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Occurrence and Concentration of Microplastics in Bottled Water in Baghdad City

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ABSTRACT: One of the emerging concerns in the environment is the presence of microplastic in drinking water since it has been linked to human consumption. In the present study, the aim was to study the presence and concentration of micro plastic particles and to determine the physicochemical parameters of the commercial bottled drinking water in the city of Baghdad, Iraq. In February 2026, 10 local markets were visited, and a water sample was collected from each of the brands, with a total of three samples collected for each brand. Samples were stained with 30% hydrogen peroxide, filtered through a 38 µm sieve and 0.45 µm membrane filters and observed under fluorescent microscope with Nile Red staining. Conventional analytical procedures were used to determine the physicochemical characteristics. The statistical analysis was done using GraphPad Prism . All brands were found to contain microplastic pieces, with the following average abundances of microplastics per litre: 14.00 ± 2.00 particles/L in brand D to 34.00 ± 2.00 particles/L in brand I. There were significant variations across brands (P = 0.0015). The physicochemical investigation revealed big variations between the commercial brands on their electrical conductivity and there content of dissolved ionic constituents. Significant differences existed between the glass bottled water and plastic bottled water for electrical conductivity, total dissolved solids, potassium, chloride, sulfate and bicarbonate concentrations. The independent comparison of the number of microplastic fragments did not show any significant difference between brand E and brand

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K (P = 0.1000). The results indicated that the bottled water products offered in Baghdad varies in the amount of microplastic fragments and chemical makeup. To conduct future studies on bottled drinking water quality, more research is required on contaminating sources and to improve analytical consistency and reliability for polymer-specific identifications and sampling.

Keywords: *Microplastics; Bottled drinking water; Nile Red staining; Fluorescence microscopy; Baghdad City.*

Introduction

The manufacturing, utilization, and breakdown of plastic products, on a global scale, have created a significant environmental issue, especially in terms of microplastic contamination (Ziani et al., 2023). Microplastics (MPs) are generally defined as particles of plastic less than 5 mm in size and can be either manufactured to be that small (primary microplastics) or result from breaking larger plastic objects into smaller pieces and decomposing them (secondary microplastics) (Laskar & Kumar, 2019). These particles were discovered in many environmental compartments, such as marine environments, freshwater, soil, sediments and drinking water, which suggests their ubiquitous dispersion and persistence in the environment (Koelmans et al., 2019). Concern is growing about the possibility for human exposure via the consumption of contaminated food and water, while the long-term health effects are little known (Eerkes-Medrano et al., 2018). Water is a regular use, and it is known as a potential source of exposure to humans for microplastics (Akbari et al.,2024). Bottle water is frequently chosen for its convenience, availability and its perceived quality. But several studies have proved that commercially bought bottled water can have micro-plastic particles. Mason et al. (2018) conducted a study on synthetic polymer contamination in bottled water from various commercial brands, and in 75% of the samples they analysed they detected microplastic particles. Similarly, Oßmann et al. (2018) detected small-sized microplastic particles and colored particles in bottled mineral water, which suggests the potential for human exposure from bottled water. These results highlight the need for studies on microplastic contamination in commercially available drinking water (Ahmad et al., 2025). There are a number of factors that can influence the presence and concentration of micro plastics in bottled water such as source of water, treatment and filtering process, bottling process, packaging materials and storage

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conditions (Taheri et al., 2022). Particles can be generated from plastic bottles and caps by mechanical abrasion, friction and deterioration in manufacturing, transport, and the many times they are handled (Gambino et al., 2022). Moreover, micro plastic pollution is not only a problem with plastic packaging products, a glass bottle can also contain particles. Bottled mineral water was investigated by Schymanski et al. (2018) in a range of container materials with variation found in the incidence of microplastics among the different packaging materials. Kankanige and Babel (2020) also investigated microplastic pollution in single use polyethylene terephthalate (PET) bottled water in Thailand giving more evidence of microplastic incidence in commercially accessible drinking water (Rahman et al., 2025). So, depending on the production process, packing material and environment exposure, variations in the amount of particle content per commercial brand are possible (Bhowmik & Saha, 2025). The microplastics can be present in a variety of shapes, such as fragments, fibres, films, pellets and foams. Among these types, fragments are usually of irregular shape and might be the result of physical degradation of bigger plastic materials (Hebner & Maurer-Jones, 2020). The number and characteristics of the identified particles may vary based on the sample processes, the ranges of particle sizes, the extraction techniques and the analytical equipment used (Balkenbusch et al., 2025). Therefore, large discrepancies have been seen in the levels of microplastics in drinking water investigations, which are partially explained by the disparities in analytical techniques and detection limits (Cheng et al., 2025). Danopoulos et al. (2020) highlighted the importance of adopting standardized sampling and analytical approaches to enhance the reliability and comparability of reporting the presence of microplastics in drinking water in a comprehensive assessment. Different analytical strategies have been developed for the detection and characterization of microplastics in ambient water and drinking water. They are optical microscopy, fluorescence microscopy, Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy (Agbasi et al., 2024). The combination of fluorescence microscopy and Nile Red staining has been a focus of much research as a viable screening tool for the detection of microplastic-like particles (Jin et al., 2026). Nile Red is a fluorescent dye, which binds to hydrophobic surfaces and allows the detection of stained particles under fluorescence light. Erni-Cassola et al. (2017) showed the use of Nile Red staining for the identification and quantification of tiny microplastic particles in environmental samples. However, fluorescence-based inspection cannot be entirely relied

