The Effect of Temperature and Storage Time into the Bottled Drinking Water at Seiyun City in Hadhramout Governorate, Yemen.

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Abstract:

Inductively Coupled Plasma Emission Technique (ICPE) was used to study the effect of temperature and storage time into the bottled drinking water at Seiyun City in Hadhramout Governorate, Yemen. Three tap water samples, collected randomly from different locations in this city, were used as study samples. The plastic containers of water were heated under the normal sunlight for 60 days, and it was stored for 40 days. Before heating and storage duration, the results analysis for three samples showed that the major and trace metals like (Sulfur, Boron, Calcium, Copper, Potassium, Magnesium, Sodium, Silicon, Zinc, and Lithium) were found at various concentrations. Also, the heavy and radioactive atoms such as (Cadmium, Strontium, Thallium, Barium, and Scandium) were detected at different values for all samples, due to the locations of samples and vital activities. After temperature and storage period, the obtained results for three samples proved that new trace and toxic metals, such as Selenium, Cerium, Holmium, and Ytterbium, were found at various amounts. Furthermore, the concentrations for other major, trace, and radioactive metals which mentioned above were changed after this physical process affected by heating and storage period, that may be associated with interaction between water and plastic, and storage duration, and all metals within the accepted ranges of the guideline-recommended values except Thallium.

Keywords: Bottled Drinking Water, Plastic, Trace metal, Storage time, Sunlight.

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تأثير الحرارة وزمن التخزين في قوارير مياه الشرب البلاستيكية في مدينة سيئون بمحافظة حضرموت اليمن

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الملخص

تقنية التحليل الطيفي لانبعاثات البلازما المقترنة بالحث استخدمت لدراسة تأثير الحرارة وزمن التخزين خلال قارورة مياه الشرب البلاستيكية في مدينة سيئون بمحافظة حضرموت، اليمن. ثلاث عينات من مياه الحنفية تم اختيارها عشوائيا من هذه المدينة، والتي اعتبرت عينات للدراسة. حاويات المياه البلاستيكية تم تسخينها تحت ضوء الشمس الطبيعي ٦٠ يوما ومن ثم خزنت لمدة ٤٠ يوما. قبل التسخين والتخزين، نتائج التحليل الطيفي للثلاثة العينات أوضحت وجود عدد من المعادن الأساسية والنادرة مثل (الكبريت، البورون، الكالسيوم، النحاس، البوتاسيوم، المغنيسيوم، الصوديوم، السليكون، الزنك، والليثيوم) عند تراكيز مختلفة) وأيضا العناصر الثقيلة والمشعة مثل (الكادميوم، الاسترنشيوم، الثاليوم، الباريوم، والا سكانديوم) تم حسابها عند قيمة مختلفة، وذلك بسبب مواقع العينة والأنشطة الحيوية. بعد التسخين ومدة التخزين، النتائج المسجلة للثلاثة العينات أثبت وجود بعض مثل (السلينيوم، السيريوم، الهومليوم، والإتيربيوم) وجدت عند مقادير مختلفة. بالإضافة، أن تراكيز بعض العناصر الأساسية، النادرة، والمشعة المذكورة أعلاه قد حصل لها تغيير بعد هذه العملية الفيزيائية المتأثرة بالتسخين وفترة التخزين، وتعود هذه النتائج إلى عملية التفاعل بين الماء والبلاستيك والفترة الزمنية للتخزين، كما أنه نتائج هذه المعادن التي تم الحصول عليها تكون في المدى المسموح به ضمن القيم المرجعية باستثناء (الثاليوم).

كلمات مفتاحية: مياه الشرب المعبأة، البلاستيك، المعادن النادرة، فترة التخزين، ضوء الشمس.

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1. Introduction:

1.1. General Background

It is well-known that water is recognized as fundamental component for the sustenance of life. It is crucial for the physiological survival of humans and all other living organisms [1]. Access to safe and satisfactory drinking water is an essential prerequisite for ensuring the well-being of both urban and rural populations, enabling them to lead healthy lives [2].

