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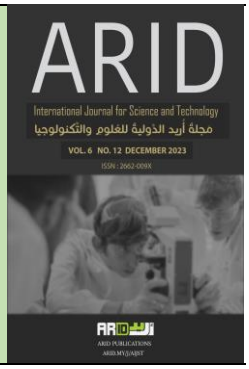

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The Effect of Heat and Storage Duration on Physicochemical Properties of Plastic Bottled Water at Sharq El Nile Locality in Khartoum State, Sudan

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تأثير التسخين وزمن التخزين على الخصائص الفيزيائية الكيميائية للمياه المعبأة في قارورة بلاستيكية في محلية شرق النيل بالخرطوم السودان

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ABSTRACT

The physicochemical properties of plastic bottled water were studied using the Inductively Coupled Plasma Emission Spectroscopy Technique (ICPE) before and after heating and storage duration. One sample was taken from Al Byara Well - Block (39) in Sharq El Nile Locality, Sudan at fall season in 2019.This sample was exposed to sunlight in plastic bottled for (50 days) and stored for (40 days). Before heating and storage duration, various macro and micro minerals such as (Sulfur, Calcium, Potassium, Magnesium, Sodium, Copper, Silicon, Manganese, and Zinc) have been detected with different concentrations at ((0.0057, 0.170,0.003, 0.390, 0.089, 0.016, 0.085,0.0014,and 0.00057) $(\times 10^{-3})(Kg/L)$) respectively. The concentrations some toxic and radioactive elements including (Cadmium, Holmium, Thallium, Barium, Scandium, and Strontium) were also appeared with various concentrations at ((1.3,1.5,27,0.62,0.31,and 0.77) $(\times 10^{-6})(\mu g/L)$) consecutively. These results may return to the location of sample, and vital activities. After heating and storage duration, concentrations of macro and micro minerals above were changed to (0.0047,0.190, 0.0026, 0.093, 0.072, 0.014,0. 067, 0.00, and 0.00) $(\times 10^{-3})(Kg/L)$) respectively. However, two new micro minerals which called (Iodine and Boron) was found with concentration at ((0.0095 and 0.00060) $(\times 10^{-3})(Kg/L)$ successively. Moreover, the concentrations of some toxic and radioactive elements above were modified to (1.1,0.00,24,0.65,0.23,and 0.96) $(\times 10^{-6})(\mu g/L)$) successively, and three new toxic elements like (Mercury, Nickle, and Antimony) were existed with concentrations at ((1.1,3.7,and 6.9) $(\times 10^{-6})(\mu g/L)$) respectively. These results may be attributed to the interaction between water and plastic and storage period. However, the results before and after heating and storage duration were discovered within background values except for (Thallium).

Keywords: Inductively Coupled Plasma Emission Spectroscopy, Concentration, Sunlight, Drinking Water, Plastic Bottled.

الملخص

في هذا العمل، استخدمت تقنية التحليل الطيفي لانبعاثات البلازما المقترنة بالحث لدراسة الخصائص الفيزيائية الكيميائية لعينة مياه المعبأة في قارورة بلاستيكية قبل وبعد التسخين وزمن التخزين. عينة واحدة تم أخذها من مياه بئر البيارة محلية شرق النيل بالسودان في فصل الخريف 2019. هذه العينة تم تعريضها لأشعة الشمس (50 يوما) من ثم (40 يوما). قبل التعريض التسخين وزمن التخزين، عدد من عناصر الماكرو والميكرو مثل (الكبريت، الكالسيوم، البوتاسيوم، المغنسيوم، الصوديوم، النحاس، السليكون، المنجنيز، والزنك) اكتشفت عند التراكيز ((0.0057، 0.17، 0.0026، 0.093، 0.089، 0.016، 0.085، 0.0014، و0.00057) $(\times 10^{-3})(Kg/L)$) على التوالي. بعض العناصر السامة والمشعة مثل (الكادميوم، الهومليوم، الثاليوم، الباريوم، الاسكانديوم، والاسترنشيوم) ظهرت عند التراكيز (1.3، 1.5، 27، 00.65، 0.31، و0.77 $(\times 10^{-6})(Kg/L)$) على التعاقب. هذه النتائج قد تعود إلى موقع العينة، الأنشطة الحيوية. بعد التسخين وزمن التخزين، تراكيز عناصر الماكرو والميكرو أعلاه قد تغيرت إلى ((0.0047، 0.190، 0.003، 0.390، 0.072، 0.014، 0.067، 0.0014، 0.00، و0.00) $(\times 10^{-3})(Kg/L)$) على التسلسل. عنصران جديدان من الميكرو وهما (اليود والبورون) اكتشف عند التركيز ((0.0095 و0.00060) $(\times 10^{-3})(Kg/L)$). تراكيز العناصر السامة والمشعة أعلاه قد تغيرت إلى (1.1، 0.00، 24، 0.65، 0.23، و0.96 $(\times 10^{-6})(Kg/L)$) على التتالي. وثلاثة عناصر سامة جديدة مثل (الفضة، النيكل، الأنتيمون) وجدت عند التراكيز (1.1، 3.7، و6.9 $(\times 10^{-6})(Kg/L)$) على التعاقب، وهذه النتائج تعود إلى التفاعل بين الماء والبلاستيك وفترة التخزين. النتائج قبل وبعد التعرض لأشعة الشمس وفترة التخزين وجدت في المدى ضمن القيم المرجعية باستثناء (الثاليوم).