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upon to clearly differentiate a polymer as some nonplastic particles might fluoresce as well. Particles detected only using fluorescence microscopy should, therefore, be classified as suspected microplastics until proven to be polymer using an appropriate chemical analysis approach (Surendran et al., 2025). The global studies of drinking water contamination with microplastics are increasing but more studies are needed to define commercially available bottled water in different geographic areas (Chang & Yang, 2026). The presence and characteristics of microplastic particles could vary depending on the source of the water, the method of bottling, packaging materials and distribution conditions (Xu et al., 2025). Iraq is one of the great metropolises where many different brand of bottled drinking water is commercially available (Abbas et al., 2025). The detection and quantification of potential plastic microfragments in these products could provide some useful baseline data and could be a part of future monitoring and environmental studies (Cai et al., 2025). The number and concentration of suspected microplastic particles in commercially available bottled drinking water were collected from the local markets of the Baghdad City, Iraq (Al-Aadhami et al., 2025; AbdelJabbar & Kamel, 2026). The study was specifically designed to quantify the fluorescent fragment-shaped particles, by Nile Red staining and fluorescence microscopy, to compare the abundance of fragment-shaped particles in various commercial brands and in different categories of packaging, and to assess selected physicochemical properties of the water samples studied. The results are provided as background data on potential microplastic contamination of bottled drinking water and for future drinking water quality and potential sources of microplastic exposure research.

2. Materials and Methods

2.1. Study Area and Sample Collection

The present research aimed at studying the level and occurrence of micro-plastic particles in commercially available drinking water from Baghdad City, Iraq. In February 2026, water samples of 10 different commercial brands (A, B, C, D, E, F, G, H, I and J) were collected from the local retail markets of Baghdad. Three different bottled water samples were taken from each brand to enable repeat measurements for physicochemical and microplastic analyzes. The samples analyzed were 250 mL plastic and 330 mL glass bottle sized bottled water. The collected samples were transferred to the Environment and Water

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Research and Technology Center, Scientific Research Authority, Ministry of Science and Technology, Iraq where the laboratory studies were performed. The physicochemical analyzes and the microplastics exams were carried out and results were obtained in May 2026. The analysis is divided into two parts: chemical and physical.The analysis is conducted in two stages: Chemical and Physical. The bottled water samples were analyzed for physicochemical parameters to indicate the differences in the quality of water of selected commercial brands. The parameters measured include pH, electrical conductivity (EC), total dissolved solids (TDS), calcium (Ca2+), magnesium (Mg2+), sodium (Na+), potassium (K+), chloride (Cl-), sulfate (SO42-), bicarbonate (HCO3-), carbonate (CO32-) and nitrate (NO3-). The pH value was measured using a pH meter while the electrical conductivity was measured using an EC meter and reported in µS/cm. Total dissolved solids were measured gravimetrically. The calcium and magnesium were estimated by titrimetric method with ethylenediaminetetraacetic acid (EDTA) . Flame photometer (AFP100) was used for measuring sodium and potassium concentrations. The content of chloride was determined by argentometric titration (Mohr technique), the concentration of sulfate by UV spectrophotometry. Acid-Base titration of suitable indicators and hydrochloric acid (HCl) was used to assess the bicarbonate and the carbonate. Table 1 shows the analytical procedures and the equipments used for water quality evaluation.

Table 1. Physicochemical parameters, analytical methods, and instruments used for bottled water analysis.

Parameter	**Analytical method / Instrument**
pH	pH meter
Electrical conductivity (EC, µS/cm)	EC meter
Total dissolved solids (TDS, mg/L)	Gravimetric method
Calcium (Ca^{2+}, mg/L)	EDTA titrimetric method
Magnesium (Mg^{2+}, mg/L)	EDTA titrimetric method
Sodium (Na^{+}, mg/L)	Flame photometer (AFP100)
Potassium (K^{+}, mg/L)	Flame photometer (AFP100)
Chloride (Cl^{-}, mg/L)	Argentometric titration (Mohr method)
Sulfate (SO_4^{2-}, mg/L)	UV spectrophotometric method
Bicarbonate (HCO_3^{-}, mg/L)	Acid–base titration using HCl
Carbonate (CO_3^{2-}, mg/L)	Acid–base titration using HCl

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2.3. Sample Preparation, Digestion, and Filtration

The sampling of bottled water for analysis of microplastic was performed by using digestion and filtering approach in accordance to the reported technique of Manzoor et al. (2021) and also as per the available methods for microplastic analysis in aquatic environment (Mai et al., 2018). At first, 250 mL of each bottled water sample was put into a glass container and 20 mL of hydrogen peroxide (H 2 O 2 , 30%) was added to aid the breakdown of organic debris which may interfere with the microscopic identification of microplastic particles. Time was allowed for the digestive process to occur (24-48 hours). The materials were digested and then filtered through a 38 µm screen sieve to remove the suspended particles. The sieve was then washed several times using distilled water which flowed from the outside to the inside and down the side walls in an attempt to recover the particles. The rinse water (which contained the collected particles) was placed in a 2 L glass beaker. The rinse water was collected and filtered through a Millipore glass filtering device connected to a vacuum pump. Particulate material was filtered on 0.45-µm pore-size cellulose membrane filters. Each membrane filter was carefully put onto a glass Petri plate after filtration. The sample identification number and size of the sieve were inscribed on the lid of the dish for identification of the sample during microscopic observation. Constructed membrane filters were then characterized by fluorescence, to detect and quantify the presence of suspected microplastic particles.

