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Assessment of Microplastics Contamination in River Water, Bottled Water, Sachet Water and Branded Table Salt Samples in Kaduna Metropolis, Nigeria

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Abstract: Microplastics (MPs) < 5 mm-sized are regarded as global environmental contaminants. This study analyzes MP concentrations in the Kaduna River (raw water), treated water from two conventional water treatment plants, brands of bottled water, and food-grade salts available in Kaduna Metropolis, Nigeria using standard methods. Data obtained show that levels of MPs ranged from 25 to 36 particles L^{-1} in treated water, and to 153 particles L^{-1} in raw water. While samples of bottled water contained 1.4 to 3.7 particles L^{-1} and samples of table salt contained 0.13 to 0.27 particles g^{-1}. Water and salt samples contained five different types of polymers, including polyethylene, polypropylene, polyester, polyvinyl chloride and polyethylene terephthalate. Additionally, MPs were divided into three groups based on their physical characteristics. In both raw and treated water, fragments were clearly more prevalent; in samples of bottled water and table salt, fragments and fibers predominated. Microplastics in bottled water pose a medium pollution risk, according to pollution risk indices. The estimated daily intake was generally minimal, indicating little harm from daily consumption, but it also demonstrates that children have a larger intake of microplastics than adults. Leaching from the packing material was identified as the MPs' primary source. This study fills the knowledge gap in the area of emerging microplastic pollution of water sources, drinking water, and food-grade salt.

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Plastic waste has increased as a result of increased plastic manufacture and consumption (UNEP, 2009). Plastic waste is considered the major source of microplastics, because they are mostly single-use plastic items and packaging materials, although fifty percent of these plastic products fall into the disposable product category (Brachner *et al*., 2020; Joystu and Moharana, 2018). Rather than being collected in waste bins for further processing, recovery, and standard disposal via recycling centers, incinerators, or landfills, a large number of waste plastic products are carelessly scattered or discarded into regions that are inaccessible for waste collection, effectively ending the possibility of recovery/recycling (Joystu and Moharana, 2018). According to Eriksen *et al*. (2014), at least 5.25 trillion plastics are now flowing in the surface waters, mostly as a result of run-off and dumping. Plastics in surface water are constantly broken down into tiny bits by marine processes such as surface circulation and mixing, rather than totally decaying over time (Moore, 2008). As a result, plastics can be found in the ocean for decades, releasing hazardous compounds into bodies of water. More recently, potential threats of MPs to human health have attracted intense attention because of the widespread detection of MPs in human-related food and environments, such as milk, seafood, table salt and drinking water (Yang *et al*., 2015;

Santillo *et al*., 2017; Mason *et al*., 2018 Peixoto *et al*., 2019; Kutralam-Muniasamy *et al*., 2020). Consumption of some food products such as seafood, honey, and beer can be intentionally minimized or avoided, but exposure to MP-contaminated table salt and drinking water is inevitable (Barboza *et al*., 2018). In countries like Croatia, Italy and Turkey that have high regulation standard organization, has been reported high daily intake of MPs (Barboza *et al.*, 2018) above recommended intake threshold (Erkoyun *et al*., 2016). Although based on a relatively small sample size, the first evidence of MPs found in human stools suggests that humans are being exposed to MPs (Schwabl *et al*., 2019). From literature survey, assessing human health risk of MPs remains in its infancy with limited information on exposure routes, biological fates, and health effects. Hence, a need for studies on microplastics in Nigeria, since waste are indiscriminately dump into various facets of the environment. Environmental contamination is rife with microplastics. They have been discovered in a variety of salts, including sea salt, rock salt (Yang *et al.*, 2015), table salt (Iniguez *et al.*, 2017) and water types, including drinking water, both bottled and tap (Mason *et al.*, 2018), fresh water, and surface water (Andrady, 2011). With the information from this research, it would be easy to develop a data base of composition of microplastics together with their possible health risk due to the fact that salt and water are consumed directly by human beings. In Nigeria, particularly in Kaduna metropolis, there is no available information on the extent of microplastic presence in our water and salt. Clearly there is a gap in knowledge related to water-human pollution especially in Nigeria and empirical data is needed as the basis for wider modelling assessment which form the basis of this research. Therefore, this study is aimed at investigating the presence of microplastics in river water, sachet water, bottled water and branded table salts sold in Kaduna metropolis and establish the risk in consumption of these products among the populace.

MATERIALS AND METHOD

Sampling site description: Kaduna metropolis is estimated to have about 1.3 million population (Kaduna city population, 2020). Majority of the populace especially those around the river bank use Kaduna River as a source of water for various purposes which include domestic, agricultural, fishing and industrial purposes (Yusuf and Sonibare, 2004). The River also serve as the source of raw water for the two conventional water treatment plants in Kaduna metropolis located at Kaduna North and Kaduna South LGAs as shown in Figure 1a. Thousands of tonnes of waste flow daily due to different activities from the dwellers around the river which include food/beverages waste, textile waste, fertilizer, papers, plastics, glass and ceramics from industries and domestic activities (Yusuf *et al.*, 2008). The two drinking water treatment plant (DWTP) are located at Kaduna North, Malali (MWTP) which has the capacity of 240 million liters and Kaduna South (KSWTP) which has the capacity of 27 million liter. These DWTPs are the major sources of water to water production factories and drinking water to the populace in Kaduna metropolis.

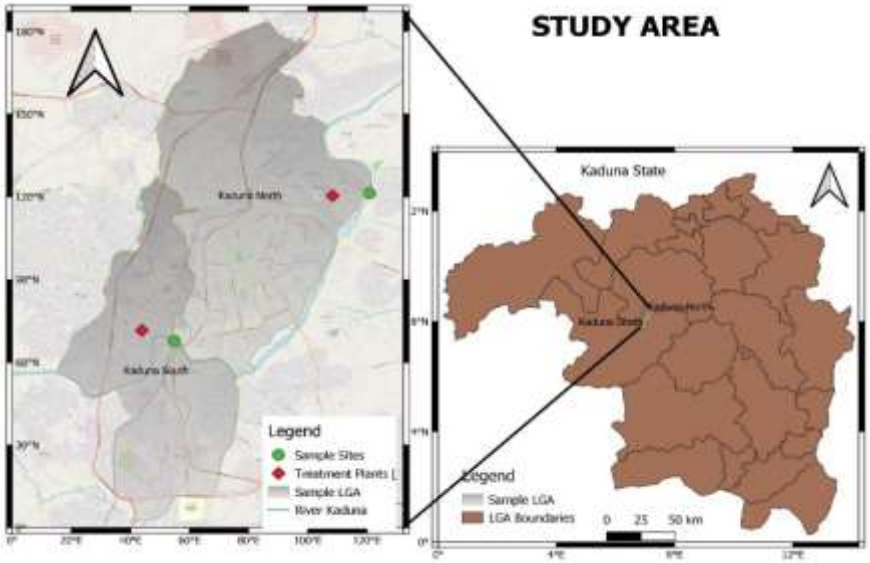

Fig 1a: Map of Kaduna State showing the location of River Kaduna and the two conventional treatment plants

Sampling of Untreated and treated water sample collection: The untreated and treated water samples were collected from two conventional Drinking Water Treatment Plant (DWTP) located at Kaduna North (MWTP) and Kaduna South (KSWTP) as shown in Fig. 1a and River Kaduna in Kaduna metropolis. The pH of the samples was taken *in-situ* to ensure good presentation of the sites condition after calibration of the pH meter.

