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Assessment Of Impact of Sunlight Exposure on Occurrence of Micro Plastic in Selected Packaged Water Sold in Ilorin Metropolis

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Abstract- Microplastics are increasingly present in the environment, including drinking water. However, data on microplastic contamination in packaged water and the effects of sunlight exposure remain limited, hindering assessment of potential health risks. Sunlight and heat can accelerate leaching of toxic chemicals, while deterioration of polythene packaging may allow microbial contamination. This study investigated the effect of sunlight on microplastic levels in bottled and sachet water sold in Ilorin Metropolis, Nigeria. Fifteen samples (nine bottled and six sachet) were collected from two major markets and analysed using vacuum filtration, Nile red staining, stereomicroscopy, and FTIR spectroscopy. The results showed that microplastic concentrations ranged from 5 to 18 particles L^{-1}, with sachet water exhibiting higher contamination levels than bottled water. The smallest particles measured 22.5 µm, while the largest reached 32.5 µm, indicating high bioavailability and ingestion risk. Sample L (sachet water) recorded the highest concentration (18 particles L^{-1}), whereas bottled samples A, C, and F had the lowest (5 particles L^{-1}). The Microplastics Pollution Index (MPI) ranged from 0 to 100 %, classifying bottled water mostly as low-risk (MPI 0–23 %), while sachet water ranged from moderate (23–46 %) to very high (100 %). One-sample t and Wilcoxon tests ($p < 0.05$) revealed that the average MPI exceeded acceptable safety thresholds, indicating potential health risks from microplastic ingestion. The findings reveal sunlight-induced degradation of packaging as a key driver of contamination. It concludes that sachet water poses a greater microplastic exposure risk and recommends improved storage, stricter regulation, and public awareness to ensure safer drinking water in Nigeria.

I. INTRODUCTION

Access to safe and clean water is a basic human right that remains a challenge in many developing nations (Koelmans *et al.,* 2019). In *Nigeria*, inconsistent and often poor public water supply has driven many residents to rely on sachet and bottled water for drinking. These alternatives are usually seen as cleaner and more hygienic, especially in cities and towns. However, Kumar et al. (2023) argue that the growing presence of microplastics in packaged water raises serious questions about its actual safety. Microplastics are tiny plastic particles less than five millimetres in size, and they can come from the breakdown of larger plastics or be directly released from plastic packaging materials (Syuhada *et al.,* 2023). When present in drinking water, they can carry harmful chemicals and microorganisms into the body, increasing the risk of oxidative stress, gut problems, and hormonal disruption (Smith *et al*., 2019; Semmouri *et al*., 2022).

Faizah (2020) found that bottled water exposed to sunlight contains a much higher amount of microplastics than water stored in shaded conditions. This happens because heat and ultraviolet rays from sunlight break down plastic packaging in a process known as photodegradation. As the plastic weakens, small fragments are released into the water. Alemu and Getahun (2020) also explain that exposure to sunlight causes chemical changes in the packaging, including the release of toxic additives such as phthalates and antimony. These substances have been linked to serious health risks. For example, Mrema et al. (2024) reported that such chemicals can interfere with hormones, affect reproductive health, and may even increase the risk of certain cancers. Within the water itself, heat exposure can lower pH and increase dissolved solids, both signs of chemical contamination (Okoro *et al*., 2021).

Studies from the Middle East, Asia, and Africa confirm that sunlight exposure speeds up the release of microplastics into packaged water. Brancaleone et al. (2024) observed that water bottles kept under direct sunlight had significantly more plastic particles than those stored in the shade. This pattern has been seen in several regions and follows a clear scientific explanation. The more a plastic container is exposed to sunlight and heat, the faster it breaks down and releases microplastics. In some cases, Park et al. (2022) also noticed higher levels of dissolved organic compounds in bottled water that had been sun exposed, suggesting that plastics release not only particles but also chemical substances. Ravanbakhsh et al. (2022) found that bottles stored in sunlight contained more than twice the amount of microplastics than shaded samples.