2.4. Nile Red Staining and Fluorescence Microscopy

Bottled water samples were tested for the presence of possible microplastic particles using fluorescence microscopy and Nile Red dye and were characterized visually. The Nile Red was selected as a fluorescent dye that makes the hydrophobic particles visible with the fluorescent light as it is a staining technique. Previously, the use of fluorescence-assisted microscopy for the identification of occurrence and characterisation of aquatic microplastics has been studied (Cheng et al., 2021; Mai et al., 2018; Primpke, 2020). The Nile Red staining solution was made by dissolving Nile Red powder in acetone to a final concentration of 5 mg/L. The prepared solution was held for 24 hours before to use. The membrane filters obtained after digestion and filtering were stained with Nile Red solution, and then air-dried for ~30 min. The stained membrane filters were examined with an Italian made BEL Engineering fluorescence microscope at ×20 magnification. Fluorescent

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particles were seen and visually characterized based on their morphological features. Special attention was paid to particles morphologically classified as pieces, which are irregular shaped particles.Particles morphologically categorized as pieces are irregular shaped particles that were paid special attention. The counts of fluorescent fragments were made for each membrane filter for every sample. Microscopic identification of particles was based on the fluorescence response and microscopic morphology. As a result the particles found were described as suspected microplastic fragments, as no polymer-specific chemical characterisation was carried out. The presence and quantitative counts of fragment-shaped particles in the examined bottled drinking water can be approximated using the inspection with the help of fluorescence microscopy.

2.5. Quantification of Microplastic Fragments

Quantification of suspected micro-plastic fragments was performed by counting the particles which were detected on the membrane filters under microscopic analysis and were shaped as fragments of plastic. Each of the three independent samples was individually recorded for the number of particles for each commercial brand.

The number of the microplastic fragments was therefore expressed as the number of particles per litre (particles/L) to enable comparisons with other published studies of bottled water. The number of particles obtained were normalized to the amount of water studied by applying the following equation:

$C = N \times 1000/V$, with C = abundance of fragments (particles/L) in the water sample, N = the number of fluorescent fragments in the sample, and V = the volume of the water (in mL) measured in the sample.

The abundance values collected were used to determine if differences in occurrence of suspected microplastic fragments among the different brands of bottled water and packaging categories were present. The abundance of particles was not based on gravimetric microplastic concentration but on the number of particles.

2.6. Statistical Analysis

Analysis of the data was carried out with GraphPad Prism Software (Version 10.6.1). The Shapiro-Wilk test was used to determine if data was normally distributed. Mean ± SD

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(standard deviation) is presented for parametric data and median and interquartile range (IQR: 25%-75%) is presented for nonparametric data. Unpaired Student's t-test was used to compare 2 independent groups of data that were normally distributed. The differences between several groups were evaluated using one-way ANOVA and Tukey's multiple comparisons test. The Mann–Whitney U test was performed for comparisons between two independent groups for non parametric data, and multiple comparisons test (Dunn's test) was used for more than two independent groups. P values of ≤ 0.05 were considered statistically significant. All the statistical procedures were performed following the widely accepted rules for biostatistical analysis (Pagano et al., 2022).

Result

3.1. Occurrence and Abundance of Microplastic Fragments in Bottled Water

The mean abundance of microplastic fragments, expressed as particles per liter, ranged from 14.00 ± 2.00 particles/L in brand D to 34.00 ± 2.00 particles/L in brand I. Brand I exhibited the highest particle abundance, followed by brand H (27.67 ± 0.58 particles/L), whereas the lowest values were recorded in brands D (14.00 ± 2.00 particles/L) and A (15.67 ± 0.58 particles/L). Brands C and F showed identical mean values of 23.67 ± 0.58 particles/L, while brands E and G recorded 22.00 ± 2.00 particles/L. The abundance of microplastic fragments in the investigated bottled water brands is presented in Table 2.

Table 2. Abundance of suspected microplastic fragments in bottled drinking water from different commercial brands in Baghdad City.

Water brand	Microplastic fragments (particles/L), Mean ± SD
A	15.67 ± 0.58
B	18.00 ± 2.00
C	23.67 ± 0.58
D	14.00 ± 2.00
E	22.00 ± 2.00
F	23.67 ± 0.58
G	22.00 ± 2.00
H	27.67 ± 0.58
I	34.00 ± 2.00
J	19.67 ± 0.58

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Values are expressed as mean ± standard deviation (SD), based on three samples per brand (n = 3).