كلمات مفتاحية: تقنية التحليل الطيفي لانبعاثات البلازما المقترنة بالحث، تركيز، ضوء الشمس، مياه الشرب، القوارير البلاستيكية.

1. Introduction:

Water performs a multitude of vital functions within our bodies by circulating nutrients, oxygen, and wastes products to and from our organs and cells. It plays a crucial role in regulating temperature and helps to keep us cool. Movement, it assists in the digestion and absorption of food, as well as in the elimination of waste materials from bodies [1-2].

Water molecules possess unique characteristics such as being odorless, tasteless, transparent, and ubiquitous, owing to their attractive properties [3]. Furthermore, water molecules have diverse physicochemical parameters, such as color, dissolved oxygen, temperature, pH, turbidity, chemical oxygen demand, biochemical oxygen demand, hardness, chloride, and sulphate [4-5]. The Water molecule contains various elements including macro, micro, toxic, and radioactive [6]. Macro and micro minerals, such as Calcium , Potassium, Magnesium, Sodium, Sulfur, Copper, Iron, Iodine , Rubidium, Silicon, and Lithium can be found in the water molecules [4-6] . Toxic and radioactive elements including Aluminum, Cadmium, Lead, Arsenic, Mercury, Silver, Uranium, Titanium, Thorium, Thallium , Holmium, Erbium, and Strontium can be present in drinking water and can cause severe health issues such as cancer, kidney failure, hemolytic anemia, integumentary, nervous, respiratory, cardiovascular, hematopoietic, immune, endocrine, hepatic, renal, diarrhea, stomach pains, bone fracture, and reproductive failure [7- 14].

On the other hand, Polyethylene (PE) is a simple polymer that is synthesized through the polymerization of (CH_2=CH_2). This material contains some very toxic and radioactive elements that can be hazardous to human health when exposed directly to the normal sunlight [15-17].

The Inductively Coupled Plasma Emission Spectroscopy Technique (ICPE) is utilized for detecting macro, micro, toxic, and radioactive metals, and determining their concentrations in various environmental samples like soil, powders, and drinking water. The principle of this

technique involves including elements. to emit light of specific wavelengths, which can then be measured. The ICPE method was initially developed in the early 1960 century to improve crystal-growing techniques, and since then, the spectroscopy technique has been used in combination with other methods for quantitative analysis. Additionally, the excitation source for this technique occurs at very high temperature, typically in the range (7000-8000K). An ICPE system typically includes various components like sample introduction system, ICPE torch, high frequency generator, transfer optics and spectrometer, and computer interface [18-20].

The bottled water market shows 73% growth from 2010 to 2020, and consumption is on track increase from around 350 billion liters in 2021 to 460 billion liters by 2030, according to the U.N. University's Institute for Water, Environment and Health [21].

The current work aims to measure and analyze the concentrations of macro, micro, toxic, and radioactive metals in the selected sample before and after heating and storage period. The sample was obtained from Al Byara Well - Block (39) in Sharq El Nile Locality, Sudan at the fall season in 2019.