Sampling of Bottle water, sachet water and table salt samples: Prior to this study, a preliminary survey was first undertaken to determine the common sold bottle water, sachet water and table salts brands produced in Kaduna at various supermarket and stores in Kaduna Metropolis. From a method adopted by Sarva and Sawanya (2021), ten (10) liters of five different brands of bottled water and sachet water samples commonly consumed were randomly purchased from Kaduna central market as shown in Figure 1b. The samples were labeled as BW-1, BW-2, BW-3, BW-4 and BW-5 and SW-1, SW-2, SW-3, SW-4 and SW-5 and then stored at the temperature of 4˚C prior to pre-treatment.

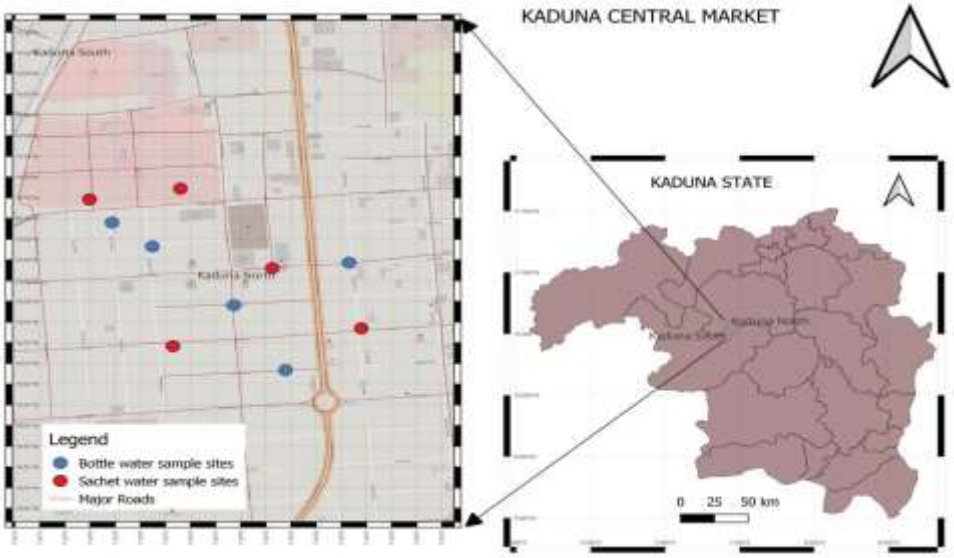

Fig. 1b: Map of Kaduna Metropolis showing the sampling location of bottled water and sachet water

On the basis of the preliminary survey, five different brands of commercial table salts that are sold in Kaduna metropolis were randomly purchased from Kaduna central market. Three replicates of these brands were processed for a particular sample set. Hence, a total of 15 salts were purchased. These salts were available in the market in 500g and 5000g packs. The samples were labeled as TS-1, TS-2, TS-3, TS-4 and TS-5 and stored in the laboratory under hygienic condition prior to analysis.

Determination of physicochemical properties of water samples: pH and electrical conductivity were determined with a pH meter and digital conductivity meter respectively while total solids and total suspended solids were determined by gravimetry method (Ibeto *et al*., 2021).

Micro plastics extraction from samples: The river water samples were first oxidized using Wet Peroxide Oxidation (WPO) to remove organic materials from the water sample (Anderson *et al.,* 2017) and further treated to extract the micro plastics according to the method of Radityaningrum *et al.* (2021). Similarly, a vacuum filtration device was used to process the bottled water and extract microplastics (Zhou *et al*., 2020). The preparation and analysis of microplastics in the salt samples were carried out using the method of Sathish *et al.* (2020).

Quality control: All stock solutions were filtered using 0.45 µm mesh size filter paper before use to avoid MPs contamination. Also, all the glasswares were rinsed thrice with de-ionized water. All samples were kept covered with aluminum foil or glassware whenever possible or under analysis to avoid external microplastics (MPs) contamination. Three blank samples were analyzed simultaneously to correct any possible MPs contamination from sample processing. Polyester-type clothing was avoided to prevent contamination of microplastics in the samples, and during handling, cotton-made laboratory aprons were used. All non-plastic sieves were washed properly, before and after use. All MPs samples were kept in Petri dishes and appropriately covered with aluminum foil then, all Petri dishes were placed in a glass

desiccator to avoid airborne MPs contamination (Rakib *et al.,* 2022).

Analysis of micro plastics: The counting and identification of microplastics in the samples were done using Stereo Microscope and Scanning Electron Microscopy (SEM) (JSM-JEOL-7600F). The qualitative analysis of microplastics composition was done using FTIR-ATR (CARY630 FTIR Agilent Technologies USA).

Health Risk Assessment of Microplastics: Microplastics contamination factors and pollution load index

The microplastics contamination factors (MPCfs) and pollution load index (MPPLI) in the bottled water were estimated as described in previous studies (Verla *et al.,* 2019). The MPCf refers to the contamination of MPs in the studied drinking water (River and bottled water) compared to the background values. The MPCf and MPPLI were mathematically computed using equations (1) and (2). Where MPi is the quantity of MPs in sample i while MPb is the minimum baseline concentration taken from the lowest MPs abundance recorded in the study of (Mason *et al.*, 2018) as it shares similar environments and analytical context as this study.

$$\text{MPCF} = \frac{MPi}{MPb} \qquad (1)$$

$$\text{MPPLi} = (\text{MPCf}_1 \times \text{MPCf}_2 \times \text{MPCf}_3 \ldots\ldots\ldots \text{MPCf}_n)^{1/n} \qquad (2)$$

The MPCfs will be categorized according to (Verla *et al.,* 2019). Values with MPCf < 1 are low contamination, 1≤ MPCf < 3 are moderately contaminated, 3 ≤ MPCf ≤ 6 are considerably contaminated and MPCf ≥ 6 very highly contaminated.

Estimated Daily Intake: An individual risk pathway as a result of human exposure to microplastic contamination of drinking water could be through oral ingestion. Therefore, the estimated daily intake (EDI) due to exposure to overall MPs resulting from ingestion of contaminated water is determined using equation 3.

$$\text{EDI}_q = \frac{MPi \times RI}{Bw} \qquad (3)$$

Where, EDIq: estimated daily intake of MPs based on quantity (EDIq) through ingestion of the drinking water (particle/L/Bw-day); MPi: average quantity of the MPs in drinking water (MP particle/L); RI: ingestion rate (2.2 L/day for adults; 1.8 L/day for children); BW: average body weight (70 kg for adults; 15 kg for children) as described by (Verla *et al.,* 2019).

Statistical Analysis: Descriptive statistics were carried out using Microsoft excel. Correlation Analysis and Principal Component Analysis (PCA) were carried out on the data using IBM SPSS Statistics Version 23 software package.

RESULT AND DISCUSSION

Physicochemical Parameters of Water Samples: The mean and standard deviation of physicochemical parameters of water samples collected from different sites are presented in Table 1 which includes pH, electrical conductivity (EC), and total suspended solids (TSS).