In Nigeria, this issue is especially important due to hot climate conditions and widespread use of sachet and bottled water. Umoafia et al. (2022) observed that many vendors store and display their sachet water in open areas exposed to sunlight, which speeds up packaging breakdown and leads to higher contamination. Across the country, this is a common practice. According to Yahaya et al. (2024), over sixty million sachets are consumed daily, meaning the potential for exposure to contaminated water is very high. In one study, Duan et al. (2024) confirmed that direct sunlight causes polyethylene packaging to release plastic fragments into the water. At the same time, the heat also causes harmful substances to leach out from the packaging. Balogun et al. (2024) further explained that when sachet water is stored in warm conditions for long periods, the plastic becomes brittle and easier to break apart. These findings are especially relevant in places like Ilorin where vendors often store water in the open and where daily temperatures remain high for most of the year.

Although there is growing global awareness of microplastic contamination in packaged water, research in Nigeria is still limited, especially in terms of understanding how local climate affects contamination levels. Omokpariola (2022) pointed out the need for more studies that focus on the specific impact of sunlight and heat on water safety in Nigerian cities. Current safety standards often do not include microplastics as part of regular water quality checks. Oni and Sanni (2022) observed that the packaging itself can be a source of contamination when not handled or stored properly. In many cases, consumers and vendors are unaware of these risks. Velasco et al. (2022) added that many water treatment systems are not able to remove microplastics, so once they enter the supply chain, they often end up in drinking water. This situation calls for new research that considers both environmental exposure and public storage practices.

This study was carried out to investigate how sunlight affects the concentration and types of microplastics found in bottled and sachet water sold in Ilorin Metropolis. The specific objectives of the study are to determine the concentration and size distribution of microplastics in packaged water exposed to sunlight, identify and categorize the types of plastics such as polyethylene, polypropylene, polyethylene terephthalate, polyvinyl chloride, nylon and polystyrene, and calculate the Microplastics Pollution Index to evaluate how contaminated each brand is. These results are expected to help raise awareness about packaging safety, guide better water storage practices, and support policies that protect public health in Nigeria and other countries facing similar challenges.

II. MATERIALS AND METHODS

Study Area: This study was conducted in Ilorin Metropolis, the capital of Kwara State, Nigeria. The area is characterized by high levels of sunlight throughout the year, which makes it suitable to conduct this study. Two major commercial centres, Mandate Market and Oja Oba Market, were selected for sample collection. These locations were chosen due to their central role in distributing sachet and bottled water and because many products are displayed in open sunlight, reflecting real-world exposure conditions.

Study Population: The population of interest comprised sachet and bottled water brands commonly consumed in Ilorin Metropolis. Five frequently purchased brands of sachet water and five brands of bottled water were selected from each market, based on their availability, visibility, and consumer preference. These brands were chosen because they are regularly exposed to sunlight during storage and transportation.

Study Design: A cross sectional laboratory based design was adopted. The study focused on packaged water products that had been exposed to sunlight during routine market display.

Inclusion and Exclusion Criteria: Only sealed sachet and bottled water brands with clear labeling and verifiable production details were included. Samples were selected if they had been exposed to direct sunlight at retail points. Brands were required to display manufacturing date, batch number, and approval by regulatory authorities. Samples that were damaged, opened, or poorly labeled were excluded, as were uncommon or rarely consumed brands.

Sample Size Determination: A total of fifteen water samples were selected using purposive sampling. These included nine bottled water samples labeled A to I and six sachet water samples labeled J to O.

Sampling Technique: Purposive sampling was used to identify Mandate Market and Oja Oba Market as key collection sites due to their accessibility and commercial significance. Within each market, bottled and sachet water brands were selected based on frequency of consumption and visible exposure to sunlight. This approach ensured that the study focused on representative and relevant packaged water products.

Sample Collection: Samples were purchased directly from sun exposed displays in both markets. Nine bottled water and six sachet water brands were selected and inspected to ensure they met inclusion criteria. Each sample was labeled from A to O to maintain confidentiality. Samples were transported under controlled conditions to the laboratory for analysis.