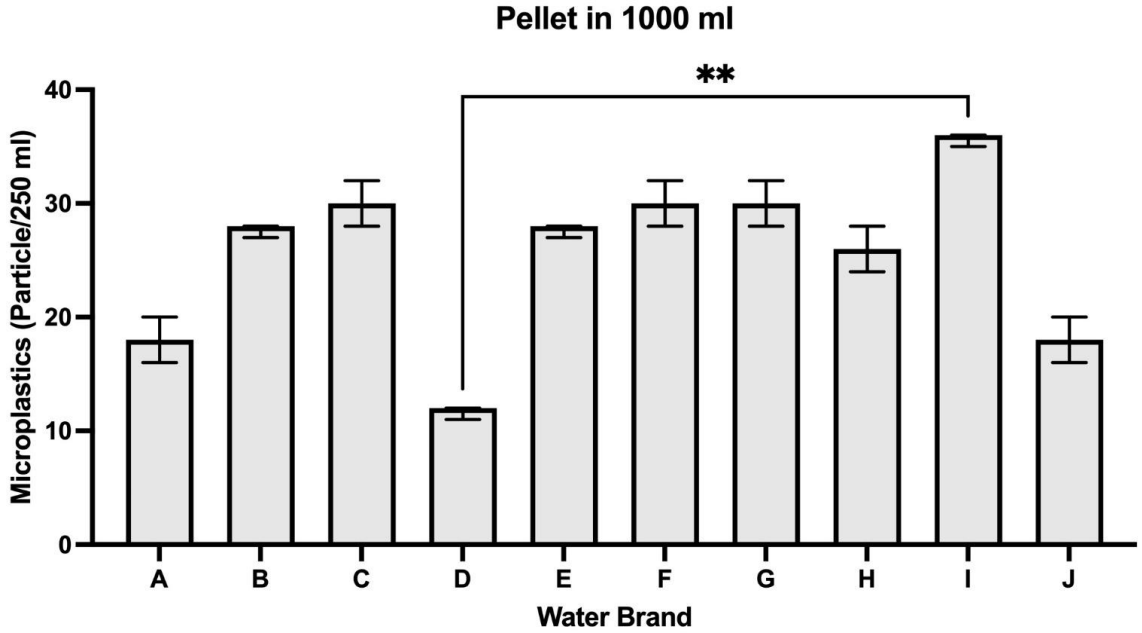


Figure 1. Abundance of suspected microplastic fragments in bottled drinking water from ten commercial brands in Baghdad City (particles/L).

3.2. Physicochemical Characteristics of Bottled Water

The physicochemical analysis of bottled drinking water revealed considerable variations in the concentrations of dissolved ions and electrical conductivity among the ten investigated commercial brands (A–J). The examined parameters included electrical conductivity (EC), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), bicarbonate (HCO_3^{-}), and nitrate (NO_3^{-}). The mean concentrations and standard deviations of these parameters are presented in Table 3.

Electrical conductivity varied significantly among the investigated brands ($F(9, 20) = 1333$, $P < 0.0001$). The highest mean EC was recorded in brand C (133.25 ± 1.52 µS/cm), followed by brand B (122.42 ± 1.91 µS/cm) and brand A (121.32 ± 1.41 µS/cm). In contrast, the lowest EC was observed in brand G (49.89 ± 0.58 µS/cm), followed by brand I (60.89 ± 1.28 µS/cm).

Calcium concentrations also showed significant differences among commercial brands ($F(9, 20) = 69.40$, $P < 0.0001$). The highest calcium concentration was detected in brand H

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(30.00 ± 2.00 mg/L), followed by brand J (23.67 ± 1.53 mg/L), whereas brand G exhibited the lowest concentration (3.33 ± 1.53 mg/L). Similarly, magnesium concentrations differed significantly among brands ($F(9, 20) = 60.72$, $P < 0.0001$), with the highest concentration observed in brand H (12.83 ± 0.76 mg/L) and the lowest in brand F (1.20 ± 0.20 mg/L).

Sodium concentrations varied among the examined brands, ranging from 2.33 ± 0.58 mg/L in brand G to 18.67 ± 1.53 mg/L in brand B. The Kruskal–Wallis test indicated significant differences in sodium concentrations among brands ($H = 26.78$, $P = 0.0015$). Potassium concentrations also differed significantly ($F(9, 20) = 6.091$, $P = 0.0004$), with the highest mean concentration recorded in brand A (2.17 ± 0.21 mg/L), while the lowest concentrations were observed in brands J and I (0.53 ± 0.15 mg/L).

Chloride concentrations showed statistically significant variations among the studied brands ($F(9, 20) = 62.97$, $P < 0.0001$). Brand C recorded the highest mean chloride concentration (23.33 ± 1.53 mg/L), followed by brand B (21.33 ± 1.53 mg/L), whereas brand I exhibited the lowest concentration (5.33 ± 1.53 mg/L). Significant differences were also observed in bicarbonate concentrations ($F(9, 20) = 93.75$, $P < 0.0001$). The highest bicarbonate concentration was recorded in brand C (31.67 ± 1.53 mg/L), while brand E showed the lowest concentration (7.33 ± 1.53 mg/L).

Nitrate concentrations were relatively low across the investigated brands, ranging from 0.53 ± 0.15 mg/L in brand E to 3.33 ± 1.53 mg/L in brand C. One-way ANOVA indicated statistically significant differences in nitrate concentrations among the commercial brands ($F(9, 20) = 3.249$, $P = 0.0135$).

Table 3. Physicochemical characteristics of bottled drinking water from ten commercial brands in Baghdad City

Brand	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	NO_3^{-}
A	121.32 ± 1.41^{b}	11.67 ± 1.53^{cd}	3.33 ± 0.12^{bc}	13.33 ± 1.53	2.17 ± 0.21	11.67 ± 0.58^{b}	25.33 ± 1.53^{c}	0.77 ± 0.15
B	122.42 ± 1.91^{b}	13.67 ± 1.53^{cd}	2.33 ± 1.53^{c}	18.67 ± 1.53	0.97 ± 0.21	21.33 ± 1.53^{cd}	22.67 ± 1.53^{c}	1.00 ± 0.20
C	133.25 ± 1.52^{a}	14.00 ± 1.00^{cd}	2.53 ± 0.55^{bc}	17.67 ± 0.58	0.77 ± 0.15	23.33 ± 1.53^{d}	31.67 ± 1.53^{d}	3.33 ± 1.53