Table 1: Mean ± SD of Physicochemical Parameters of Water Samples

Sample	pH	EC(µS/cm)	TSS (mg/L)
RW	8.36 ± 0.08^{h}	195.65 ± 1.48^{l}	97.55 ± 0.35^{l}
MWTP-1	6.65 ± 0.00^{e}	90.80 ± 0.57^{i}	44.40 ± 0.28^{i}
MWTP-2	6.63 ± 0.06^{de}	89.00 ± 0.85^{i}	44.45 ± 0.49^{ij}
KSWTP-1	6.68 ± 0.00^{e}	94.50 ± 0.42^{j}	45.75 ± 0.21^{jk}
KSWTP-2	6.62 ± 0.06^{de}	97.10 ± 0.99^{k}	47.05 ± 0.49^{k}
BW-1	8.34 ± 0.16^{h}	29.40 ± 1.41^{c}	13.60 ± 0.57^{c}
BW-2	5.69 ± 0.04^{ab}	63.20 ± 0.85^{f}	30.60 ± 0.42^{f}
BW-3	5.59 ± 0.03^{a}	78.85 ± 1.06^{h}	38.90 ± 0.57^{h}
BW-4	6.12 ± 0.14^{c}	37.40 ± 1.70^{d}	17.70 ± 0.85^{d}
BW-5	5.77 ± 0.06^{b}	14.80 ± 0.57^{a}	5.86 ± 0.22^{a}
SW-1	6.47 ± 0.05^{d}	56.30 ± 0.70^{e}	26.15 ± 1.06^{e}
SW-2	7.03 ± 0.01^{f}	28.40 ± 0.28^{bc}	12.95 ± 0.50^{bc}
SW-3	7.31 ± 0.03^{g}	56.50 ± 0.14^{e}	27.00 ± 0.42^{e}
SW-4	6.77 ± 0.04^{e}	66.40 ± 0.00^{g}	32.70 ± 0.00^{g}
SW-5	5.59 ± 0.01^{a}	26.40 ± 1.13^{b}	12.20 ± 0.57^{b}

Values are Mean±SD triplicate analysis of samples from each site.

Mean values in the same column followed by the same superscript letters are not significantly different (p > 0.05)
RW: Control

The RW sample, which serves as the control, has a pH of 8.36±0.08, EC of 195.65±1.48 µS/cm, and TSS of 97.55±0.35 mg/L. The other samples collected from different water treatment plants (MWTP-1, MWTP-2, KSWTP-1, and KSWTP-2) and different bottled water samples (BW-1 to BW-5 and SW-1 to SW-5) have varying pH, EC, and TSS values. The pH values of the samples range from 5.59±0.03 to 8.36±0.08. The highest pH value is observed in the RW sample, which is expected since it serves as the control. The lowest pH value is observed in BW-3, which is significantly different from the other samples. The EC values range from 14.80±0.57 to 195.65±1.48 µS/cm. The highest EC value is observed in the RW sample, while the lowest EC value is observed in BW-5. The TSS values range from 5.86±0.22 to 97.55±0.35 mg/L. The

highest TSS value is observed in the RW sample, while the lowest TSS value is observed in BW-5. The levels of pH, electrical conductivity (EC) and total suspended solids (TSS) in the raw and treated water are presented in Table 1. KSWTP has pH values accounting 6.68±0.00 and 6.62±0.06 for KSWTP-1 and KSWTP-2 respectively, while MWTP has the pH values of 6.65±0.00 and 6.63±0.06 for MWTP-1 and MWTP-2 respectively. The pH of the raw water was 8.36±0.08. Therefore, all the samples of treated water showed pH within the normal range (6.5 to 8.5) for drinking water, according to the World Health Organization (WHO, 2019). The differences in pH of raw and treated water may be as a result of presence of unwanted materials disposed in the raw water body which makes it more basic than the treated water. Despite having the same water treatment processes between the treatment plants, the difference in pH may be as a result of different activities that are carried out around the water intake of the treatment plant. The treated water samples showed to have EC values within the stipulated limits of 100 μS/cm for drinking water, but as for the raw water, the EC happen to be higher than the stipulated limit of 100 μS/cm which was expected since the water is untreated. Also, all the samples of treated water analyzed showed TSS value range between 44.40±0.28 - 47.05±0.49 mg/L which was categorized to be within the stipulated limit (<500 mg/L). But the raw water shows TSS value 97.55±0.35 higher than the treated water which was expected since the raw water contained more suspended materials. The results of a correlation analysis of physicochemical parameters among water samples collected from the two conventional water treatment plants are shown in Table 2. The parameters included in the analysis are pH, electrical conductivity (EC), and total suspended solids (TSS) for both treatment plants (MWTP and KSWTP).

Table 2: Correlation analysis of physicochemical parameters among the water samples collected from treatment plant

Parameter	**pH_{MWTP}**	**EC_{MWTP}**	**TSS_{MWTP}**	**pH_{KSWTP}**	**EC_{KSWTP}**	**TSS_{KSWTP}**
pH_{MWTP}	1.000	.				
EC_{MWTP}	0.677	1.000				
TSS_{MWTP}	0.786	0.414	1.000			
pH_{KSWTP}	0.898	0.909	0.543	1.000		
EC_{KSWTP}	-0.640	-0.907	-0.149	-0.906	1.000	
TSS_{KSWTP}	-0.640	-0.907	-0.149	-0.906	1.000**	1.000

**. *Correlation is significant at the 0.01 level (2-tailed)*

The results show that there is a strong positive correlation between pH and TS for both treated water samples (MWTP) and (KSWTP), with correlation coefficients of 0.786 and 0.543, respectively. This suggests that as pH increases, so does the concentration of suspended solids in the water. This finding is consistent with previous studies that have reported a positive correlation between pH and TS in water bodies (Zhang *et al.,* 2015). There is also a strong positive correlation between pH and EC for both MWTP and KSWTP, with correlation coefficients of 0.898 and 0.909, respectively. This indicates that as pH increases, so does the electrical conductivity of the water. This finding is consistent with the fact that pH and EC are closely related, as changes in pH can affect the ionization of dissolved salts and thus the electrical conductivity of the water (Sawyer *et al.,* 2003). In contrast, there is a strong negative correlation between EC and TS for both MWTP and KSWTP, with correlation coefficients of -0.907 and -0.149, respectively. This suggests that as the electrical conductivity of the water increases, the concentration of suspended solids decreases. This finding is consistent with previous studies that have reported a negative correlation between EC and TSS in water bodies (Zhang *et al.,* 2015). On the other hand, Table 1 also lists the pH, electrical conductivity (EC), and total suspended solid (TSS) concentrations in the bottled water. The pH was in the range between 5.59±0.03 in sample BW-3 to 8.34±0.16 in sample BW-1. From the results, sixty (60%) of the samples has pH values that were outside the acceptable range (6.5 to 8.5) for drinking water (WHO, 2019). The variation in pH of the samples is a result of different water sources, which indicate that some of the water is more acidic while some are basic. However, all of the samples of bottled water had EC values that were within the permitted limits of 100 μS/cm for drinking water. Additionally, all samples of bottled water that were tested have TSS values that ranged from 5.86±0.22 to 38.90±0.57 mg/L, which was considered low and within the established limit. (< 500 mg/L). The correlation analysis of physicochemical parameters between water samples collected from a treatment plant and bottled water are presented in Table 3. The parameters included in the analysis are pH, electrical conductivity (EC), and total solids (TS). The analysis shows that there is a strong positive correlation between the EC and TSS of bottled water (r=1.000**), indicating that as the EC increases, so does the TSS. This finding is consistent with previous studies that have reported a positive correlation between EC and TSS in water samples (Kazi *et al.,* 2009). There is also a moderate positive correlation between the pH and TSS of bottled water (r=0.337), suggesting that as the pH increases, so does the TSS.

This finding is consistent with the fact that some minerals that contribute to the TSS, such as calcium and magnesium, can increase the pH of water (Schoeller *et al.*, 2004). The correlation analysis of physicochemical parameters between the water samples collected from treatment plant and bottle water are shown in Table 3. In contrast, there is a weak negative correlation between the pH and EC of bottled water (r=-0.409), indicating that as the pH increases, the EC decreases. This finding is not consistent with previous studies that have reported a positive correlation between pH and EC in water samples (Singh *et al.*, 2011).