Laboratory Analysis: Each water sample (20 millilitres) was vacuum filtered using a suction pump and 0.7 micrometre Whatman cellulose filter paper. The filter paper was rinsed with 40 millilitres of 35 percent hydrogen peroxide into a 100 millilitre flat bottom flask. The flasks were allowed to stand for 48 hours at room temperature to digest residual organic matter. After digestion, 5 millilitres of Nile red dye were added to each sample and allowed to react for 24 hours. The stained samples were then mounted on microscopic slides and dried in a desiccator for another 24 hours. Microplastic particles were identified and counted using an AmScope Trinocular Stereo Zoom Microscope. Particles were recorded as counts per litre. Microplastics were classified by shape (fiber, fragment, film), color (black, blue, red, white, yellow, green, purple), and size using a calibrated eyepiece lens. Representative particles were subjected to polymer characterization using attenuated total reflectance Fourier transform infrared spectroscopy. A Nicolette Nexus 470 ATR FTIR spectrometer was used for confirmation and classification into common polymers such as polyethylene, polypropylene, polyethylene terephthalate, polyvinyl chloride, polystyrene, and nylon. Polymer identification was performed using Omic software.

Data Analysis: Descriptive statistics were used to summarize the concentration, size distribution, shape, color, and polymer types of microplastics across all samples. The Microplastics Pollution Index was calculated for each sample to determine contamination levels. Inferential statistics were applied to test study hypotheses using SPSS version 25. Mann Whitney U test compared microplastic concentrations between sachet and bottled water. Chi square test was used to assess differences in microplastic types. One sample t test and Wilcoxon signed rank test were used to evaluate whether the Microplastics Pollution Index values exceeded acceptable safety thresholds. Statistical significance was set at p less than 0.05.

Microplastics Pollution Index: The Microplastics Pollution Index was used to quantify contamination levels in each sample relative to the most polluted sample. It was calculated as follows: MPI percent = (Microplastic Count in Sample minus Minimum Microplastic Count) divided by (Maximum Microplastic Count minus Minimum Microplastic Count) multiplied by 100. In this study, the maximum microplastic count observed was 18 particles per litre. A sample with 9 particles per litre, for instance, would have an MPI of 50 percent. Pollution risk was

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classified as low for MPI values between 0 and 20 percent, moderate for 21 to 50 percent, high for 51 to 75 percent, and very high for 76 to 100 percent.

Ethical Considerations: This study did not involve human or animal subjects. All samples were commercially available and purchased from public markets. No private or personal data were collected. Brands were anonymized using alphabetical labels to prevent commercial bias. Laboratory procedures were performed with care to ensure data accuracy and scientific integrity. The study was approved by the appropriate research ethics committee within the university in line with institutional environmental research guidelines.

III. RESULTS AND DISCUSSION

Figure 1 presents the concentration and average particle size of microplastics detected in selected bottled and sachet water samples sold within Ilorin Metropolis. Among the bottled water samples, Sample A contained 5 microplastic particles per litre with an average particle size of 30 micrometres. Sample B recorded 6 particles per litre with a slightly larger size of 32.5 micrometres, while Sample C showed 5 particles per litre with an average of 30 micrometres. Sample D had 6 particles per litre, also with an average size of 30 micrometres. The highest concentration among the bottled samples was observed in Sample E, which contained 13 particles per litre with an average particle size of 32.5 micrometres. Sample F had 5 particles per litre and an average size of 30 micrometres, while Sample G recorded 7 particles per litre with an average of 32.5 micrometres. Sample H showed 8 particles per litre, with the smallest average size among the bottled samples at 22.5 micrometres. Sample I contained 7 particles per litre and an average particle size of 32.5 micrometres.

For sachet water, Sample J contained 11 particles per litre with an average size of 22.5 micrometres, while Sample K recorded 8 particles per litre with an average size of 30 micrometres. Sample L exhibited the highest microplastic concentration in all samples, with 18 particles per litre and an average size of 32.5 micrometres. Sample M followed closely with 13 particles per litre and an average size of 30 micrometres. Sample N contained 14 particles per litre with a particle size of 32.5 micrometres, while Sample O had 8 particles per litre and an average particle size of 30 micrometres.