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D	105.12 ± 1.01^{d}	14.33 ± 2.08^{c}	4.57 ± 0.15^{b}	10.33 ± 1.53	1.33 ± 0.25	10.00 ± 1.00^{ab}	12.00 ± 1.00^{b}	0.67 ± 0.15
E	72.18 ± 1.46^{e}	9.33 ± 1.53^{df}	1.47 ± 0.47^{c}	9.33 ± 0.58	2.10 ± 0.26	6.67 ± 1.53^{ab}	7.33 ± 1.53^{a}	0.53 ± 0.15
F	71.71 ± 1.56^{e}	5.33 ± 1.53^{ef}	1.20 ± 0.20^{c}	9.33 ± 1.15	1.27 ± 0.31	10.33 ± 1.53^{ab}	13.67 ± 0.58^{b}	1.43 ± 0.51
G	49.89 ± 0.58^{g}	3.33 ± 1.53^{e}	1.27 ± 0.15^{c}	2.33 ± 0.58	0.93 ± 0.15	5.67 ± 1.53^{a}	12.33 ± 1.53^{b}	1.10 ± 0.26
H	120.87 ± 1.25^{b}	30.00 ± 2.00^{a}	12.83 ± 0.76^{a}	12.33 ± 1.53	1.67 ± 1.15	11.67 ± 1.53^{bc}	9.67 ± 1.53^{ab}	1.43 ± 0.59
I	60.89 ± 1.28^{f}	12.00 ± 2.00^{cd}	4.67 ± 1.53^{b}	2.67 ± 0.58	0.53 ± 0.15	5.33 ± 1.53^{a}	10.67 ± 1.53^{ab}	2.33 ± 1.53
J	112.71 ± 1.85^{c}	23.67 ± 1.53^{b}	5.27 ± 0.15^{b}	8.67 ± 1.53	0.53 ± 0.15	18.67 ± 1.53^{c}	13.33 ± 1.53^{b}	1.67 ± 1.15
P-value	<0.0001	<0.0001	<0.0001	0.0015	0.0004	<0.0001	<0.0001	0.0135

Values are expressed as mean ± standard deviation (SD), n = 3. EC is expressed in µS/cm, whereas all ionic concentrations are expressed in mg/L.

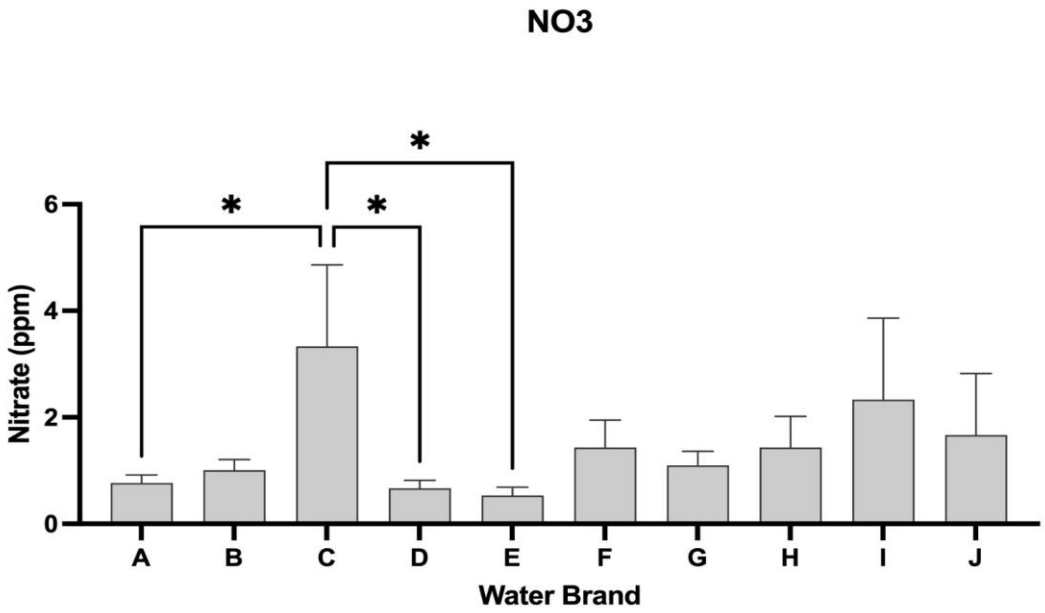


Figure 2. Variation in nitrate (NO_3^-) concentrations among different commercial bottled water brands in Baghdad City.

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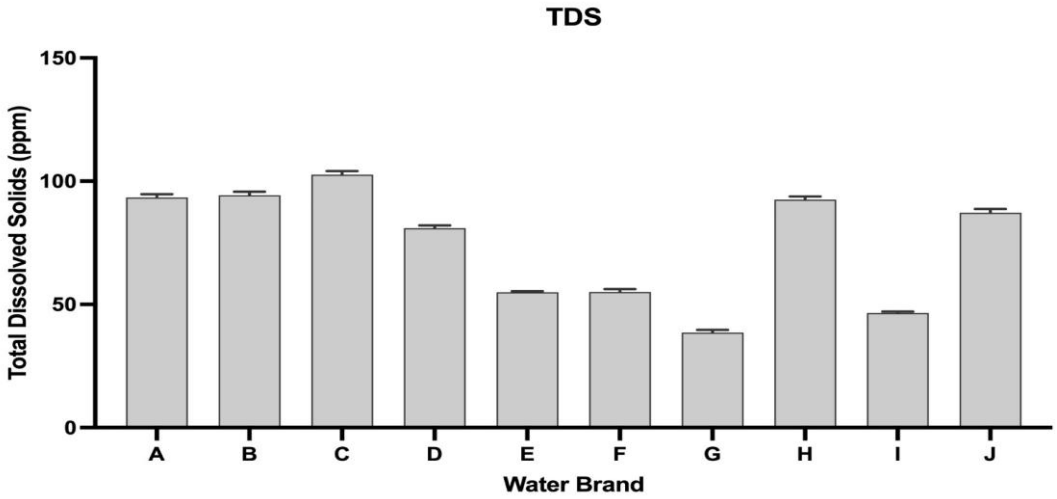


Figure 3. Variation in total dissolved solids (TDS) among different commercial bottled water brands in Baghdad City.