Seiyun is a city in the region and Hadhramout Governorate in Yemen. It is located in the middle Hadhramout Valley, Approximately 360 Kilometers from the governorate's capital and its center, Al- Mukalla city, via the western road [3]. Most of people in Seiyun city are using bottled water every day, the total water sales in Seiyun city in 2022 to about $(2233290\ m^3)$ [4].

1.2. Polyethylene Material Structure (PE)

Polyethylene is a ubiquitous material that we encounter in our daily lives [5]. Its applications include food and pharmaceutical packing films, wire and cable insulation, and pipes [6]. Consequently, the production of polyethylene is tremendous, and it one of the most widely used polymer materials [7]. Plastic products, such as bags, films, and milk barrels, can be fabricated from polyethylene using various manufacturing techniques, including hollow molding, injection molding, and extrusion [8]. These techniques can produce a wide range of products, including containers, cable cladding, pipes, profiles, and sheets [9]. On the other hand, PE has the simplest structure of the polymer, it is still the most widely used polymer material [10]. The (PE) is synthesized by polymerization of ethylene ($CH_2 = CH_2$), and the performance of (PE) depends on its polymerization which was carried out under medium pressure (15-30 atmosphere) [11]. In addition, the heavy and toxic metals were found at the structure of polyethylene material such as (Pb, Cr, Cd, Hg, As, Ba, Sc, Al, Ni, Sr, Bi, Tl, Ho, and Yb) [12] .

1.3. The Effect of Temperature and Storage Time into Bottled Drinking Water

Heavy metals have the potential to cause harm to many organisms when they are absorbed or exposed to them, even at low levels [13]. Overall, plastic materials have been used regularly in all aspects of daily life [14]. The lack of suitable destination for these materials can be a worldwide environmental problem, especially because plastic materials can take hundreds of years to decompose [15]. On the other hand, the reuse of waste by efficient recycling provides social, environmental, and economic gains and at the local level, it ensures money savings for communities [16]. However, water is filled into transparent plastic bottles made from polyethylene terephthalate (PET) and exposed to full sunlight for many hours or many days [17]. During this period there is an interaction between water and plastic, which was very dangerous for human life. Plastic produces some extremely toxic elements, which cause many diseases [18].

1.3. Literature Review

The effect of temperature and storage time for drinking water samples in plastic bottles, which made of polyethylene, have been confirmed by many researchers using (ICPE) technique as shown at below:

The effect of sunlight exposure and storage duration of heavy metals from polyethylene terephthalate drinking water bottles were reported by Jafari et al., (2015) in Iran using (ICPE) technique, and the levels of Pb, Ni, Cd, and Sb were determined in bottled waters in different conditions [19] .

In addition, the effect of temperature and storage time in plastic bottled drinking water was studied by Bach et al., 2014. Bottled waters were exposed to natural sunlight for 2, 6, and 10 days. Migration was dependent on the type of water. Formaldehyde, acetaldehyde, and Sb migration increased with sunlight exposure in ultrapure water [20].

Also, the effects of storage conditions on bottle water samples were investigated by Okeola et al., 2021 in Ilorin Metropolis Kwara State, Nigeria. The results showed that the heavy metals like (Cr, Pb and Fe) were investigated above the permissible limits based on World Health Organization (WHO) [21].

1.5. Research Problem

There is an increase of using people for Bottled Drinking Water in Seiyun city, Yemen. Also, there is a lack of awareness and an absence of clear information about the health effects of toxic, and radioactive metals in drinking water. This study might give us more information about the amount of these elements in the collected sample before and temperature and storage time. Furthermore, this work will show the relationship between the concentrations of these elements of the collected sample in in Seiyun city, Yemen.

1.5. Aims of the Work:

The aims of the research were summarized as below:

- ❖ The first aim of the present work is to detect toxic and radioactive elements in the selected sample and measure the concentration of these metals via the (ICPE) technique before and after temperature and storage time.
- ❖ The second aim is to compare (ICPE) results before and after exposure samples to sunlight and the storage period.