The results reveal clear variations in both the concentration and size of microplastics between bottled and sachet water samples exposed to sunlight. The sachet water samples generally showed higher microplastic concentrations than bottled water, with Sample L recording the peak value at 18 particles per litre. The lowest concentrations were found in the bottled water samples A, C, and F, each with 5 particles per litre. The smallest microplastic particles, measuring 22.5 micrometres, were found in Sample H (bottled water) and Sample J (sachet water). The largest particles, measuring 32.5 micrometres, appeared in several samples, including B, E, G, I, L, and N.

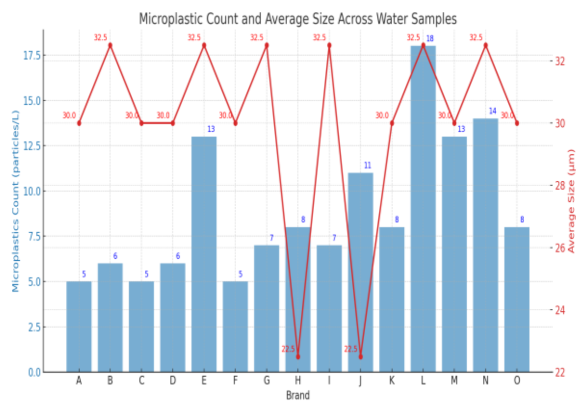


Figure 1: microplastic count and average size across water samples

To evaluate whether there was a significant difference in microplastic concentration between bottled and sachet water sold in Ilorin Metropolis, a Mann-Whitney U test was performed. As shown in Figure 2, the bottled water samples had a mean rank of 5.0, while the sachet water samples had a lower mean rank of 3.5. The test produced a U-value of 4.5 and an asymptotic significance (2-tailed) of 0.00883. Since the calculated p-value is less than the 0.05 significance threshold, the null hypothesis is rejected. This finding indicates that there is a statistically significant difference in the concentration of microplastics between bottled and sachet water brands in the study area. The higher concentration observed in sachet water samples.

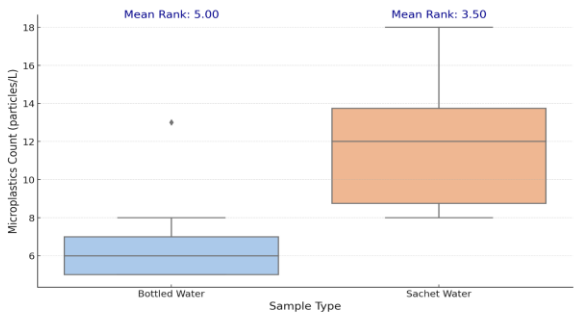


Figure 2: boxplot of mean difference of microplastic concentration in water samples

The heatmap in Figure 3 illustrates the types of microplastics identified in bottled and sachet water samples sold in Ilorin Metropolis after exposure to sunlight. In the bottled water category, Sample A contained polyethylene (PE) and polyvinyl chloride (PVC), with a total of 5 microplastic particles per litre. Sample B showed the presence of polypropylene (PP) and polyethylene (PE) with 6 particles per litre, while Sample C contained only polypropylene (PP) with 5 particles per litre. Sample D, similar to Sample A, had both PE and PVC with 6 particles detected. Sample E exhibited a higher concentration of 13 particles per litre and consisted of PP and PVC. Sample F contained 5 particles made up of PP and polystyrene (PS), while Sample G included polyethylene terephthalate (PET) and nylon with 7 particles per litre. Sample H was one of the most compositionally diverse, containing PP, PE, and PS, with 8 particles per litre. Sample I showed a mix of PP and PE, totalling 7 particles per litre.