Table 3: Correlation analysis of physicochemical parameters between the water samples collected from treatment plant and bottle water

Parameters	pH_{WTP}	EC_{WTP}	TSS_{WTP}	pH_{BW}	EC_{BW}	TSS_{BW}
pH_{WTP}	1.000					
EC_{WTP}	-0.060	1.000				
TSS_{WTP}	-0.171	0.965**	1.000			
pH_{BW}	-0.030	-0.256	-0.390	1.000		
EC_{BW}	0.332	-0.055	-0.027	-0.409	1.000	
TSS_{BW}	0.337	-0.046	-0.022	-0.403	1.000**	1.000

***. Correlation is significant at the 0.01 level (2-tailed).*

The pH, electrical conductivity (EC), and total suspended solids (TSS) concentrations in the sachet water as shown in Table 1 showed that the pH ranged from 5.59±0.01 in sample SW-5 to 7.31±0.03 in sample SW-3. The World Health Organization (WHO) determined that the pH of sample SW-5 was outside the range of 6.5 to 8.5, which is considered to be the standard for drinking water. However, all of the sachet water samples had EC values that were within the allowed range of 100 µS/cm for drinking water. Additionally, all of the sachet water samples that were evaluated had TSS values that ranged from 12.20±0.57 to 32.70±0.00 mg/L, which was considered to be within the specified limit. (< 500 mg/L). The correlation analysis of physicochemical parameters between water samples collected from a treatment plant and sachet water are presented in Table 4. The parameters analyzed include pH, electrical conductivity (EC), and total suspended solids (TSS). The table shows the correlation coefficients between these parameters for both the sachet water (SW) and the water from the treatment plant (WTP).

Table 4: Correlation analysis of physicochemical parameters between the water samples collected from treatment plant and sachet water

Parameter	pH_{SW}	EC_{SW}	TSS_{SW}	pH_{WTP}	EC_{WTP}	TSS_{WTP}
pH_{SW}	1.000					
EC_{SW}	0.449	1.000				
TSS_{SW}	0.446	0.998**	1.000		.	.
pH_{WTP}	0.310	0.042	0.009	1.000		
EC_{WTP}	0.120	0.830*	0.859**	-0.060	1.000	.
TSS_{WTP}	0.158	0.680	0.721*	-0.171	0.965**	1.000

***. Correlation is significant at the 0.01 level (2-tailed).*. Correlation is significant at the 0.05 level (2-tailed).*

The results show that there is a positive correlation between pH and EC for sachet water (r=0.449, p<0.01) and also a positive correlation between pH and EC for water from the treatment plant (r=0.120, p<0.05). This finding is consistent with previous studies that have reported a positive correlation between pH and EC in water samples (Al-Jasser, 2011; Khan *et al.*, 2017). There is also a strong positive correlation between TSS and EC for sachet water (r=0.998, p<0.01) and a weaker positive correlation between TSS and EC for water from the treatment plant (r=0.965, p<0.01). This finding is consistent with previous studies that have reported a positive correlation between TSS and EC in water samples (Al-Jasser, 2011; Khan *et al.*, 2017). Interestingly, there is no significant correlation between pH and TSS for either sachet water or water from the treatment plant. This finding is somehow surprising, as previous studies have reported a positive correlation between pH and TSS in water samples (Al-Jasser, 2011; Khan *et al.*, 2017). However, it is possible that the sample size in this study was too small to detect a significant correlation

Surface Morphology of MPs Samples in Water Samples and Table Salt Samples: Microplastics are created when larger plastic breaks down into smaller pieces. Therefore, in this study, fragments were by far the most abundant morphotype in the raw water supplying the water treatment plants (WTP) as shown in Fig. 2. The proportion of granules/pellets was also significant because it is the second most abundant morphotype (Pivokonsky *et al*., 2018; Tong *et al*., 2020), which was consistent with the findings of earlier studies regarding the shape of microplastics. According to Zhang *et al*. (2015) and Di and Wang (2018), plastic granules and fragments in water are

predicted to come from the breakdown of a variety of plastic items, such as packaging materials, cleaning products, and cosmetics. Laundry discharge, which is transported by sewage waterways, is frequently a source of plastic fibers in aquatic settings (Browne *et al.,* 2011). Two predominant shapes of microplastics (MPs) were detected in bottled water: fragment and pellet/granule. Mason *et al.* (2018) and Ibeto *et al.* (2021) both reported that bottled water included a significant amount of fragments. These could be the result of plastic particles that were released into the water by packaging and capping materials. In this study, more fiber than fragment MP forms was discovered in salt samples, this corroborate with Gündogdu (2018) in similarly study in Turkey. Based on the fiber and fragment forms, it indicates that the MPs discovered in this study are secondary MPs created through photolysis, thermo-oxidation, thermo-degradation, and biodegradation (Zhao *et al.,* 2016; Laglbauer *et al.,* 2014). The high quantity of fiber contamination is likely the result of nearby home wastewater, commercial fisheries, laundry, and other local human activities. A large deposits of MPs of the fiber type was also facilitated by fishing equipment and airborne MPs.

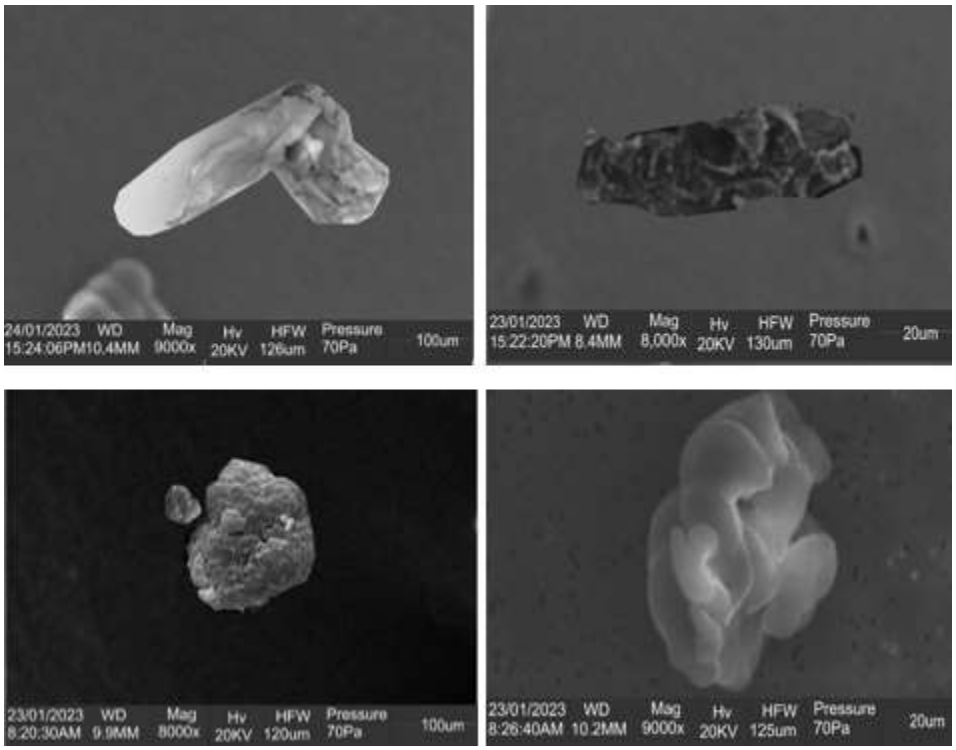

Fig. 2: microscopic image taken by scanning electron microscope (SEM)

