Environmental Health Engineering and Management Journal 2023, 10(2), 217–224
http://ehemj.com
doi 10.34172/EHEM.2023.24

Environmental Health Engineering and Management Journal

Original Article

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A study of the microplastic contamination of commercial table salts: A case study in Nigeria

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Abstract

Background: Environmental pollution caused by microplastics (MPs) is quite ubiquitous and has become a global issue. Several studies have focused on MPs in marine and freshwater systems. However, there is a paucity of data about the presence of MPs in sea products like table salt and the risks they likely pose. Hence, this study investigated the presence of MPs in commonly consumed commercial table salts in South-West, Nigeria.

Methods: A total of 8 different brands of commonly consumed commercial salts were purchased from open supermarkets in Ogun and Lagos States, Nigeria. Salt samples were digested with 30% H_2O_2, extracted for MPs, and observed under a digital microscope for shape, quantity, and colour.

Results: Fibres and fragments were the plastic shapes found in the samples, with fibres being more prominent. The average content of MPs obtained was 12 particles/kg. Blue, pink, and purple colours of MPs were commonly found. The sizes of MPs were between 50 µm and 1 mm. Considering our findings and based on the World Health Organization's (WHO's) recommended daily intake of 5 g of salt, Nigerian adults will consume an average rate of 21.9 microplastic particles/year.

Conclusion: According to the results of the study, table salts commonly consumed in Nigeria are polluted with MPs. Due to the importance of table salt as related to daily food intakes, it becomes very necessary to fine-tune technologies in their production to improve the quality and lower MPs ingested by consumers in Nigeria.

Keywords: Dietary, Microplastics, Nigeria, Salts, World Health Organization

Citation: Shokunbi OS, Jegede DO, Shokunbi OS. A study of the microplastic contamination of commercial table salts: a case study in Nigeria. Environmental Health Engineering and Management Journal 2023; 10(2): 217–224. doi: 10.34172/EHEM.2023.24.

Article History:
Received: 8 September 2022
Accepted: 21 December 2022
ePublished: 1 June 2023

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Introduction

The annual increase in the production of plastic waste has contributed to major pollution of the environment across the world (1). Plastic pollution is one of the major concerns in the environment. Globally, plastics are emerging and ubiquitous environmental pollutants. The annual production of plastics has increased continuously and tremendously over the years. In 2020, about 370 million tons of plastics were produced worldwide (2).

Microplastics (MPs) are plastic debris, which are found in coastal, freshwater, and marine environment (3). Each has a diameter of less than 5 mm. They are classified into primary MPs (such as microbeads from cosmetics and pellets), which are manufactured and released directly into the oceans, and secondary MPs, which are formed as a result of the degradation of larger particles through biological, chemical, and physical processes (4,5).

A larger portion of these plastics have been reportedly found in different freshwater (6,7), marine (8-10), and terrestrial (11,12) ecosystems due to the inappropriate disposal of plastic products. MPs are being transferred to animals (13) and humans (14) from sediments (15-18) and water (19,20). The transfer of MPs to humans and animals can also occur through the food chain.

MPs in marine organisms such as mussels and fish have been examined several years ago (21,22). Yang et al (23) hypothesized that pollution of the sea with MPs will lead to the pollution of sea products, which can transfer MPs to humans through the food chain, thereby, increasing health risks to humans. To date, only a few studies have reported MP pollution in sea products (23-27).

Salts come mainly from the sea, rocks, lakes, and well. Table salts provide humans with the needed essential elements for physiological processes (23). The production of sea salt is basically through the process of crystallization by the action of wind and sunlight. The process involves the concentration of seawater via evaporation. Thereafter, the salt undergoes condensation and crystallization on the surface of the crystallizer and it is fragmented and collected using a controlled collection process (23,25).

Although several studies have been reported on MPs pollution in table salts in countries like Spain, China, Turkey, and India (23-27); however, only one study is known to be reported in Nigeria and Africa as a whole (28). There are three major forms of table salt in the Nigerian markets: refined (iodized and non-iodized), coarse, and sea salts.