For sachet water samples, Sample J contained polystyrene (PS) and polyethylene terephthalate (PET), with 11 particles per litre. Sample K was composed entirely of polyethylene (PE) with 8 particles. Sample L, which had the highest overall microplastic concentration at 18 particles per litre, contained PE and nylon. Sample M recorded 13 particles composed of PET and nylon. Sample N presented 14 particles made up of PE and PP, while Sample O contained 8 particles consisting of PS and PE. Across both bottled and sachet water samples, six major types of microplastics were detected: polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), and nylon. PE and PP were the most frequently occurring polymers, appearing in most of the samples and across both water types. PVC was detected only in bottled water, while nylon and PET were more common in sachet water.

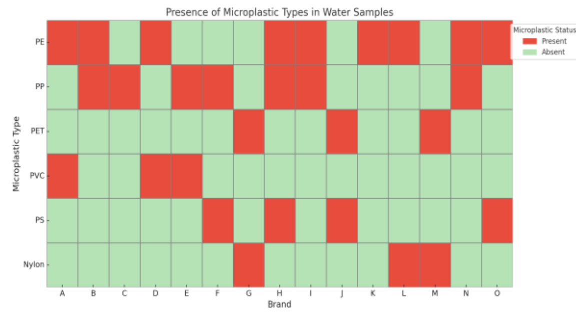
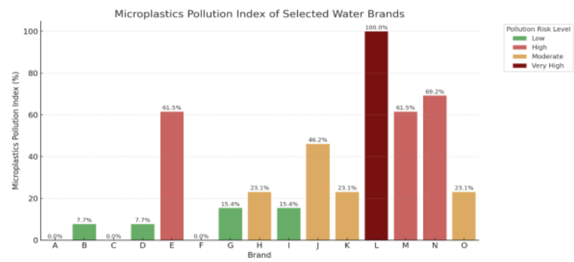


Figure 3: heatmap of types of microplastic in water samples

Figure 4 presents the Microplastics Pollution Index (MPI) for selected bottled and sachet water brands sold in Ilorin Metropolis following exposure to sunlight. Among the bottled water samples, brands A, C, and F recorded the lowest microplastic concentration of 5 particles per litre, each corresponding to an MPI of 0 percent, placing them under the low pollution risk level. Brands B and D showed slightly higher concentrations of 6 particles per litre, with MPI values of about 7.69 percent, which still fall within the low-risk category. Brands G and I both had 7 particles per litre and MPI values of approximately 15.38 percent. Brand H contained 8 particles per litre with an MPI of 23.08 percent, categorising it under the moderate pollution risk level. Brand E, however, had the highest microplastic count among bottled water samples, with 13 particles per litre and an MPI of 61.54 percent, placing it in the high pollution risk category.

For sachet water, brand J contained 11 particles per litre with an MPI of 46.15 percent, corresponding to a moderate pollution risk. Brands K and O each recorded 8 particles per litre, with MPI values of 23.08 percent, also categorised as moderate risk. Brand L had the highest overall microplastic concentration across all samples, with 18 particles per litre and an MPI of 100 percent, which classified it under the very high pollution risk level. Brand M followed with 13 particles per litre and an MPI of 61.54 percent, while brand N had 14 particles per litre and an MPI of 69.23 percent, both of which were categorised as high pollution risk. The findings indicate that sachet water samples generally exhibited higher microplastic concentrations and higher MPI values than bottled water samples.



MPI range pollution risk level: 0-20 = low, 21-50 = Moderate, 51-75 = High, 76-100 = Very High

Figure 4: Microplastic Pollution Index of selected water brands

To test the hypothesis that microplastic ingestion from bottled and sachet water exposed to sunlight does not pose significant health risks to consumers in Ilorin Metropolis, both a one-sample t-test and a Wilcoxon signed-rank test were conducted using the Microplastics Pollution Index (MPI) values obtained from the analysed samples. As presented in Table 1, the one-sample t-test produced a test statistic of -2.51 with a p-value of 0.025, while the Wilcoxon signed-rank test yielded a test statistic of 22.5 and a p-value of 0.030. Since both p-values are less than the 0.05 level of significance, the null hypothesis is rejected. This finding indicates that the average MPI across the selected bottled and sachet water brands exposed to sunlight significantly exceeds the assumed safety limit.