2.1Material and Methods:

This part described the experiment part including materials, equipments and methods, and spectroscopy technique as shown below:

2.1. The Samples and Samples Collection:

Three drinking water samples were collected from different locations at Seiyun City in Hadhramout Governorate, Yemen during a period from 20/3/2023 to 10/7/2023. Three plastic bottles of (220 ml) were cleaned thoroughly with distilled water, and they were filled and closed very well as displayed in figure (1) at below:

Figure (1) Bottles of three samples

All three samples were analyzed by (ICPE) spectroscopy technique to detect and measure the concentrations of the major, trace, toxic and radioactive metals before exposing all samples to sunlight and the storage period such as (S, B, Ca, Cu, K, Mg, Na, Si, Zn, Li, Cd, Sr, Tl, Ba, and Sc) [22].

After that, three plastic bottles of (220 ml) were placed under the normal sunlight for a period time about (60) days as displayed in figure (2), and the temperature average of the normal sunlight was recorded about $33^{\circ}C$. Also, all three samples were stored also for (40) days to prove the interaction between water molecules and plastic, as well as to ensure the change occurs in the composition of water.

Figure (2) the sample under

After temperature and storage time, all three samples were analyzed via the (ICPE) spectroscopy technique to find the difference in the concentrations of the major, trace, toxic, and radioactive metals which were mentioned above, and to detect the new metals such as that can be found in the structure of three samples after exposing them to sunlight and the storage period [23].

2.2 Characterization Technique:

The selected samples were analyzed by (ICPE) spectroscopy technique two times before and after exposing them to sunlight and the period time. In fact, water samples was placed in a beaker, and they were injected in (0.1 ml) of Nitric acid (HNO_3) to restrict the elements and to dissolve the residue of all contents of the samples [24]. The beaker was heated for approximately two hours below boiling. After leaving it to cool to room temperature, it was transferred to a plastic container, made up of (5 mL) with ultrapure water to adjust the sample solution volume separately [25]. Calibration curve samples were prepared so their acid concentration was equivalent to that present in samples used for analysis as displayed in figure (3) [26]. After this step, all metals were chemically filtered in the device, and the spectra of elements were recorded on the computer screen, and the spectrum was independent for each element.

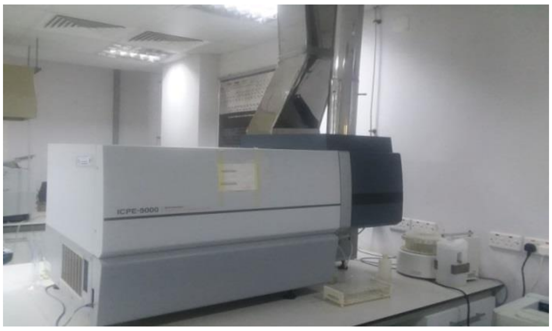

Figure (3) Shimadzu ICPE-9000 Manufactured in Japan

3.Results and Discussion:

This section was explained the results of characterization three samples of drinking water which were collected from three different locations at Seiyun city in Hadhramout Governorate, Yemen before and after heating and storage time using (ICPE) spectroscopy technique as shown below:

3.1. Results and Discussion for Major and Trace metals:

This part was discussed the results for major and trace metals that can be found at all three samples of drinking water which were collected from three different locations at Seiyun city in Hadhramout Governorate, Yemen before and after sunlight and storage period as displayed below:

Table (1): The existing major and trace metals before and after temperature and storage time for sample No.1:

Metal	Type of metal	Concentrations before temperature storage time (ug/L)	Concentrations after temperature and storage time (ug/L)	Background values
S	Major metal	8500	7300	Allowed limits
B	Trace metal	3.1	3.1	Allowed limits
Ca	Major metal	250	320	Allowed limits
Cu	Trace metal	19	13	Allowed limits
K	Major metal	4.8	4.7	Allowed limits
Mg	Major metal	130	130	Allowed limits
Na	Major metal	84	75	Allowed limits
Si	Trace metal	87	68	Allowed limits
Zn	Trace metal	4.2	3.5	Allowed limits
Li	Trace metal	0. 06	0.04	Allowed limits
Se	Trace metal	0.00	22	Allowed limits