2. Material and Methods

This study focused on analyzing a single sample that was obtained from Al Byara Well - Block (39) in Sharq El Nile Locality, Sudan. The plastic bottle, with a capacity of I.5 Liters, was cleaned thoroughly using distilled water, followed by washing it with the sample water to prevent any pollution traces. The ICPE Technique was employed to detect and measure the concentrations of the macro, micro, toxic, and radioactive elements before heating and storage duration. Later, the plastic bottle was placed under the normal sunlight for a approximately 50 days, with an average temperature of $33^{\circ}C$, and then stored for 40 days . Afterward, the same technique was utilized to

analyze the sample again and identify the difference in the concentrations of the aforementioned element classifications.

3. Results

This experiment aimed to investigate the physicochemical properties of plastic bottled water by detecting and measuring the concentrations of the macro, micro, toxic, and radioactive minerals before and after heating and storage duration. The results of this study were presented below:

3.1. The Levels of Macro and Micro Minerals Before and After heating and Storage Duration

The findings depicted in figure (1) and table (I) demonstrate of variable concentrations of the macro and micro minerals before and after heating and storage duration, as displayed below.

Table (I): The ICPE results of major and trace elements before and after heating storage duration:

Element	Classification of element	Level before sunlight	Level after sunlight	Standards in the background values [24-32]
S	Macro minerals	5.7mg / L	4.7mg / L	Permissible limits
Ca	Macro minerals	170μg / L	190μg / L	Permissible limits
K	Macro minerals	3.0μg / L	2.6μg / L	Permissible limits
Mg	Macro minerals	390μg / L	93μg / L	Permissible limits
Na	Macro minerals	89μg / L	72μg / L	Permissible limits
Cu	Micro minerals	16μg / L	14μg / L	Permissible limits
Mn	Micro minerals	1.4μg / L	0.00μg / L	Permissible limits
B	Micro minerals	0.00μg / L	0.60μg / L	Permissible limits
Si	Micro minerals	85μg / L	61μg / L	Permissible limits
I	Micro minerals	0.00μg / L	9.5μg / L	Permissible limits
Zn	Micro minerals	0.57μg / L	0.00μg / L	Permissible limits

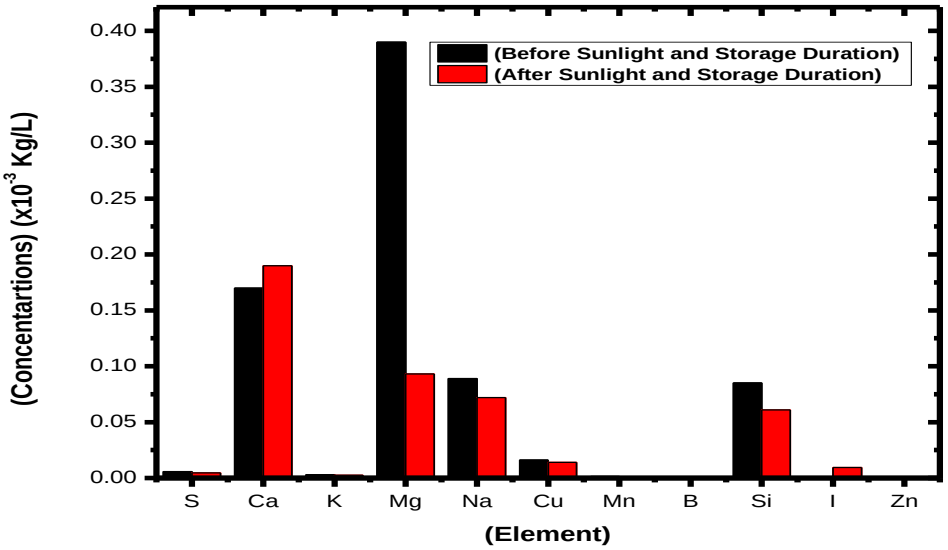

Figure (1): the ICPE results for major and trace elements before and after heating and storage duration

3.2. The Levels of Toxic and Radioactive Elements Before and After heating and Storage Duration

The results in figure (2) and table (II) confirmed that the concentrations of the toxic and radioactive elements can be found with different values before and after heating and storage duration as displayed below:

Table (II): The ICPE results of toxic and radioactive elements before and after heating and storage duration:

