and clear particles 58%, followed by blue 26%, black 11%, and others 5%.

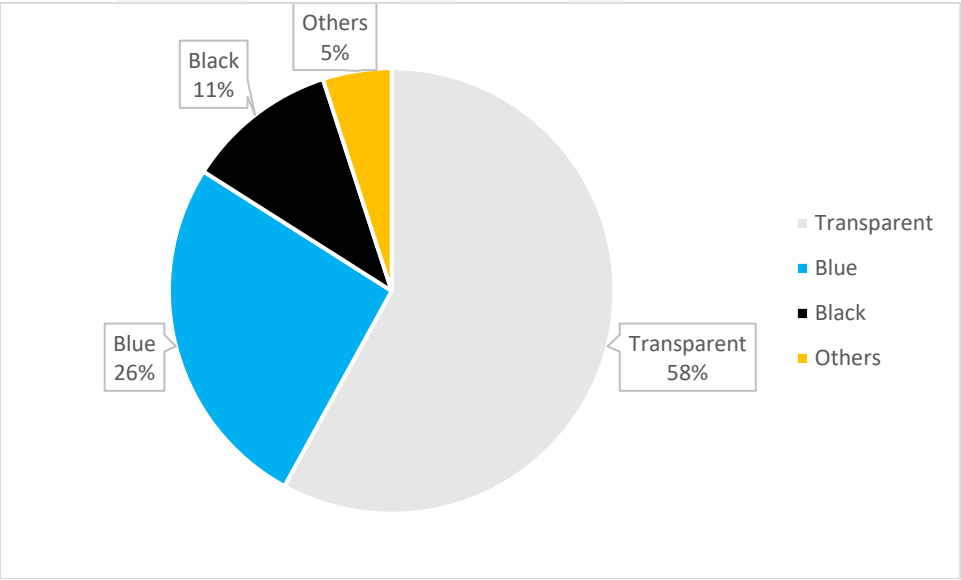


Figure 10. Microplastic Colour Distribution Chart.

4.3 Characterization of Polymer Types (FTIR Identification)

The ATR-FTIR confirmed the chemical identities of the extracted microplastics by comparing their infrared absorption spectra against reference polymer libraries.

1. Low-Density Polyethylene (LDPE) contributed 68% of microplastic and the source suspected for the percentage contribution are the inner layers of the sachet and its outer film matrices.
2. High-Density Polyethylene (HDPE) contributed 18% of microplastic and the source suspected for the percentage contribution are the Storage tank linings and supply pipes.
3. Polypropylene (PP) contributed 9% of microplastic and the source suspected for the percentage contribution are the Commercial plastic caps and plumbing source.
4. Polyethylene Terephthalate (PET) contributed 5% of microplastic and the source suspected for the percentage contribution are the Upstream source water contamination

4.4 Packaging-Related Release Mechanisms Under Stress

A key objective was isolating how transport and storage stresses advance microplastic release. The data demonstrates that while physical mechanical agitation causes a marginal increase in abundance, ambient solar/thermal exposure accelerates the degradation of the packaging material exponentially.The figure below shows the growth of microplastic concentration as a factor of prolonged exposure to outdoor sunlight and temperature elevation (~31^0C – 35^0C), copying typical open-air display layouts used by roadside vendors in Lagos.