Before temperature and storage time, the presented results in table (1) for sample No.1 indicated that the major metals like (S, Ca, K, Mg, and Na) were appeared with different concentrations of (٨٥٠٠, ٢٥٠, ٤.8, 130, and 84 (ug/L)) respectively. Similarly, the trace minerals such as (B, Cu, Si, Zn, Li, and Se) were detected in various amounts of (3.1, 19, 87, 4.2, 0. 06, and 0.00 (ug/L)) successively, and these results may be related to the samples locations and the geological structure and [27]. Also, the geological structures play an important role in groundwater flow and quality that may be related to many problems like dykes, lineaments, and fractures act as both carries as well as barriers for groundwater flow [28].

After temperature and storage time, the values of many atoms like (S, Na, K, Si, Zn, Cu, and Li) were decreased to (7300, 75,4.7, 68,3.5,1.3, and 0.04 (ug/L)) consecutively. Also, the amount of (Ca) was increased to (320 ug/L) during these chemical transformations. Additionally, the concentrations of some metals such as (Mg and B) did not change after this experiment. On the other hand, only one new atom which called (selenium) was discovered with amount at (22 ug/L), due to the interaction between to water molecules and plastic container that was manufactured from polyethylene material , and the migration of atoms from plastic to water during this chemical process [29] . In fact, the polythene plastic used in packaging the water is usually susceptible to degradation under high temperature or direct sunlight condition. As such, ultraviolet rays from sunlight could have the potential to speed up degradation reactions that affects the photosensitive polyethylene material used for packaging of the water. More so, during the degradation process, potential toxic metals, micro plastics and bacteriological activities are bound to affect the water quality. These potential toxic metals are highly persistent, and can bio accumulate in the tissues of biological organisms, resulting in severe health issues in the process over time [30].

Table (2): The existing major and trace metals before and after temperature and storage time for sample No.2:

Metal	Type of metal	Concentrations before temperature storage time (ug/L)	Concentrations after temperature and storage time (ug/L)	Background values
S	Major metal	7900	7000	Allowed limits
B	Trace metal	3.0	3.06	Allowed limits
Ca	Major metal	170	212	Allowed limits
Cu	Trace metal	16	11	Allowed limits
K	Major metal	4.0	3.9	Allowed limits
Mg	Major metal	120	120	Allowed limits
Na	Major metal	79	70	Allowed limits
Si	Trace metal	80	59	Allowed limits
Zn	Trace metal	3.7	3.0	Allowed limits
Li	Trace metal	0. 038	0.037	Allowed limits
Se	Trace metal	0.00	20	Allowed limits

Before temperature and storage time, the obtained results in table (3) for sample No.3 proved that major metals like (S, Ca, K, Mg, and Na) were appeared with different concentrations of (7900, 170, 4.0, 120, and 79 (ug/L)) respectively. Similarly, the trace minerals such as (B, Cu, Si, Zn, Li, and Se) were detected in varying amounts of (3.0, 16, 80, 3.7, 0. 038, and 0.00 (ug/L)) successively, and these results may be associated with reasons and details for major and trace metals for sample No.1 and No.2 which were mentioned above before heating and storage duration.

After temperature and storage time, the values of major atoms like (S, Cu, K, Na, Si, Zn. and Li) were decreased to (7000, 11, 3.9, 70, 59, 3.0, and 0.039 (ug/L)) consecutively. Additionally, the concentrations of trace elements such as (B and Mg) were increased to (3.06 and 212 (ug/L)) successively, the amount of (mg) did not change after this experiment. On the other hand, Selenium atoms were discovered as new atoms after heating and storage duration with amount at (20 ug/L), due to the interaction between to water molecules and plastic containers that were manufactured from polyethylene material, and the migration of atoms during this chemical process based on causes and details for sample No.1 and No.2 that were mentioned above after temperature and storage period.