Element	Classification of element	Level before sunlight	Level after sunlight	Standards in the background values [24-32]
Cd	Toxic	$1.3\mu g / L$	$1.1\mu g / L$	Permissible limits
Ho	Toxic	$1.5\mu g / L$	$0.00\mu g / L$	Permissible limits
Tl	Toxic	$27\mu g / L$	$24\mu g / L$	More than permissible limits
Ba	Toxic	$0.62\mu g / L$	$0.65\mu g / L$	Permissible limits
Sc	Toxic	$0.31\mu g / L$	$0.23\mu g / L$	permissible limits
Sr	Radioactive	$0.77\mu g / L$	$0.96\mu g / L$	Permissible limits
Hg	Toxic	$0.00\mu g / L$	$1.1\mu g / L$	Permissible limits
Ni	Toxic	$0.00\mu g / L$	$3.7\mu g / L$	Permissible limits
Sb	Toxic	$0.00\mu g / L$	$6.9\mu g / L$	Permissible limits

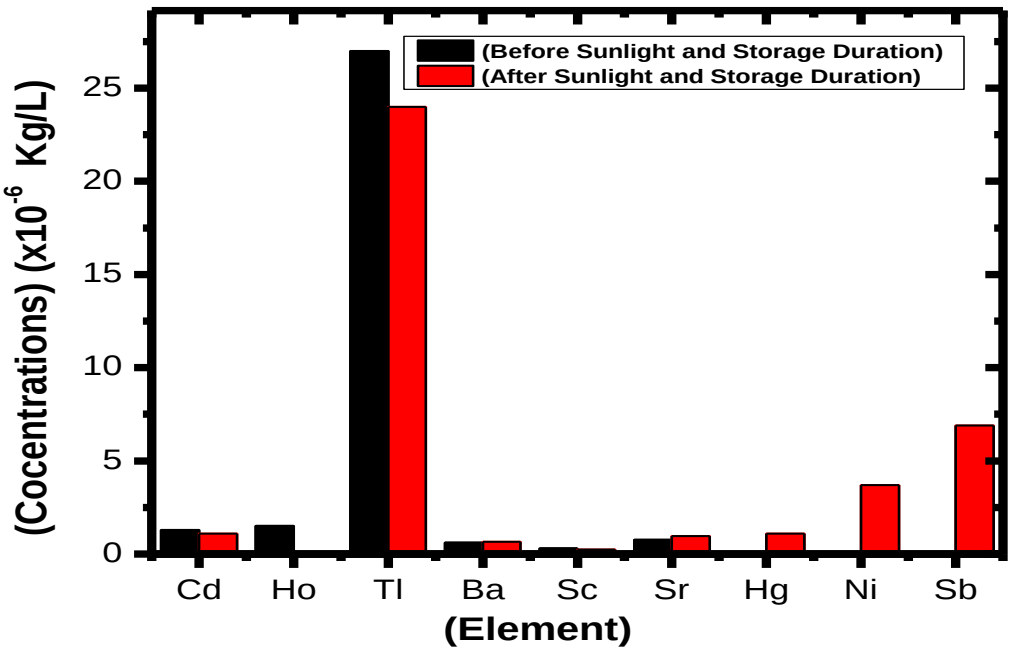

Figure (2): the ICPE results for major and trace elements before and after exposure to heating and storage duration

4. Discussion

This section provides further discussions on the results obtained from the selected sample before and heating and storage duration:

4.1. The Levels of Macro and Micro Elements Before and After heating and Storage Duration

The results presented in table (I) and figure (1) before heating and storage duration confirmed that the macro elements like (S, Ca, K, Mg, and Na) were appeared with different concentrations at ((0.0057, 0.170, 0.003, 0.390, and 0.089) $(\times 10^{-3})(Kg/L)$) respectively. Similarly, the micro minerals such as (Cu, Mn, Si, and Zn) were showed with divers concentrations at ((0.016, 0.0014, 0.085, and 0.000057) $(\times 10^{-3})(Kg/L)$) selectively. The outcomes may be attributed to the geological structure of the selected sample location [21]. Following heating and storage duration, slight decreases were observed in the content of (S) to ($4.7\times 10^{-3} Kg/L$), while certain macro elements for example (K, Mg , and Na) were decreased to ((0.0026, 0.093, and 0.072) $(\times 10^{-3})(Kg/L)$) respectively. Conversely, the concentrations of (Ca) were increased significantly to ($4.7\times 10^{-3} Kg/L$). Additionally, the concentration of two micro elements like (Cu and Si) were decreased to values of ((0.014 and 0.061) $(\times 10^{-3})(Kg/L)$). Moreover, two micro minerals, (Mn and Zn) were no longer detectable after heating and storage duration. On the other hand, two other micro minerals like (B and I) were appeared with contents of ((0.0006 and 0.0095 $(\times 10^{-3})(Kg/L)$) after heating and storage duration. These variations in results might return to the interaction between water and polyethylene material, and the migration of atoms during this chemical process [22-23]. Furthermore, the concentrations of the macro and micro minerals before and after exposure to the sunlight were found be within the globally accepted limits [24-29].