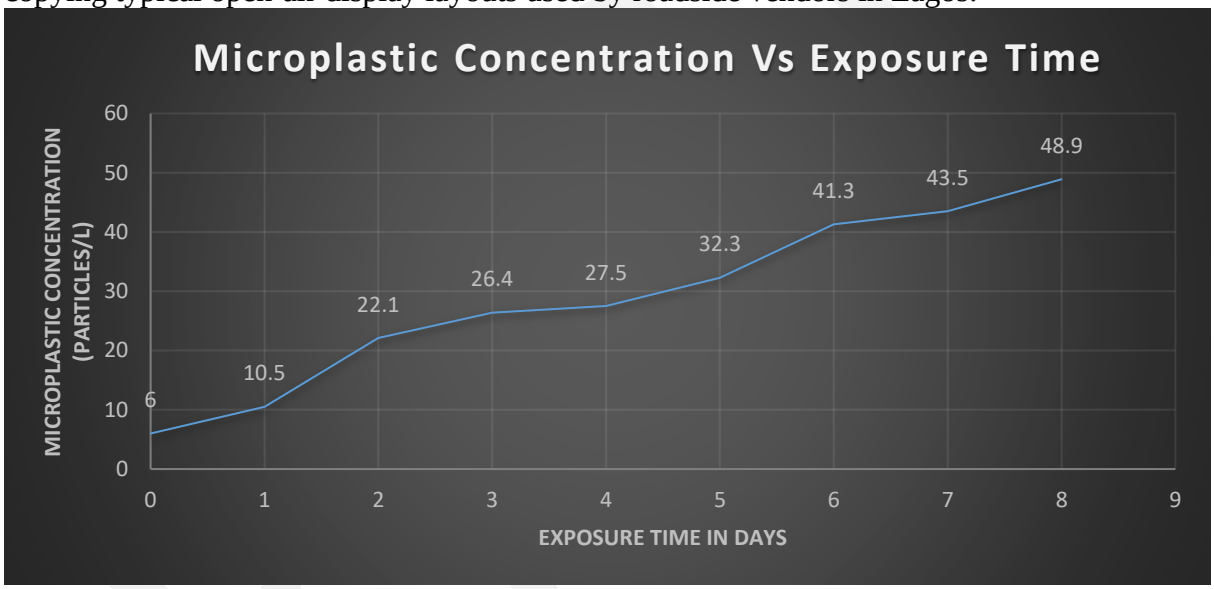


Figure 11. A graphical illustration of Microplastic Concentration against its Exposure Time.

4.5 Discussion of Release Kinetics

The increase in number of particles over 120 hours follows an exponential trend. This implies that there is a photo-oxidative process is taking place. The material of the sachet sheet is Low-Density Polyethylene, which is characterized by poor thermal stability and is vulnerable to UV light. Upon exposure to solar radiation, polymer chains are broken to form free radicals, which further reacts with oxygen to cause chain scission. The weakened polymer layer is shed as tiny (<1 mm) plastic flakes which enter the drinking water directly.

4.6 Implications for Human Exposure

To calculate the risk on human health, the Estimated Daily Intake (EDI) was calculated using the initial standard data alongside the value of exposed sachet water that has undergone road stress, assuming an average daily consumption rate (CR) of 2.5 L of water for a 60 kg adult living in Lagos.

1. Optimal Storage (Standard Baseline):

EDI = (7.90 x 2.5)/60

EDI = 0.33
The estimated daily intake of the microplastics is 0.33 particles per kg of the body weight daily
2. Roadside Stressed Sachet Water:
EDI = (34.68 x 2.5)/60
EDI = 1.45
The estimated daily intake of the microplastics is 1.45 particles per kg of the body weight daily

4.7 Discussion of Human Health Risks
The transition from an EDI of 0.33 under control conditions to 1.45 particles/kg to bw/day for sun-exposed sachets highlights a major environmental health concern for Lagos residents. Sachet water is the main source of affordable hydration for millions of daily commuters and low-income earners in Lagos/Nigeria.
Once taken in, microplastics under 150µm can travel through the intestinal epithelium via para-cellular paths or per sorption. The chemical profile derived via FTIR shows that these particles are commonly LDPE.

This presents two distinct risks:
1. Physical Cytotoxicity: Particles possess the ability to induce irritation towards the intestinal tissue thereby inducing inflammatory responses within the affected region.
2. Chemical Carrier Function: The breakdown of LDPE tends to generate structures that have a vast surface area as compared to their volumes. Consequently, this allows them to absorb chemicals like endocrine-disrupting phthalates and heavy-metal stabilizers and subsequently deliver it directly into the human digestive tract.