The World Health Organization (WHO) recommended the consumption of an average of 5 g of salt per day for a healthy adult (29,30). A report from Zhang et al (31) showed that a large amount of about $0\text{-}7.3\times10^4$ MPs are consumed annually by humans, through table salt. Indeed, there is a paucity of data on MPs in commonly consumed table salts in Nigeria. Until our review of October 7, 2022, only Fadare et al (28) reported MPs in four different brands of table salts in Nigeria. Thus, this study aimed to identify MPs in commonly consumed table salts in Nigeria. Also, the daily intake of the MPs per individual was estimated in this study.

Materials and Methods

Sample collection

Eight different brands of commonly consumed commercial table salts were obtained from local markets and supermarkets in Ogun and Lagos States, Nigeria, between September and October 2021 as shown in Figure 1. Details of the production date, expiry date, batch number, place of purchase, and weight per package are documented in Table 1. For privacy purposes, the company and brand names are not provided. The weight of the collected table salt samples ranged from 350 g to 800 g for each of them and the collections were done in triplicate.

Hydrogen peroxide treatment and microplastic extraction

MPs in the collected table salt samples were extracted using the slightly modified method of Yang et al (23). Figure 2 shows the summarized method of extraction of MPs from the table salts. Briefly, three replicates of 250 g of each of the salt samples were transferred into three different 2 L conical flasks. Thereafter, the organic matter present in each of the samples was digested with 100 mL of 30% H_2O_2. The samples in the conical flasks were subjected to incubation at 80 rpm and 65ºC and for 24 hours using an orbital shaker incubator (ZHP-100, Gallenkamp, England). The flasks were fully covered with aluminium foil during incubation. Following digestion, 800 mL of filtered distilled water was used to dissolve the salt samples in each of the flasks. Aluminum foil was then used to cover each of the flasks and the samples were left till the next day. Furthermore, the dissolved samples

Table 1. Details of commonly consumed table salt from South-West Nigeria

Sample	Expiration year	Batch number	Weight of sample (g)
1	April 2023	Sv.5020421-A	500
2	July 2023	Rmc22107	500
3	December 2022	NA	350
4	September 2022	9287	750
5	December 2022	1041W	750
6	October 2022	14410	750
7	March 2025	A-080720	800
8	January 2025	NA	800

NA: Not available.