Microplastics Abundance in Water Samples: The abundance of microplastics in different water samples are shown in Fig. 3. The samples which consist of the raw water (Kaduna River) and treated water from two different water treatment plants in Kaduna metropolis shown to contain microplastics. But the number of MPs differed among the WTPs and also varied between the raw water and the treated water. The content of MPs in raw water was 153 particles L^{-1}, the highest reported in this study. The high value of MPs in raw water is attributed to the fact that this water is repository of all waste within the environs and untreated. Similar observations were also reported in literature, (Wang *et al.,* 2018; Mintenig *et al.,* 2018;; Pivokonsky *et al.,* 2018; Zhang *et al.,* 2020). However, some factors including human activities (such as laundry, waste disposal), water source type, sampling location and method, sample volume, surrounding environment, particle size detection limit, counting techniques, pipe materials of the Drinking Water Distribution System (DWDS), and weather conditions, affect the amount of MPs in the environment (Pivokonsky *et al.,* 2018). As for MWTP-1, MWTP-2, KSWTP-1, and KSWTP-3, the amount of MPs in the treated water was 32, 36, 25 and 28 particles L^{-1} respectively. These findings show that the treatment procedures successfully eliminated a sizeable amount of the microplastics which is consistent with (Radityaningrum *et al.,* 2021) who reported that treatment stages in the WTP were able to minimize the amount of MPs contamination in the water supply up to 70%. However, because the water

treatment processes involve different stages, therefore a reasonable amount of MPs will be removed compared to the raw water which is untreated. Similarly, observations were also reported from previous studies (Pivokonsky *et al.,* 2018) that a number of factors, including the type of water body and particularly its ambient environment, including human activity in its surroundings, current weather conditions, etc., will contribute to the differences in the abundance of microplastics between raw water and treated water.

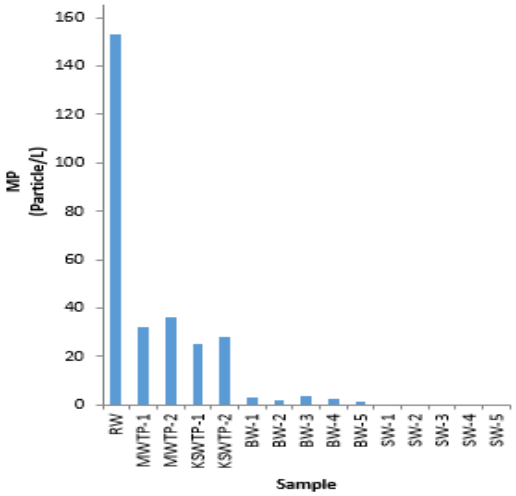

Fig 3: Microplastics abundance in the water samples

Both WTPs are supplied with water from the same source (Kaduna River) but at different locations. Therefore, the difference in MPs abundance between MWTP is KSWTP is due to the variation in treatment efficiency between the plants caused by the differences in treatment capacity. The MWTP has the capacity of 240 million liters while KSWTP has the capacity of 27 million liters. In the case of human activities the area of MWTP water source is more populated with residence which contributes in waste water discharge into the river from laundry activities compared to KSWTP water source which has lesser activities around the river. The MWTP water intake point is closer to residential settlements than the KSWTP where there are dump sites around the river are expected to pollute some part of the river through wind, direct disposal and other factors. A total of 2.9, 1.7, 3.7, 2.2 and 1.4 particles L^{-1} of MPs was found in BW-1, BW-2, BW-3, BW-4 and BW-5, respectively. The abundance of MPs observed for the BW samples is due to residue plastics that were left on the inner surface during moulding process of the bottles. The variation among the samples is due to the type of sample and treatment process of the BW. (Sarva and Sawanya, 2021). The source of these microplastics might be from the production stages, which is during cleaning and packaging of finished products (Weisser *et al.,* 2021).

Nearest neighbor quadrant mapping for the different water samples: The nearest neighbour and distances of microplastic (MP) between samples are shown in Fig. 4 and Table 5. The table shows the sample name, its nearest neighbour, and the distance between them. The distance is measured in millimeters (mm) and represents the Euclidean distance between the two samples. The numeric value between 0 and 2.15 shows whether the samples are regular (greater than 1 to 2.15), random (1), or clustered (0 to less than 1). Figure 4 shows the nearest neighbor quadrant mapping for the MPs in various water samples, and Table 5 shows the separation between closest neighbors. Based on these distances, 90% of the samples displayed clustered mapping (0 – 0.147) and 10% displayed regular mapping (1 – 2.15), suggesting that the majority of the samples' MP presence may have comparable origins.

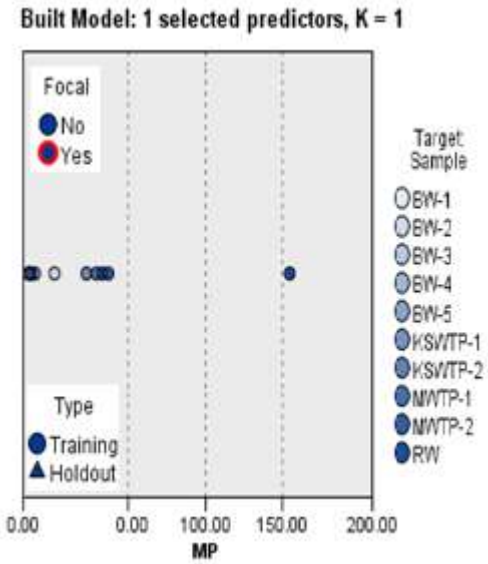

Fig 4: Nearest neighbour quadrant mapping for the different water samples

Table 5: Nearest neighbours and distances for microplastic (MP) between samples

Sample	Nearest Neighbour	Nearest Distance
BW-5	BW-2	0.002
BW-4	BW-2	0.011
BW-1	KSWTP-1	0.147
KSWTP-1	KSWTP-2	0.046
KSWTP-2	MWTP-1	0.027
MWTP-1	KSWTP-1	0.027
MWTP-2	MWTP-1	0.027
RW	MWTP-2	1.558
BW-3	BW-4	0.016
KSWTP-1	BW-1	0.147

*Principal Component Analysis of bottled water samples***:** Table 9 presents the results of a principal component analysis (PCA) conducted on physico-chemical properties and microplastic (MPs) concentration in bottled water samples. The PCA is a statistical technique used to identify patterns and relationships among variables. In this case, the PCA was used to identify the underlying factors that contribute to the variance in the physicochemical properties and MPs concentration in the bottled water samples. The table shows the initial eigenvalues, extraction sums of squared loadings, and rotation sums of squared loadings for each component. The initial eigenvalues represent the amount of variance explained by each component, while the extraction and rotation sums of squared loadings represent the amount of variance explained by each variable in each component. From Table 6, component 1 explains 61.064% of the total variance, while Component 2 explains 32.425% of the total variance. Together, these two components explain 93.489% of the total variance. Component 3 and Component 4 do not contribute significantly to the variance and are not included in the rotation sums of squared loadings as shown in Figure 5.