4.2 The Levels of Toxic and Radioactive Elements Before and After heating and Storage Duration

The obtained results from Figure (2) and Table (II), prior to heating and storage duration, indicated that toxic elements for instance (Cd, Ho, Tl, Ba, Sc, Hg, Ni , and Sb) were found at various concentrations of ((1.3, 1.5, 27, 0.62, and 0.31) $(\times 10^{-6})(\mu g / L)$) respectively. Additionally, a radioactive element named (Sr) was exhibited different concentration of ($0.77 \times 10^{-6} Kg / L$). The findings can be attributed to the sample's location and it associated human activities [21]. Following heating and storage duration, some toxic metals namely (Cd, Tl, and Sc) exhibited decreased concentrations of ((1.1, 24, and 0.23) $(\times 10^{-6})(\mu g / L)$) respectively, Moreover, a toxic metals ,(Ba) was appeared with concentration of $0.65 \times 10^{-6} Kg / L$). Conversely, three toxic like (Hg, Ni, and Sb) were appeared with values of ((1.1, 3.7, and $6.9 (\times 10^{-6})(\mu g / L)$) successively, due to the interaction between water and plastic, as well as the duration [24]. Additionally, the toxic metal which called (Ho) were vanished after heating and storage duration. These results may be related to the interaction between water and plastic, as well as the and the migration of atoms during this chemical process [23]. The concentrations of toxic and radioactive elements before and after heating and storage period were found to be within the globally allowed acceptable limits expect for (Tl) [24-33].

5. Conclusion

From the results obtained in this research, one can conclude that:

1-The ICPE results before heating and storage duration showed that the macro and micro minerals such as (S, Ca, K, Mg, Na, Cu, Si, Mn, and Zn) were detected with different concentrations at ((0.0057, 0.170,0.003, 0.390, 0.089, 0.016, 0.085,0.0014,and 0.00057) $(\times 10^{-3})(Kg/L)$) respectively. The concentrations some toxic and radioactive elements including (Cd, Ho, Tl, Ba, Sc, and Sr) were also appeared with various concentrations at ((1.3,1.5,27,0.62,0.31,and 0.77) $(\times 10^{-6})(\mu g/L)$) consecutively.

2-The ICPE results after heating and storage duration proved that the of macro and micro minerals above were changed to (0.0047,0.190, 0.0026, 0.093, 0.072, 0.014,0. 067, 0.00, and 0.00) $(\times 10^{-3})(Kg/L)$) respectively. Two new micro minerals which called (Iodine and Boron) was found with concentration at ((0.0095 and 0.00060) $(\times 10^{-3})(Kg/L)$ successively. The concentrations of some toxic and radioactive elements above were modified to (1.1,0.00,24,0.65,0.23,and 0.96) $(\times 10^{-6})(\mu g/L)$) successively, and three new toxic elements like (Mercury, Nickle, and Antimony) were existed with concentrations at ((1.1,3.7,and 6.9) $(\times 10^{-6})(\mu g/L)$) respectively.

3- The results which were mentioned above may be related to the location of the samples and the interaction between the water molecules and the polyethylene material from which the bottle was manufactured.

6. Abbreviations

Sb: Antimony.

Ba: Barium.

B: Boron.

Ca: Calcium.

Cd: Cadmium.

Cu: Copper.

Ho: Holmium.

ICPE: Inductively Coupled Plasma Emission Spectroscopy Technique.

I: Iodine.

Mg: Magnesium.

Mn: Manganese.

Hg: Mercury.

Ni: Nickel.

PE: Polyethylene.

K: Potassium.

Sc: Scandium.

Si: Silicon.

Na: Sodium.

Sr: Strontium.

S: Sulfur.

Tl: Titanium.

Zn: Zinc.

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