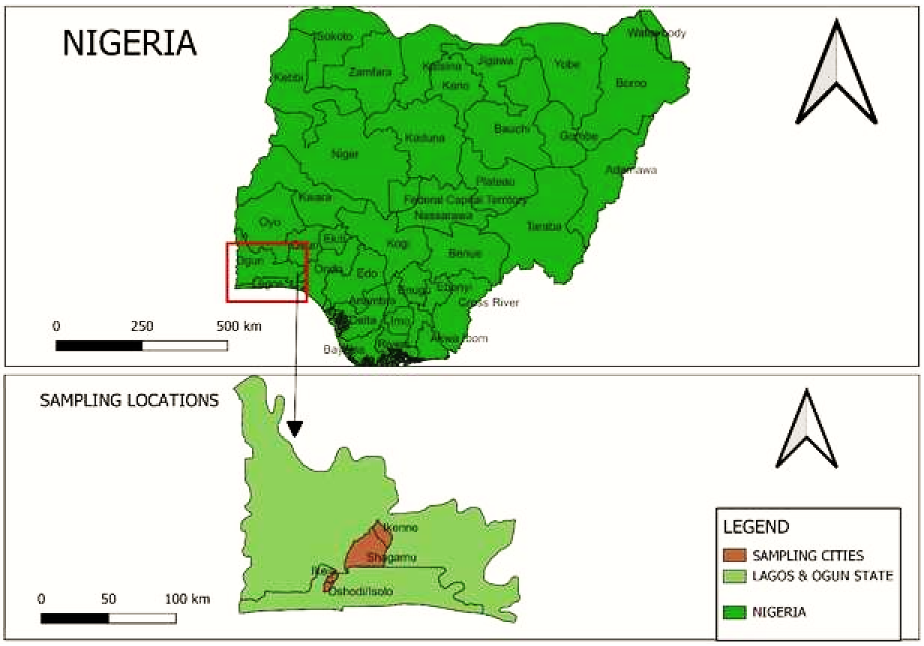

Figure 1. Map of sampling locations

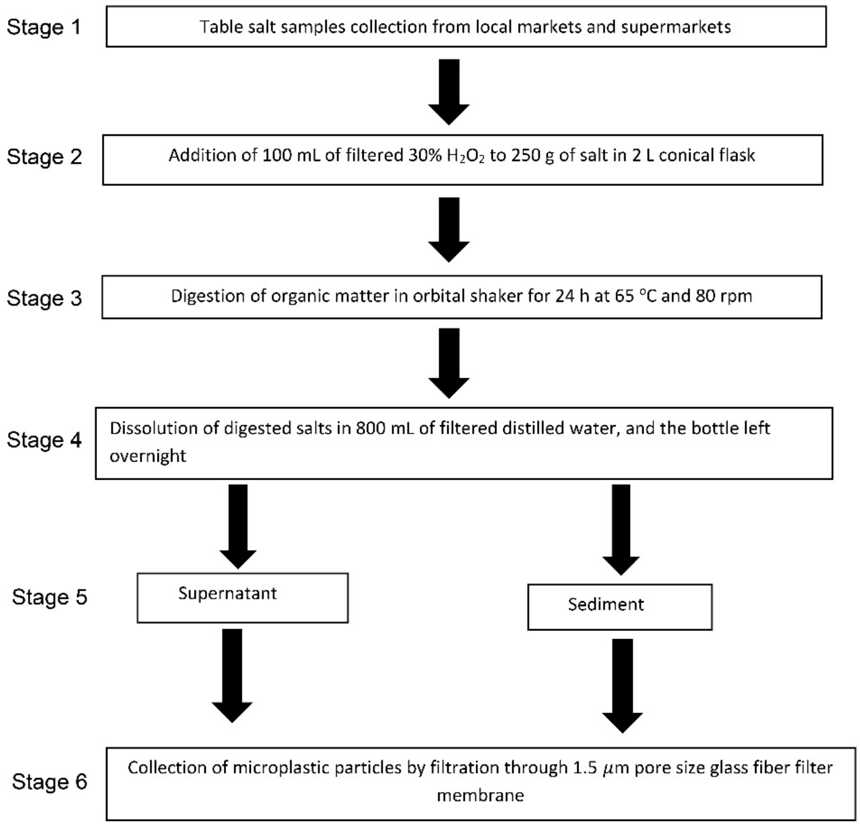

Figure 2. Flow chart of microplastics extraction and analysis from commercial table salts

in the flasks were filtered through individual glass fibre filter membranes (GF/D; 1.5 µm; Whatman, China) into three different glass containers, using a vacuum pump apparatus (VP 180, China).

The fibre filters used were then collected and kept separately in clean glass Petri dishes to dry up at room temperature before microscopic characterization of the MPs.

Visualization of extracted microplastics

Observations of air-dried and recovered MPs on glass fiber filters, with varied magnifications)4X and 10X) were done under OMAX digital microscope (A3550S, China) and the images were captured with a built-in camera on the microscope. The assessment of the various shapes and colours of MPs was done visually, while the size measurement was done using ImageJ. The quantification of MPs was done by counting the total number of the extracted MPs on each of the glass fibre filters (for an average of the triplicate), excluding the plant tissues and invertebrate exoskeleton.

Quality control and quality assurance of the experiment

To prevent contamination from air, the distilled water and hydrogen peroxide used was carefully filtered using a 1.5 µm pore size filter. All experimental procedures were carried out in a fume cupboard and a 100% cotton laboratory coat was worn throughout the process. The laboratory equipment, working space, and benches were cleaned with 70% ethanol before use. All beakers were rinsed thoroughly with filtered distilled water. Furthermore, the samples were properly covered with aluminium foil when the experiment was not going on. In addition, to prevent procedural contamination, two sets of blanks or controls were used. These blanks included the filtered water used for the extraction process (procedural blank) and the water left open in the laboratory during the extraction period (air blank). Both blanks were subjected to the same protocol as the samples, before being analyzed for MPs.

Data analysis

The concentration of MPs was determined by dividing the average number of MPs counted per sample by the weight of the sample and multiplying by 1000 g to obtain the concentration of MPs in particles/kg of the sample. Descriptive statistics were determined using an Excel sheet.