Table 6: Total variance of physicochemical properties and MPs concentration in bottled water samples

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.443	61.064	61.064	2.443	61.064	61.064	2.051	51.272	51.272
2	1.297	32.425	93.489	1.297	32.425	93.489	1.689	42.217	93.489
3	0.260	6.510	99.999						
4	4.812E-5	0.001	100.000						

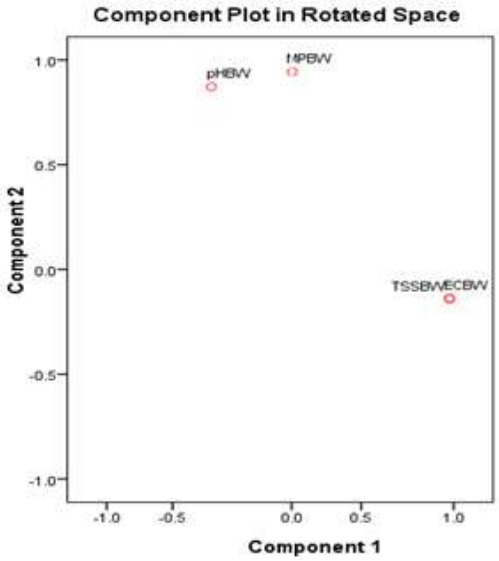

Fig. 5: Principal component plot of pH, TSS and MPs in bottled water in rotated space

The results suggest that there are two underlying factors that contribute to the variance in the physicochemical properties and MPs concentration in the bottled water samples. These factors could be related to the source of the water, the manufacturing process, or the packaging materials used. The results of this analysis are consistent with previous studies that have identified physicochemical properties and MPs concentration as important factors in bottled water quality. For example, a study by Ibeto *et al.* (2021) found that the physicochemical properties of bottled water, such as TS and TSS were important predictors of MPs concentration because MPs exhibited a strong correlation with TS and TSS, suggesting that the presence of high MPs in the water is most likely if the sample of bottled water has high TS or TSS levels.

Microplastics abundance in table salt samples: As shown in Figure 6, all the samples contain microplastics and the particle content was found to be 32 particles in 250 g of sample TS-1, which makes it about 0.13 particles g^{-1} of the salt, and 48, 67, 55 and 51 particles in 250 g of TS-2, TS-3, TS-4 and TS-5 respectively.

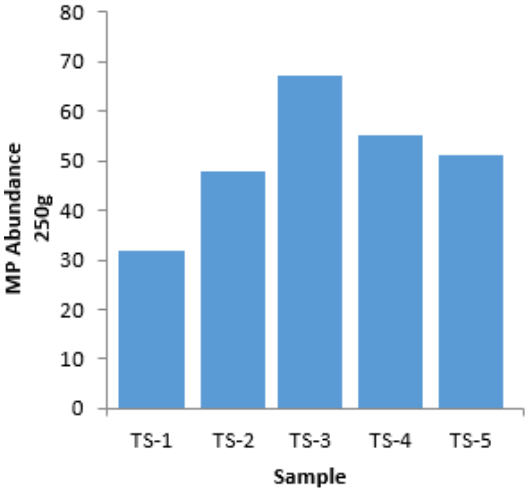

Fig 5: Microplastics abundance in the salt samples

These shows that the content of microplastics are 0.19, 0.27, 0.22 and 0.20 particles g^{-1} of the samples

respectively. The lowest value of microplastics content accounting for 0.19 particles g^{-1} was recorded in TS-1 which was a refined and iodized table salt packaged in a small sachet containing 500 g, while the higher value of microplastics content accounting for 0.27 particles g^{-1} was recorded in TS-3 which was refined and packaged in a 25 kg sack. The difference may be as a result of packaging and handling of the products, and also from the original source of the salts.

Identification of Microplastics present in Raw, Treated, Bottled water and Table Salt using FTIR Analysis: The identification of different types of polymers present in raw water, treated water, bottled water and table salt samples was shown in Table 7. The absorptions at 2915 cm^{-1}, 2945 cm^{-1} indicates CH_2, CH_3 asymmetrical stretching, the peak at 2838 cm^{-1} represent CH_3 stretching, while 1455–800 cm^{-1} indicates CH_3 symmetrical bending and C-C stretching, which confirm the particle to be a polypropylene (PP) (Sathish *et al.,* 2020). The characteristic peak at 2959 cm^{-1}, 2922 cm^{-1}, 1714 cm^{-1}, 1241 cm^{-1} and 1088 cm^{-1} also indicates the C-H symmetrical stretching, stretching of C=O carboxylic acid group, terephthalate group and vibration of the ester C-O bond, which also confirm the presence of Polyethylene terephthalate (PET) (Periera *et al.,* 2017). The absorptions peaks at 2967 cm^{-1}, 2929 cm^{-1}, represent the asymmetrical stretching of bond of C-H and symmetrical stretching of bond of C-H. The peak around 1244 cm^{-1} is attributed to the bending bond of C-H near Cl. The peak around 1095 cm^{-1} is attributed to the C-C stretching bond of backbone chain which confirmed the particle as Polyvinyl Chloride (PVC) (Pandey *et al.,* 2016).

Table 7: Identification of Microplastics present in Raw, Treated, Bottled water and Table Salt

Type of polymer	Absorbance peak	Functional group
PP	2918, 2952, 2851, 1461 and 1375	CH_3, CH_2, C-C
PET	2959, 2922, 1714, 1241 and 1088	CH_3, CH_2, C=O, C-O and terephthalate group.
PE	2914, 2847, 1468 and 715	CH_3, CH_2, stretch CH_3 bend
PVC	2967, 2929, 1244 and 1095	CH_3, CH_2, stretch C-C and C-Cl
PES	3432, 2970, 1714, 1237 and 1088	O-H stretch, C-H stretch, C=O, anhydride group.

The absorptions at 2914 cm^{-1} and 2847 cm^{-1} account for CH_3 asymmetric C-H stretching and CH_2 symmetric C-H stretching while the peak at 1470 cm^{-1} account for CH_3 umbrella bending mode. Also, the peak at 718 cm^{-1} account for CH_2 rocking vibration. Therefore it shows that the particle tested was polyethylene (PE) (Sathish *et al.,* 2020). The absorptions at 3432 cm^{-1} shows the stretching vibration of OH groups, the peak at 2970 cm^{-1} is attributed to CH_3 asymmetric C-H stretching, absorption peak at 1714 cm^{-1} shows C=O vibration, while 1237 cm^{-1} and 1088 cm^{-1} is attributed to ester or anhydride group, which ultimately confirm the presence of polyester (PES). (Bhattacharya and Chaudhari, 2014).

However, as a result of aging, plastic debris can become weathered, gain more surface area, and produce oxygen groups, which can enhance their polarity, charge, roughness, and porosity. Therefore some of the polymer spectra have additional degradation peaks at certain wavelengths (Fotopoulou and Karapanagioti, 2012). As a result, microplastic that has been exposed to a contaminated marine environment for a long period has a potential to acquire additional elements on its surface (Wang *et al.,* 2017). PVC is also a material used to create pipes (Chu *et al.,* 2022). As a result, the MP types in the treated water were quite comparable to those in the samples of raw water. Considering the different stages involved in the water treatment process of bottled water, very small amount of MPs could escape those treatment stages from the untreated water into the finished products. So we can think of a number of additional factors that can result in contamination by these polymers. Based on this study, the manufacturing procedure itself may be the source of the MPs contamination. Production and bottling facilities for drinking water are kept in excellent condition. However, it is hard to guarantee that those plants are completely free of MP contamination due to the ubiquitousness of MPs in the environment (WHO, 2019). Consequently, airborne MPs could be a source of contamination. There is a possibility where by during the cleaning process of the bottles used for packaging, high tension is associated with bottle

washing because the cleaning equipment sprays high-pressured water, which could release MPs from the packaging material. Also, the bottling procedure of the products was studied, and it could be noted that during the water packaging, the high-pressure water injection into the bottles can result in the discharge of plastic particles from the packaging bottles, even though they are considered to be cleaned. Moreover, during storage and shipping, bottles may experience external stress that can have an impact which might cause the release of MPs into the bottled water. Additionally, opening a bottle can put physical strain on the packaging or caps, which might also be a reason for release of MPs into the bottled water (Weisser *et al.,* 2021). Thermal influences can accelerate the leaching of plastic additives and the release of plastic particles into the water which is also originated from the packaging or capping material. The polymer composition of the particles present in table salt samples were shown in Table 10. Out of which some particles were established as plastic and some as non-plastic particles. Three different types of polymers were detected by FTIR-ATR analysis, were polyethylene (PE), polypropylene (PP) and polyester (PES). Other countries' salts have also been found to contain polyethylene (Gündogdu 2018; Iiguez *et al.,* 2017; Karami *et al.,* 2017; Yang *et al.,* 2015). According to Kumar *et al.,* (2018), polyethylene and polypropylene were abundant in the Tuticorin coastal environment. The accumulation of microplastic in seawater, which is primarily the source of table salts, may be due to wastewater intrusion and fishing activity in the marine environment. This study also provides evidence that the fibers (PE and PP) discovered in table salts may have come from fabric materials dumped in bodies of water and PE envelopes used in packaging.