Table 1: One sample t-test and Wilcoxon signed rank test of microplastics pollution index of selected brands

Sample Type	Brand	MPI (%)	Test	Test Statistic	P-Value
Bottled Water	A	0	One-sample t-test	-2.51376	0.024798
Bottled Water	B	7.692308	Wilcoxon signed-rank test	22.5	0.030151
Bottled Water	C	0			
Bottled Water	D	7.692308			
Bottled Water	E	61.53846			
Bottled Water	F	0			
Bottled Water	G	15.38462			
Bottled Water	H	23.07692			
Bottled Water	I	15.38462			
Sachet Water	J	46.15385			
Sachet Water	K	23.07692			
Sachet Water	L	100			
Sachet Water	M	61.53846			
Sachet Water	N	69.23077			
Sachet Water	O	23.07692			

This study confirmed the presence of microplastics in both sachet and bottled water samples sold in Ilorin Metropolis, with concentrations ranging from 5 to 18 particles per litre. Sachet water showed consistently higher contamination, with Sample L recording the highest level. The particle sizes (22.5 to 32.5 micrometres) suggest a high likelihood of human ingestion, aligning with earlier reports by Hossain et al. (2023) and Yahaya et al. (2024). Statistical analysis revealed a significant difference in microplastic levels between sachet and bottled water ($U = 4.5$, $p = 0.00883$), indicating that packaging material and sunlight exposure play a critical role in microplastic release. Similar findings by Faizah (2020) and Alemu and Getahun (2020) support the influence of UV radiation and heat in accelerating polymer degradation.

Sachet water's higher contamination is likely due to its thin polyethylene packaging and frequent exposure to direct sunlight. This observation supports the work of

Hadeed and Al-Ahmady (2022) and Balogun et al. (2024), who linked increased microplastic release to prolonged sunlight exposure. The detected particle sizes fall within the biologically reactive range, with potential health implications such as oxidative stress and immune disruption, as reported by Pico et al. (2022) and Ghanbarian et al. (2022). These findings suggest that both packaging type and storage environment are central to microplastic contamination in drinking water.

Polymer analysis identified six microplastic types, with polyethylene (PE) and polypropylene (PP) as the most common. PET, PVC, PS, and nylon were also detected in smaller amounts. The dominance of PE and PP reflects their use in packaging, consistent with reports by Yahaya et al. (2024) and Ibeto et al. (2021). The lack of significant variation in polymer types across brands ($p = 0.8167$) suggests a shared contamination pathway driven by similar packaging and exposure conditions. However, the presence of PS and PVC, known for releasing harmful additives, raises concerns about potential health effects under sunlight exposure, echoing the findings of Syuhada et al. (2023) and Okpashi et al. (2021).

The Microplastics Pollution Index (MPI) showed that bottled water samples generally fell in the low-risk category, while sachet water samples, especially Sample L, reached high and very high-risk levels. Statistical tests confirmed that the average MPI significantly exceeded the 50 percent safety threshold ($p < 0.05$), indicating potential public health risks. This agrees with Kumar et al. (2023), who highlighted the health impact of chronic microplastic ingestion. High MPI values in sachet water likely result from environmental exposure and packaging degradation, consistent with Umoafia et al. (2022) and Gapwu et al. (2018). These results emphasize the need for improved storage practices, consumer awareness, and stricter regulation to reduce exposure to microplastics from sun-exposed packaged water.

IV. CONCLUSION

This study showed that both bottled and sachet water sold in Ilorin contain microplastics, especially when stored under sunlight. Sachet water was found to have much higher contamination levels than bottled water, likely because of its thinner plastic packaging and direct exposure to heat. The most common microplastics were polyethylene and polypropylene, which are materials used in most packaging. The Microplastic Pollution Index revealed that sachet water ranged from moderate to very high contamination, while bottled water was mostly low. Statistical tests confirmed that the contamination levels were higher than what is considered safe, indicating potential health risks for regular consumers. The study concludes that sunlight exposure increases the release of microplastics into drinking water, and it recommends keeping packaged water in shaded places, enforcing stricter quality monitoring, and increasing public awareness to protect health.

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