5.0 Summary, Conclusion, and Recommendations
5.1 Summary of Findings
This study investigated the occurrence, morphology, composition, and packaging-driven release mechanisms of microplastics (MPs) in sachet drinking water within Lagos, Nigeria, alongside the exposure risks for human consumers. The experimental findings across the selected metropolitan zones reveal several critical insights:
1. Microplastics were detected in all 100% of the commercial sachet water brands analysed. This implies that the target polymers were ubiquitously present in the consumer market. The minimal storage conditions provided baseline particle concentrations of 4.2 ± 0.8 and 12.5 ± 1.4 particles/L;
2. Physical profiling indicated that transparent films were the major portion (62%) of all the isolated particles. This suggested that the polymers originated from the rupture of the sachet bag; a hypothesis supported by the ATR-FTIR analysis which showed that Low-Density Polyethylene constituted 68% of all the isolated microplastics
3. The outdoor simulation experiment established that environmental stress accelerated the release rate of polymers from the sachet bag. Mechanical agitation had no significant effect on the release rate of polymers. However, exposure of the sachet bag to ambient Lagos heat (~310 - 350C) and sunlight for 120 hrs produced a sharp exponential increase in particle count reaching a peak of 48.9 ± 5.1 particles/L.
4. The risk assessment model established that improper storage of the sachet water outdoor exposes consumers to high health risks. The estimated daily intake (EDI) of a random consumer increased from 0.33 to 1.45 particles/kg-bw per day; a significant increase which implied greater physiological exposure.

5.2 Conclusion

Based on these findings, this study concludes that sachet drinking water in Lagos serves as a direct vector for human ingestion of microplastics. The research confirms that this contamination is not just an inherent flaw from upstream factory processing, but is actively accelerated by common downstream distribution habits.

The common practise of Storing and exposing plastic sachets under sunlight makes the plastic sachets break apart. This breakage happens in the low-density polyethylene film, where light causes the chains to split. This process weakens the inner layer of the packaging, causing it to continuously shed micro-scale plastic films directly into the water.

Given how heavily the Lagos population relies on "pure water" for daily hydration, this packaging degradation presents an ongoing, unmonitored route for micro-polymeric and chemical intake. This highlights a clear conflict between current open-air retail habits and basic public health safety.

5.3 Recommendations

To address the environmental and public health risks identified in this study, the following actions are recommended:

1. NESREA and government agencies should make sure national environmental (plastic waste control) regulations are implemented and ensure that manufacturers take responsibility for product life cycle management and circular economy.
2. Furthermore, Supply Chain and Storage Regulation should be held liable for ensuring that vendors keep packaged sachet water away from direct sunlight and high heat which enhances chemical UV degradation and migration of chemical and microplastics into the water.
3. Lagos Waste Management Authority must ramp up measures in targeted plastic scavenging, improving drainage clearing and recycling to prevent discarded sachets from choking drains and breaking down into microplastics.
4. Alternative hydration initiatives such as the government led Plastic Reboot Project which was mainstreamed by the United Nations Environment Programme, should be ramped up to develop safe, affordable and eco-friendly dispensing alternatives to single-use plastic sachets.
5. Public education and consumer behavior change campaigns to promote proper waste disposal and avoid exposure of plastic sachets to heat as well as encouraging adoption of advanced domestic water filtration (reverse osmosis or activated carbon) where verifiable

5.4 Contributions to Knowledge

1. Mechanistic Verification: This study provides empirical evidence directly linking the duration of outdoor solar exposure to the rate of physical polymer shedding in LDPE water sachets.

2. Local Risk Data: The project creates a localized exposure baseline (EDI) for residents in Lagos. This provides field data that can be used in future studies about microplastic ingestion in West Africa.

3. Supply Chain Mapping: The research identifies majorly the post-production phase. It shifts attention away from factory-level filtration to focus on contamination during transportation and retail storage habits as the sources of risk.

5.5 Suggestions for Further Research

• **Toxicological Bioassays:** Future research needs to concentrate on laboratory models to study human intestinal cells and its response or reactions to LDPE films that were found in this study.

• **Chemical Leaching:** There is a need for further research into the leaching of plasticizers, heavy-metal stabilizers and endocrine-disrupting chemicals into water accompanying the shed particles.

• **Sub-micron analysis:** There is a need for researchers to use state-of-the-art equipment, such, as micro-Raman or Nano-FTIR spectroscopy to analyse Nano-plastics (particles smaller than 1micro-metre) that may be present in sachet water as they are capable of directly entering human organs.

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