Results

Eight different brands of table salts across Southwestern, Nigeria, were analyzed for MPs. The physical properties like shape, size, and colour were determined. No MP contamination was found in the blanks for the quality control test. Table 2 shows the number of MPs extracted from each of the salt samples. All salt samples contained

MPs, except two of them. The MP particles found were either fibres or fragments of irregular or regular shapes. Fibres dominated most of the particles found (Figure 1). The size of MPs ranged from 50 μm to 1 mm (Figure 3a). The average content of MPs determined was 12 particles/kg. The MPs obtained from the salts were of blue, pink, purple, and green colours (Figure 3b). We could not characterize the MPs using FTIR because of their small quantities, which made it challenging to retrieve; hence, the types of polymers could not be ascertained.

Discussion

The pattern of identified MPs was similar to that reported by Renzi and Blašković (32). Yang et al (23) clearly stated that the source of these impurities could have been the origin of table salt or the production process. Furthermore, a study conducted by Kosuth et al (33), isolated MPs from the sea salt in the USA, which were mainly fibres, as similarly reported in this study. Another study by Seth and Shriwastav (27) extracted 37% fibres and 63% particles from the analyzed table salts, a pattern that is somewhat inverse to the current finding. This variation may be due to the varied sources of the analyzed salts. Gündoğdu (24) also reported similar forms of MPs analyzed in table salt consumed in Turkey. The presence of fibre and fragments showed that the MPs were likely of secondary origin, formed through thermal degradation, photolysis, or thermos-oxidation (34,35). In addition, the high level of fibre could be attributed to human activities like domestic wastewater, laundry, and fishing in the areas, where the salt water was collected for table salt processing. Fibres and fragments were reported to be found majorly in several studies (36,37).

The average amount of MPs in this study (12 particles/kg) is lower than those reported in sea salts (550-681 particles/kg), well salts (7-204 particles/kg), and lake salts (43-364 particles/kg) obtained from China (23), and well salts (50-280 MPs/kg) from Spain (25. However, it was similar to those reported in Taiwan (38). More comparisons were made with other studies around the world as shown in Table 3. All these reports showed that

Table 2. Number and shape of microplastics analyzed in each brand of table salt

S/N	Type of salts	Plastic particles			Total No. of plastics	No. of Particles/kg
		Fibers	Fragment	Pellet		
1	Fine	3	2	0	5	20
2	Fine	1	0	0	1	4
3	Fine	6	2	0	8	32
4	Fine	2	1	0	3	12
5	Fine	0	0	0	0	0
6	Fine	3	1	0	4	16
7	Fine	0	0	0	0	0
8	Coarse	2	1	0	3	12
Total		17	7	0	24	

Note: S/N 1-8 represent commercially available edible salts in Nigerian markets.

Table 3. Abundance of microplastics in salts across the globe

S/N	Country	Salt type	Colors	Shape	Polymers	Abundance (particles/kg)	References
1	Nigeria	8 Brands of commercial salts	Blue, pink, black, purple	Fibers and fragments	NA	12	Present study
2	China	15 Brands of commercial salts	Black, red, blue, white	Fragments and fibres	PET, PE cellophane	43 to 681	(23)
3	Turkey	16 Brands of commercial salts	NA	Fibres	PE, PP	8 to 102	(24)
4	Spanish	21 Brands of commercial salts	Black, blue, red, white, transparent	Fibres	PET, PP, PE	50 to 280	(25)
5	Malaysia	17 Brands of commercial salts	Phthalocyanine, hostaperm blue, hostasol green, chrome yellow	Fragments, fibres/ filaments, and films	Nylon-6, PP, PET, PE, PS/ polyisoprene, polyacrylonitrile	1 to 10	(26)
6	Nigeria	4 Table salts		Fragments, fibres	PP, PE, Polyvinyl acetate	0-0.33±0.38	(28)
7	Italy and Croatia	Commercial salt	Grey, blue, black, white, yellow	Fragments and fibres	PP, PET	4.4 to 55	(32)
8	USA	12 Brands of commercial salts	Blue, red	Fibres	NA	46.7 to 806	(33)
9	India	25 salts from salt pans	White, green, blue, colourless	Fragments, fibres	PP, PE, nylon, cellulose	60% of total pollutants in salt are MPs	(36)
10	Italy and Croatia	11 Brands of commercial salts	Green, black, blue, pink, red, yellow	Fibres	Cellulose acetate, PET, PVC, nylon, PP, PA, PS, PE	0.47–0.88 0.19 to 0.56	(37)
11	Taiwan	Commercial salts	NA	Fragments	PP, PE, PS, PES, PET, polyetherimide, polyoxymethylene	9.77	(38)
12	India	6 Brands of commercial salts	Black, blue, red, white, green	Fibres	Nylon, LDPE, PP PET	467±115 to 1633±153	(39)