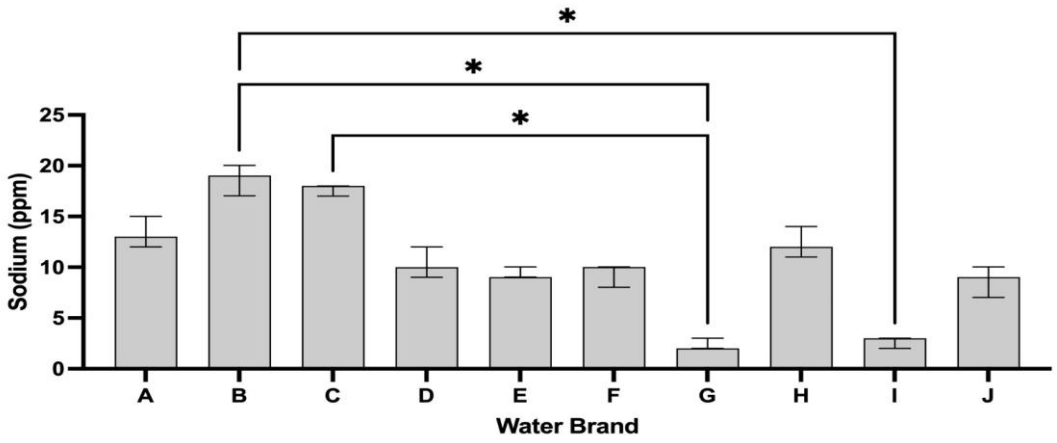


Figure 4. Variation in sodium (Na^+) concentrations among different commercial bottled water brands in Baghdad City.

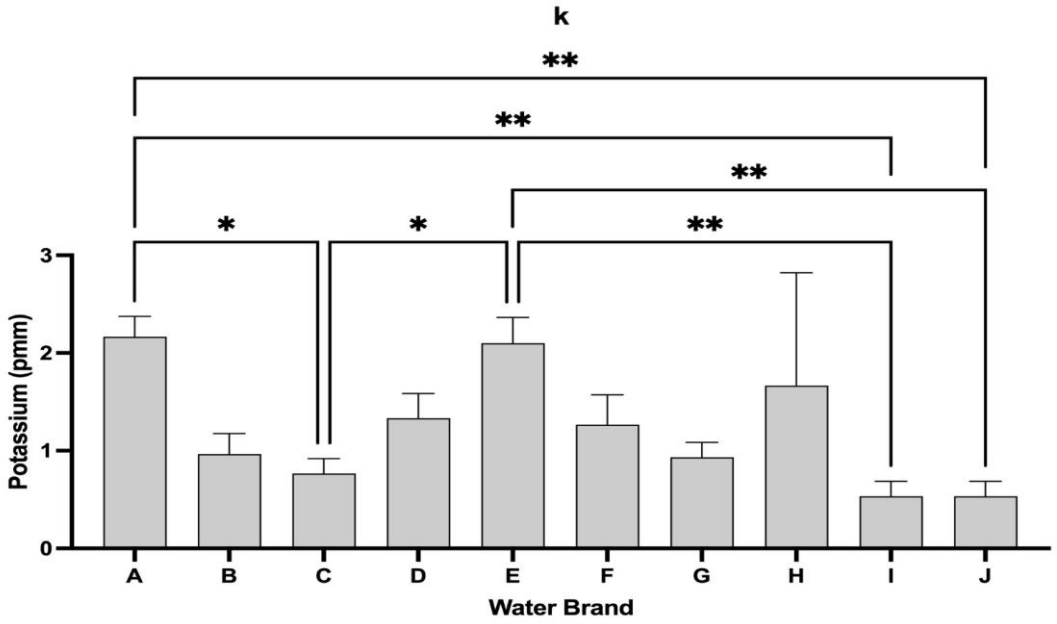


Figure 5. Variation in potassium (K^+) concentrations among different commercial bottled water brands in Baghdad City.

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3.3. Comparison of Physicochemical Parameters Between Glass and Plastic Bottled Water

The comparison of physicochemical characteristics between bottled water packaged in glass and plastic containers revealed significant differences in several measured parameters. The results of the statistical analysis are presented in Table 4.

Electrical conductivity (EC) was significantly higher in glass-bottled water (80.83 ± 1.38 µS/cm) than in plastic-bottled water (72.18 ± 1.46 µS/cm), with a statistically significant difference (P = 0.0017). Similarly, total dissolved solids (TDS) were significantly higher in glass bottles (59.43 ± 0.78 mg/L) compared with plastic bottles (54.93 ± 0.40 mg/L; P = 0.0009).