Health Risk Assessment in Microplastics: Estimated daily intake: Table 8 shows the findings for the calculated estimated daily intake of MPs from consuming the examined treated water and bottled water for adults as well as children. All Estimated daily intakes (EDIs) for samples of bottled water are typically less than 1, showing a low daily intake of MPs and suggesting that daily consumption may not be risky. But some EDIs for samples of treated water from the two conventional water treatment plants were a little bit higher, and the outcome indicated that some value was greater than 1. The findings showed that children consume more MPs than adults. This corroborates with previous studies that high EDI in children compare to adult (Koelman *et al.,* 2021; Ibeto *et al*., 2021). This generally suggests that children drinking water from conventional treatment plants are more likely to consume MPs beyond the threshold level than adults. However, Information regarding the dangers of MPs to both children's and adults' health is still very unclear.

Table 8: Estimated daily intake of MPs in sampled water

Sample	Estimated daily intake	
	Adult	Child
MWTP-1	1.006	3.840
MWTP-2	1.131	4.320
KSWTP-1	0.786	3.000
KSWTP-3	0.880	1.037
BW-1	0.091	0.348
BW-2	0.053	0.204
BW-3	0.116	0.444
BW-4	0.069	0.264
BW-5	0.044	0.168

Microplastics contamination factors and pollution load index: The Microplastics contamination factors and pollution load index in the bottled water are presented in Table 9. The values were estimated as described in previous studies (Verla *et al.,* 2019). The MPs contamination factors and pollution load indices quantify the risks the MP pose to health and ecosystems based on its composition (Ibeto *et al*., 2021).

Table 9: Microplastics contamination factors and pollution load index in bottled water

Samples	MPCF	Risk Category
BW-1	2.9	Moderately contaminated
BW-2	1.7	Moderately contaminated
BW-3	3.7	Contaminated
BW-4	2.2	Moderately contaminated
BW-5	1.4	Moderately contaminated
MPPLI = 2.24		

Based on the categorization of MPCF according to Verla *et al*. (2019), eighty percent (80%) of all samples showed moderate contamination while 20% showed considerable contamination. The profile of MPCF for the samples showed: BW-3 > BW-1 > BW-4 > BW-2 > BW-5. Similarly, MPPLI for the bottled water sample as shown in Table 12 was >1, this indicates pollution of the bottled water samples. The value 2.24 obtained in this study is higher than 1.71 documented in a similar study in south eastern Nigeria (Ibeto *et al*., 2021). The higher value obtained in this study may be attributed to the higher population density in Kaduna metropolis which will be synonymous to high waste generation that pollute the river water which are source of water used.

Conclusion: The maximum MPs concentration in this study of 153 particles L^{-1} was obtained in raw water from river Kaduna. Also, fragments type polymer predominated in raw and treated water; granules and fragments made up the majority of the bottled water, and fiber and fragment predominated in samples of table salt. The analysis of polymer type showed that raw and treated water microplastics are predominantly

PET, PP and PVC, whereas PET and PE are found in bottled water. This study provides baseline information of microplastics distribution in various drinking water and salts available in Kaduna Metropolis.

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REFERENCES

Al-Jasser, A. O. (2011). Saudi Wastewater Reuse Standards for Agricultural Irrigation: Riyadh Treatment Plants Effluent Compliance. *J. of King Saud Uni*—Engineering Sciences, 23, 1-8.

Anderson, PJ; Warrack, S; Langen, V; Challis, JK; Hanson, ML; Rennie, MD (2017). Microplastic contamination in Lake Winnipeg, Canada. *J. of Env. Poll.*, 225, 223–231.

Andrady, L (2011). Microplastics in the marine environment. *J. of Mar. Poll. Bull.* 62(8), 1596–1605.

Barboza, LGA; Vethaak, AD; Lavorante, BRBO; Lundebye, AK; Guilhermino, L (2018). Marine microplastic debris: An emerging issue for food security, food safety and human health. *J. of Mar. Poll. Bull.* 133, 336−348.

Bhattacharya, S; Chaudhari, SB (2014). Study on Structural, Mechanical and Functional Properties of Polyester Silica Nanocomposite Fabric. *International J. of Pure and App. Sci. and Tech*. 21(1) pp. 43-52

Brachner A; Fragouli D; Duarte IF; Farias, PMA; Dembski S; Ghosh M; Barisic I; Zdzieblo D; Vanoirbeek J; Schwabl P; Neuhaus W (2020). Assessment of Human Health Risks Posed by Nano-and Microplastics Is Currently Not Feasible. *Int. J. Environ. Res.* Public Health, 17: 8832. doi:10.3390/ijerph17238832.

Browne, MA; Crump, P; Niven, SJ; Teuten, E; Tonkin, A; Galloway, T; Thompson, R (2011). Accumulation of microplastic on shorelines worldwide: sources and sinks. *Env. Sci. and Tech.* 45 (21), 9175–9179.

Eriksen, M; Lebreton, M; Carson, S; Thiel, M; Moore, J; Borerro, C; Reisser, J (2014). *J. of Plastic Poll. In the World's Oceans*: 9(12), e111913.

Erkoyun, E; Sozmen, K; Bennett, K; Unal, B; Boshuizen, HC (2016). Predicting the health impact of lowering salt consumption in Turkey using the DYNAMO health impact assessment tool. *J. of Pub. Health*. 140, 228−234.

Fotopoulou, KN; Karapanagioti, HK (2012). Surface properties of beached plastic pellets. *Mar. Environ. Res.* 81:70–7767.

Gundoğdu, S (2018). Contamination of table salts from Turkey with microplastics. *J. of Food Add. and Cont.*, 35(5):1006-1014.

Ibeto CN; Enyoh CE; Ofomatah AC; Oguejiofor LA; Okafocha T; Okanya V (2021). Microplastics pollution indices of bottled water from South Eastern Nigeria, *Int. J. of Environ. Analy. Chem*, DOI: 10.1080/03067319.2021.1982926

Iñiguez, ME; Conesa, JA; Fullana, A. (2017). Pollutant content in marine debris and characterization by thermal decomposition. *Mar. Poll. Bull.* 117(1–2):359–365

Joystu, D; Moharana, C (2018). Plastic pollution: global problem from a local perspective. *J. of Was. Manag*., DOI:10.23880/oajwx-16000102

Kaduna State of Nigeria. City Population. Retrieved September 26, 2020

Karami, A; Golieskardi, A; Choo, CK; Larat, V; Galloway, TS; Salamatinia, B (2017). The presence of microplastics in commercial salts from different countries. *Sci. Rep*., 7. doi: 10.1038/srep46173

Kazi, TG; Arain, MB; Jamali, MK; Jalbani, N; Afridi, HI; Sarfraz, RA; Baig, JA (2009). Assessment of water quality of polluted lake using multivariate statistical techniques: A case study. *Ecotoxicol. and environ safety*, 72(2), 301-309.