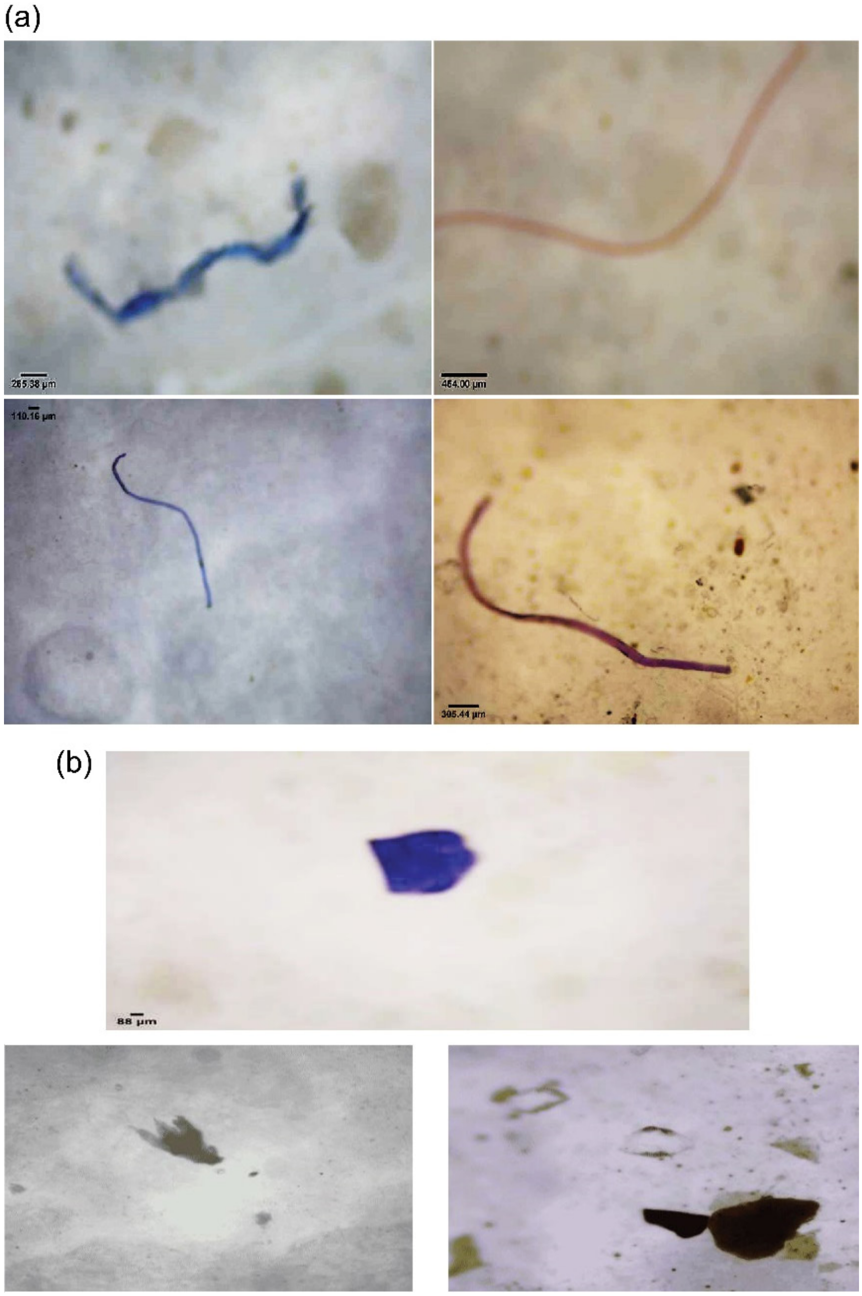

Figure 3. **(a)** Microscopic images of filter showing MPs recovered from salt samples – fibre. **(b)** Microscopic images of filter showing MPs recovered from salt samples – fragments

MPs contamination of table salts around the globe varies widely and perhaps needs further data to ultimately develop regulator standards for quality control soon.