It is noteworthy that all minerals concentrations for all three samples, both before and after heating and storage time, were found to be within globally allowed limits as shown at the details in table (4) as displayed below:

Table (4): Allowed limits for major and trace metals:

Metal	Allowed limits (ug/L)	Reference's Number
S	≥ 250000	[31]
B	≥ 1000	[31]
Ca	≥ 8000	[32]
Cu	≥ 200	[33]
K	≥ 10000	[34]
Mg	≥ 50000	[34]
Na	≥ 100000	[35]
Si	≥ 10000	[35]
Zn	≥ 200	[35]
Li	≥ 200	[36]
Se	≥ 50	[36]

3.2. Results and Discussion for Heavy and Radioactive metals:

This part was explained the results for heavy and radioactive metals that can be found at all three samples of drinking water which were collected from three different locations at Seiyun city in Hadhramout Governorate, Yemen before and after sunlight and storage period as displayed below:

Table (5): The existing heavy and radiant metals before and after temperature and storage time for sample No.1:

Metal	Type of metal	Concentrations before temperature storage time (ug/L)	Concentrations after temperature storage time (ug/L)	background values
Cd	Toxic	1.8	1.5	Allowed limits
Sr	Radiant	6.4	9.0	Allowed limits
Tl	Toxic	40	36	Above allowed limits
Ba	Toxic	0.31	0.39	Allowed limits
Sc	Toxic	0. 46	0. 51	Allowed limits
Ce	Toxic	0.00	6.0	Allowed limits
Ho	Toxic	0.00	1.6	Allowed limits
Yb	Toxic	0.00	0. 09	Allowed limits

The results obtained in table (5) before heating and storage duration for sample No.1 confirmed that the heavy metals like (Cd, Tl, Ba, and Sc) were found in various contents of (1.8, 40, 0. 31, and 0. 46 (ug/L)) respectively, while only one radioactive element which called (Sr) was presented in a level of (6.4 ug/L), and these results may be associated with vital activities locations that may be closed to the selected samples locations, for example, various factories, farms, especially phosphate fertilizers, oil companies, and waste sites that permeates by soil pores to drinking water sources [37].

After heating and storage period, there are new heavy minerals like (Ce, Ho, and Yb) were detected in various concentrations of (6.0, 1.6, and 0. 09 ug/L) consecutively. Also, the values of some heavy metals like (Cd, Tl, Ba, and Sc) were changed to (1.5, 36, 0. 39, and 0.51 ug/L) successively. The concentration of radioactive metal (Sr) was increased to (9.0 ug/L). These results may be related to the interaction between water and plastic placed under sunlight and storage duration, and the migration of atoms during this chemical process and the migration based on causes and details that were mentioned above [38]. These results above for this sample were attributed to the interaction through storage time between water and plastic that were manufactured from polyethylene material, and the migration of atoms during this chemical process [39].

Table (6): The existing heavy and radiant metals before and after temperature and storage time for sample No.2:

Metal	Type of metal	Concentrations before temperature storage time (ug/L)	Concentrations after temperature storage time (ug/L)	background values
Cd	Toxic	1.7	1.4	Allowed limits
Sr	Radiant	6.2	8.8	Allowed limits
Tl	Toxic	39	34	Above allowed limits
Ba	Toxic	0.30	0.38	Allowed limits
Sc	Toxic	0. 42	0. 50	Allowed limits
Ce	Toxic	0.00	5.8	Allowed limits
Ho	Toxic	0.00	1.4	Allowed limits
Yb	Toxic	0.00	0. 07	Allowed limits

The results obtained in table (6) before temperature and storage time for sample No.2 proved that the heavy metals like (Cd, Tl, Ba, and Sc) were found in various contents of (1.7, 39, 0. 30, and 0. 42 ug/L) respectively, while the radioactive elements (Sr) was presented in a level of (6.2 ug/L), and these results may be associated with to the reasons and details for heavy and radioactive metals for sample No.1 which were mentioned above before hating and storage period.