Khan, K; Lu, Y. Saeed, M., A., et *al.* (2017). Prevalent Fecal Contamination in Drinking Water Resources and potential Health Risks in Swat, Pakistan. *Journal of Env. Sci.* DOI: 10.1016/j.jes.2017.12.008

Kumar VE; Ravikumar, G; Jeyasanta, KI (2018). Occurrence of microplastics in fishes from two landing sites in Tuticorin, South east coast of India. *Mar. Poll. Bull.* 135:889–894

Kutralam-Muniasamy, G., Pérez-Guevara, F., Elizalde-Martínez, I; Shruti, V., C. (2020). Branded milks − Are they immune from microplastics contamination? *J. of Sci. of the Tot. Env.* doi.org/10.1016/j.scitotenv.2020.136823

Laglbauer, BJ; Franco-Santos, MR; Andreu-Cazenave, M; Brunelli, L; Papadatou, M; Palatinus, A; Grego, M; Deprez, T (2014). Macrodebris and microplastics from beaches in Slovenia. *Mar. Poll. Bull.* 89:356–366

Mason, SA; Welch, VG; Neratko, J (2018). Synthetic Polymer Contamination in Bottled Water. *Fredonia- State Uni. of New York.*

Mintenig, M., Leoder, J., Primpke, S., Gerdts, G. (2018). Low numbers of microplastics detected in drinking water from ground water sources. *Sci. of the Tot. Env.* 648, 631–635.

Moore, CJ; Lattin, GL; Zellers, AF (2011). Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of Southern California. *Revista de Gestão Costeira Integrada,* 11(1), 65–73.

Pandey, M; Joshi, GM; Mukherjee, A; Thomas, P (2016). Electrical properties and thermal degradation of poly(vinyl chloride)/polyvinylidene fluoride/ZnO polymer nanocomposites. *Polym. Int.* doi10.1002/pi.5161.

Peixoto, D; Pinheiro, C; Amorim, J; Oliva-Teles, L; Guilhermino, L; Vieira, MN (2019). Microplastic pollution in commercial salt for human consumption: A review. *J. of Estu, Coas. and Shelf Sci.* 219, 161−168.

Pereira, A; Prado da Silva, MH; Lima Júnior EP; Paula, A; Tommasini, FJ (2017). Processing and Characterization of PET Composites Reinforced With Geopolymer Concrete Waste. *Mat. Res.* 20(2): 411-420 doi.org/10.1590/1980-5373-MR-2017-0734

Pivokonsky, M; Cermakova, L; Novotna, K; Peer, P; Cajthaml, T; Janda, V (2018) Occurrence of microplastics in raw and treated drinking water. *J. of Sci.e of the Tot. Env.* 643, 1644−1651.

Radityaningrum, AD; Trihadiningrum, Y; Mar'atusholihah, Soedjono, E. S., and Herumurti, W. (2021). Microplastic contamination in water supply and the removal efficiencies of the treatment plants: A case of Surabaya City, Indonesia. *J. of Wat. Proc. Eng*. https://doi.org/10.1016/j.jwpe.2021.102195

Rakib, R; Hossain, B; Kumar, R; Ullah, A; Nahian, S; Naher, N; Choudhury, T; Mahmoud, M (2022). Spatial distribution and risk assessments due to the microplastics pollution in sediments of Karnaphuli River Estuary, Bangladesh. *Sci. Rep*. https://doi.org/10.1038/s41598-022-12296-0

Santillo, D; Miller, K; Johnston, P (2017). Microplastics as contaminants in commercially important seafood species. *J. of Integ. Env. Assess. and Manag.*. 13, 516−521.

Sarva, M; Sawanya, L. (2021). Quality assessment for methodological aspects of microplastics analysis in bottled water. *J. of food cont.* https://doi.org/10.1016/j.foodcont.2021.108285

Sathish, MN; Jeyasanta, I; Patterson, J (2020). Microplastics in Salt of Tuticorin, Southeast Coast of India. *Arch. of Env. Cont. and Toxicol.* https://doi.org/10.1007/s00244-020-00731-0

Sawyer, CN; McCarty, PL; Parkin, GF (2003). Chemistry for environmental engineering and science. McGraw-Hill.

Schoeller, H; Ayotte, JD; Szabo, Z (2004). Trace elements and isotopes in groundwater and surface water of the United States. *Groundwater*, 42(2): 201-214.

Schwabl, P; Koppel, S; Konigshofer, P; Bucsics, T; Trauner, M; Reiberger, T; Liebmann, B (2019). Detection of various microplastics in human stool: A prospective case series. *Annals of Intern. Med.* 171, 45.

Singh, KP; Malik, A; Mohan, D; Sinha, S (2011). Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India)—a case study. *Wat. Res.*, 45(13): 4341-4352.

Tong, H; Jiang, Q; Hu, X; Zhong, X (2020). Occurrence and identification of microplastics in tap water from China. *Chemosphere* doi: 10.1016/j.chemosphere.2020.126493.

UNEP (2009). Converting waste plastics into a resource assessment guidelines. An introduction to Plastic Recycling; *J. of Plast. Waste Manag. Instit.*

Verla, A. W., Enyoh, C. E., Verla, E. N. (2019). Macrodebris and microplastics pollution in Nigeria: first report on abundance, distribution and composition. *J. of Analy. Meth. in Env. Chem*. DOI: 10.5620/eaht.e2019012

Wang, J; Peng, J; Tan, Z; Gao, Y; Zhan, Z; Chen, Q. et al. (2018). Microplastics in the surface sediments from the Beijiang River littoral zone: composition, abundance, surface textures and interaction with heavy metals. *Chemosphere*. 171:248–258

Weisser, J; Beer, I; Hufnagl, B; Hofmann, T; Lohninger, H; Ivleva NP; Glas, K (2021). Identifying sources of microplastics in mineral water. *J. of Water*. doi:10.3390/w13060841.

World Health Organization. (2019). Microplastics in drinking-water. *Geneva:* Licence: CC BY-NC-SA 3.0 IGO.

Yang, D; Shi, H; Li, L; Li, J; Jabeen, K; Kolandhasamy, P (2015). Microplastic pollution in table salts from China. *J. of Env. Sci. and Tech*. 49, 13622−7.

Yusuf, RO; Durojaiye OA; Salawudeen, TA (2008). Pollution monitoring along Kaduna River. *Lnt. J. of Environ. Sci*. 4 (4): 76-82

Yusuf, RO; Sonibare, JA (2004) Characterization of Textile Industries' Effluents in Kaduna, Nigeria and Pollution Implications. *Global Nest Journal*, 6, 211-220.

Zhang, M; Li, J; Ding, H; Ding, J; Jiang, F; Ding, NX; Sun, C (2020). Distribution characteristics and influencing factors of microplastics in urban tap water and water sources in Qingdao, China. *Analy.l Lett.* 53 (8), 1312–1327.

Zhang, Y; Li, X; Li, Y; Li, Y (2015). Correlation analysis of water quality parameters in the Songhua River basin, China. *Env. Earth Sci.*, 73(11): 7325-7334.

Zhao, S; Zhu, L; Li, D (2016). Microplastic in three urban estuaries. China. *Env. Poll.* 206:597–604

Zhou, X., Jin, W., Hong-yan, L., Hui-min, Z., Hua, J., Dong, L. (2020). Microplastic pollution of bottled water in China. *J. of Water Proc. Eng.* https://doi.org/10.1016/j.jwpe.2020.101884