As for the colours of MPs obtained from this study, the blue MPs found in the studied table salts could mean that they were new to the environment. A similar colour was observed in the study of Nithin et al (39). The breakdown of packaging materials and clothing has been reported to bring about coloured MPs, while colourless MPs were envisaged to be due to the wear and tear of fishing nets and lines (40).

Ingestion of microplastics and human health risk

MPs are ubiquitous and pose an environmental threat. The presence of MPs in the environment poses a negative risk to health (25,41). The MPs are known vectors; they carry adsorbed organic pollutants polychlorinated biphenyls and inorganic pollutants like heavy metals, and also, leach additives like bisphenol into the surrounding environment. They adsorb these pollutants due to the small surface area and transfer them to products like fish and salts (42). Therefore, the presence of MPs in sea salts could pose threats to food safety and human health ultimately.

Based on the WHO recommendations, an adult should take about 5 g of salt daily (29). Given the WHO recommendation, an equivalent of about 1.825 kg of table salt would be consumed by an adult per year. Using the average of 12 MP particles in salt per kg, there would be an intake of 21.9 MP particles per year. The MPs estimated to be consumed per year in this study, are similar to those estimated from the intake of salt from Hungary (21.9 MPs/year) by Kim et al (43). However, the value is lower than the amount estimated to be consumed from the intake of table salts from Taiwan (35.8 MP particles/year) (38), and much lower when compared to other studies (Table 4).

Conclusion

This study showed that MPs are present in 75% of commonly consumed iodized and non-iodized table salts within South-Western Nigerian markets. This study will contribute to the global report on the contamination of MPs in table salts and sensitize the public on the need to minimize the intake of table salts, as much as possible. It has been indicated that the possible source of MPs is the production process. Thus, efforts should be made to improve the quality of table salts produced and distributed in Nigerian markets.

MPs are present everywhere including sea products but the potential health effects are yet to be fully understood.

Table 4. Estimated quantities of MPs ingested by the consumer of table salt per year based on the salt type

Origin	Salt type	Reported MPs concentrations (particles/kg)	Estimated MPs ingested (particles/year)
Nigeria (This study)	Rock salt	12	21.9
Australia	Sea salt	0-80	0-146
Brazil	Sea salt	200	365
China	Sea salt	120-718	219-136.35
Croatia	Sea salt	800-19800	1460-36135
France	Sea salt	0-2	0-3.65
Germany	Rock salt	2	3.65
Hungary	Rock salt	12	21.9
India	Sea salt	3-8	5.475-14.6
Indonesia	Sea salt	100	182.5
Italy	Sea salt	5-59	9.125-107.675
Italy	Rock salt	80	146
Japan	Sea salt	0-1	0-1.825
Korea	Sea salt	266	485.45
Malaysia	Sea salt	173	315.725
Portugal	Sea salt	0-10s	0-18.25
South Africa	Sea salt	1-3	1.825-5.475
Spain	Sea salt	50-280	91.25-511
Thailand	Sea salt	80-600	146-1095
Turkey	Sea salt	18-84	32.85-153.5
United Kingdom	Sea salt	120	219
USA	Sea salt	47-300	85.775-547.5
USA	Rock salt	5	9.125

Note: These estimates were based on the WHO recommendation of a 5 g daily intake of table salt (29).
WHO: The World Health Organization.

Hence, there is a need for more research on MPs in food products, and their potential impact on health should be established.

Acknowledgements

The authors would like to appreciate Mrs Faith Nwadike and Ms. Leye Abioye of the Department of Basic Sciences and Dr. Abolanle Akeredolu of the Department of Microbiology, Babcock University, for their technical support.

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Competing interests

The authors declare no conflict of interest regarding the publication of this manuscript

Ethical issues

The authors have critically observed ethical issues and no data from this manuscript has been or will be published separately elsewhere.

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