Significant differences were also recorded in chloride and bicarbonate concentrations. Chloride concentration was higher in glass-bottled water (12.00 ± 2.00 mg/L) than in plastic-bottled water (6.67 ± 1.53 mg/L; P = 0.0214). Bicarbonate concentration was also significantly higher in glass bottles (19.00 ± 1.00 mg/L) compared with plastic bottles (7.33 ± 1.53 mg/L; P = 0.0004).

In contrast, sulfate and potassium concentrations were significantly higher in plastic-bottled water. Sulfate concentration reached 20.33 ± 1.53 mg/L in plastic bottles compared with 9.33 ± 1.53 mg/L in glass bottles (P = 0.0009). Potassium concentration was 2.10 ± 0.26 mg/L in plastic bottles and 0.57 ± 0.25 mg/L in glass bottles (P = 0.0019).

No statistically significant differences were observed between glass and plastic bottled water in pH, calcium, magnesium, sodium, or nitrate concentrations (P > 0.05). The mean pH values were 7.23 ± 0.21 and 7.37 ± 0.15 in glass and plastic bottles, respectively. Calcium concentrations were 8.67 ± 0.55 and 9.33 ± 1.53 mg/L, while magnesium concentrations were 2.33 ± 1.53 and 1.47 ± 0.47 mg/L, respectively. Sodium concentrations were identical in both groups (9.33 mg/L), whereas nitrate concentrations were 1.00 ± 0.36 mg/L in glass and 0.53 ± 0.15 mg/L in plastic bottles.

Table 4. Comparison of physicochemical characteristics between glass and plastic bottled water.

Parameter	Glass (Mean ± SD)	Plastic (Mean ± SD)	P-value
pH	7.233 ± 0.208	7.367 ± 0.153	0.4216
EC (µS/cm)	80.83 ± 1.38	72.18 ± 1.46	**0.0017**
TDS (mg/L)	59.43 ± 0.78	54.93 ± 0.40	**0.0009**

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Ca^{2+} (mg/L)	8.667 ± 0.551	9.333 ± 1.528	0.5163
Mg^{2+} (mg/L)	2.333 ± 1.528	1.467 ± 0.473	0.4010
Na^{+} (mg/L)	9.333 ± 1.528	9.333 ± 0.577	>0.9999
K^{+} (mg/L)	0.567 ± 0.252	2.100 ± 0.265	**0.0019**
Cl^{-} (mg/L)	12.00 ± 2.00	6.667 ± 1.528	**0.0214**
SO_4^{2-} (mg/L)	9.333 ± 1.528	20.33 ± 1.528	**0.0009**
HCO_3^{-} (mg/L)	19.00 ± 1.00	7.333 ± 1.528	**0.0004**
NO_3^{-} (mg/L)	1.000 ± 0.361	0.533 ± 0.153	0.1079

Values are expressed as mean ± standard deviation (SD), n = 3 per group. P-values were determined using the unpaired t-test or Mann–Whitney U test, as appropriate. Bold P-values indicate statistically significant differences at $P \leq 0.05$.

3.4. Comparison of Microplastic Fragments and Physicochemical Parameters Between Brands E and K

The mean abundance of suspected microplastic fragments in the 330 mL comparison was higher in brand E (5.00 ± 0.50 fragments) than in brand K (3.33 ± 0.58 fragments). However, the Mann–Whitney U test indicated that this difference was not statistically significant (U = 0, P = 0.1000). Similarly, the reported fragment counts for the 990 mL comparison were higher in brand E (15.00 ± 0.10 fragments) than in brand K (10.00 ± 1.73 fragments), without a statistically significant difference (U = 0, P = 0.1000).

The physicochemical comparison showed significant differences in calcium concentration and electrical conductivity. Calcium concentration was significantly higher in brand K (23.67 ± 1.53 mg/L) than in brand E (8.67 ± 0.55 mg/L; P < 0.0001). Electrical conductivity was also significantly higher in brand K (142.7 ± 1.53 µS/cm) compared with brand E (80.83 ± 1.38 µS/cm; P < 0.0001).

In contrast, no statistically significant differences were observed in chloride, potassium, or nitrate concentrations between the two brands (P > 0.05). Chloride concentrations were 12.00 ± 2.00 and 10.67 ± 1.53 mg/L in brands E and K, respectively (P = 0.4107). Similarly, potassium concentrations were 0.567 ± 0.252 and 0.667 ± 0.153 mg/L (P = 0.5879), while nitrate concentrations were 1.00 ± 0.36 and 1.20 ± 0.26 mg/L, respectively (P = 0.4818).

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Table 5. Comparison of suspected microplastic fragment abundance and selected physicochemical parameters between bottled water brands E and K.

Parameter	Brand E (Mean ± SD)	Brand K (Mean ± SD)	P-value
Fragments / 330 mL	5.00 ± 0.50	3.33 ± 0.58	0.1000
Fragments / 990 mL	15.00 ± 0.10	10.00 ± 1.73	0.1000
EC (µS/cm)	80.83 ± 1.38	142.7 ± 1.53	**<0.0001**
Ca^{2+} (mg/L)	8.667 ± 0.551	23.67 ± 1.528	**<0.0001**
Cl^- (mg/L)	12.00 ± 2.00	10.67 ± 1.528	0.4107
K^+ (mg/L)	0.567 ± 0.252	0.667 ± 0.153	0.5879
NO_3^- (mg/L)	1.000 ± 0.361	1.200 ± 0.265	0.4818

Values are expressed as mean ± standard deviation (SD), n = 3. Comparisons were performed using the unpaired t-test or Mann–Whitney U test, according to the reported statistical analysis. Bold P-values indicate statistically significant differences at $P \leq 0.05$.