After heating and storage time, there are new heavy minerals like (Ce, Ho, and Yb) were detected in varying concentrations of (5.8, 1.4, and 0. 07 ug/L) consecutively. Also, the values of heavy metals such as (Cd, Tl, Ba, and Sc) which were mentioned above changed to (1.5, 36, 0. 39, and 0.51 ug/L) successively, due to the interaction between water and plastic, and storage time. The concentration of radioactive metal (Sr) increased to (8.8 ug/L). These results may be related to the interaction between to water molecules and plastic containers that were manufactured from polyethylene material, and the migration of atoms during this chemical process based on causes and details for sample No.1 that were mentioned above after temperature and storage period.

Table (7): The existing heavy and radiant metals before and after temperature and storage time for sample No.3:

Metal	Type of metal	Concentrations before temperature storage time (ug/L)	Concentrations after temperature storage time (ug/L)	background values
Cd	Toxic	1.6	1.3	Allowed limits
Sr	Radiant	6.1	8.7	Allowed limits
Tl	Toxic	37	32	Above allowed limits
Ba	Toxic	0.29	0.37	Allowed limits
Sc	Toxic	0. 41	0. 49	Allowed limits
Ce	Toxic	0.00	5.7	Allowed limits
Ho	Toxic	0.00	1.3	Allowed limits
Yb	Toxic	0.00	0. 06	Allowed limits

The results obtained in table (7) before heat and storage period for sample No.3 showed that the heavy metals like (Cd, Tl, Ba, and Sc) were found in various contents of (1.6, 37, 0. 29, and 0. 41 ug/L) respectively, while the radioactive elements (Sr) was presented in a level of (6.1 ug/L), and these results may be associated with to the reasons and details for heavy and radioactive metals for sample No.1 and sample No.2 which were mentioned above before hating and storage period.

After heating and storage duration, there are new heavy minerals like (Ce, Ho, and Yb) detected in varying concentrations of (5.7, 1.3, and 0. 06 ug/L) consecutively. Also, the values of heavy metals such a (Cd, Tl, Ba, and Sc) which mentioned above changed to (1.3 , 32, 0. 37, and 0.49 ug/L) successively ,due to the interaction between water and plastic, and storage time [37]. The concentration of radioactive metal (Sr) increased to (8.7 ug/L). These results may be related to the interaction between to water molecules and plastic containers that were manufactured from polyethylene material, and the migration of atoms during this chemical process based on causes and details for sample No.1 and sample No.2 that were mentioned above after temperature and storage period.

The results of the heavy and radioactive elements for all three samples, before and after heating and storage time were found within the globally allowed limits expect for (Tl) as shown at the details in table (8) below:

Table (8): Allowed limits for heavy and radioactive metals:

Metal	Allowed limits (ug/L)	Reference's Number
Cd	≥5	[40]
Sr	≥200	[40]
Tl	≥10	[41]
Ba	≥700	[41]
Sc	≥30	[41]
Ce	≥10	[42]
Ho	≥8	[42]
Yb	≥2.2	[42]

5. Conclusion:

During an experimental study in Seiyun City in Hadhramout Governorate, Yemen, it was discovered that the physicochemical properties of plastic containers water were affected. The concentrations of major, trace, heavy, and radiant metals in the selected samples were found to have fluctuated, with some elements increasing or decreasing and others appearing or disappearing after heating for (60) days and stored for (40) days. This indicates that there is an interaction between water molecules and the polyethylene material used in the manufactured of the bottles. The heating and duration of storage was based on a literature review, and it was concluded that the validity period of the bottles was not affected.

6. Abbreviations:

Ba: Barium.

B: Boron.

Ca: Calcium.

Cd: Cadmium.

Ce: Cerium.

Cu: Copper.

Ho: Holmium.

ICPE: Inductively Coupled Plasma Emission Spectroscopy Technique.

Li: Lithium.

Mg: Magnesium.

Na: Sodium.

PE: Polyethylene.

K: Potassium.

S: Sulfur.

Sc: Scandium

Se: Selenium

Si: Silicon.

Sr: Strontium.

Tl: Thallium.

WHO: World Health Organization

Yb: Ytterbium.

Zn: Zinc.

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