Discussion

The present study revealed microplastic particles in all 10 brands of bottled water tested in the Baghdad City with the observed mean number of particles per liter (pL) ranged from 14.00 ± 2.00 particles/L (brand D) up to 34.00 ± 2.00 particles/L (brand I). The brands varied significantly (P = 0.0015), implying that there is a diversity in the quantity of fragments produced in the commercially available bottled water products. This is in agreement with Mason et al. (2018) who found microplastic contamination in almost 93% of bottled water samples from several brands worldwide.

The abundance detected was lower than those reported by Kankanige and Babel (2020) who found mean concentration of 140 ± 19 particles/L in single use PET bottled water and 52 ± 4 particles/L in glass bottled water in Thailand. On the other hand, the bottled water samples collected in India by Sarlin et al. (2024) reported lower concentration from 3.00 ± 1.73 to 9.00 ± 1.00 particles/L. Care should be taken in the interpretation of such variations, as microplastic concentrations were reported, depending on the particle size, sample preparation and analysis methods. Danopoulos et al. (2020) indicated that there was considerable methodological diversity across the drinking water studies. Zuccarello et al. (2019) pointed out the relevance of small particle sizes when assessing microplastic exposure via bottled mineral water.

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Variations between brands could be because of varying sources of water, processing technology, or bottling/packaging materials. Schymanski et al. (2018) reported differences in the microplastic contamination of mineral water samples collected in boxes made of different materials, suggesting possible microplastic contamination from packaging. Similarly, Oßmann et al. (2018) also detected microplastics and colored particles in mineral water bottled in plastic and glass bottles. Furthermore, Pivokonsky et al. (2018) have reported the presence of micro plastic particles in both raw and treated drinking water, suggesting the potential for contamination from water sources and during the treatment process. The current investigation did not, however, directly locate the place of origin for the found items.

The physicochemical analyses revealed significant variations between the brands studied in terms of electrical conductivity and in the contents of the dissolved ions. The electrical conductivity varied from 49.89 ± 0.58 to 133.25 ± 1.52 µS/cm. The greatest calcium and magnesium contents were seen in brand H. The differences indicate differences in mineral composition of the bottled water. However, changes in mineral concentration alone do not necessarily indicate changes in microplastic pollution, as they are different aspects of water (Gouin et al., 2022).

The concentrations of EC, TDS, potassium, chloride, sulfate, and bicarbonate in bottled water collected from glass and plastic bottles showed a significant difference ($P < 0.05$) whereas no significant difference was obtained for pH, calcium, magnesium, sodium and nitrate. If the two brands (E and K) were analysed individually, then there were more microplastic pieces in brand E (15.00 ± 0.10 fragments/990 mL) than in brand K (10.00 ± 1.73 fragments/990 mL) ($P = 0.1000$). The findings should not be interpreted as evidence that package material alone affects water composition and/or quantity of microplastics. There are several environmental and analytical parameters that affect microplastics in aquatic environments (Li et al., 2018).

Fluorescence microscopy combined with Nile Red staining was easily used to detect and count the microplastic pieces. Microplastics can be identified and quantified by Nile Red staining (Shim et al., 2016) and a rapid screening method for microplastics detection based on fluorescence has been developed (Maes et al., 2017). It has also proven to be useful when detecting very small micro-plastics (Erni-Cassola et al., 2017). Fluorescence

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microscopy can not only identify the polymers, additional FTIR or Raman analysis is required for chemical identification. In a recent paper, Koelmans et al. (2019) emphasized the need for analytical quality and polymer identification to interpret the microplastic contents in drinking water.

Overall, the results provide baseline information on the amount of microplastic fragments and physicochemical parameters of commercially accessible bottled drinking water in Baghdad. There is still a need for further research with larger sample sizes, the identification of the polymers, and the use of different manufacturing batches to better understand the microplastic contamination and its likely sources (Marsden et al., 2019).

Concluding Remarks:

This preliminary study investigated the occurrence of microplastics in bottled drinking water, and the results suggest that microplastic particles are found in commercially available bottled water in Baghdad city, giving raise to potential concerns in relation to human exposure and long-term health consequences. Considering the exploratory nature of this work, further large-scale and long-term investigations are advised to describe more precisely the abundance, size distribution, polymer types, and origins of these particles. Future researches should also evaluate the application of advanced treatment techniques for bottled water, including membrane filtration (ultrafiltration, nanofiltration, and reverse osmosis), coagulation–flocculation followed by sand filtration, activated carbon adsorption, and electrocoagulation, in order to assess their effectiveness in removing microplastics and ensuring water safety.

Conclusion

The present study revealed that all the studied brands of bottled drinking water from Baghdad city contained microplastic particles and significant differences among the different brands in the concentration of the particle. The highest particle concentration (34.00 ± 2.00 particles/L) was found in brand I and the lowest (14.00 ± 2.00 particles/L) in brand D. Also, the physicochemical parameters like electrical conductivity and concentration of dissolved minerals were significantly different in bottled water. Several water quality parameters were significantly different between glass and plastic bottled water, but not brand E and K. The data obtained serve as basic data for the presence of

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microplastic in packaged drinking water sold in Baghdad. Additional testing, with larger sample sizes and polymer-specific analytical methods is recommended to improve identification of microplastic particles and determine the potential sources of microplastics.

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