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Concentration of Phthalate Esters in Bottled Water: A Case Study in Effurun, Delta State, Nigeria

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Abstract

Phthalate esters (PAEs), a group of chemical compounds, are extensively used as additives in plastics. The objective of this study was to determine how much of a few target PAEs have leached into various samples of drinking water packaged in PET bottles in Effurun, Delta State, Nigeria as well as how ambient temperature, sunshine exposure, and cold storage conditions have affected the concentration of PAE. The concentrations of Di-ethyl-phthalate (DEP), di-butyl-phthalates (DBP), benzyl-butyl-phthalate (BBP), di-n-octyl phthalate (DnOP), and Bis-(2-ethyl-hexyl) phthalate (DEHP) were determined in bottled water samples. The concentrations of PAEs were determined using a gas chromatography coupled with a mass sepctroscopy analyzer (GC-MS). Phthalate compound was observed to be in all bottled water placed under different storage conditions; cold storage (CW), ambient storage (AW), and sunlight storage (SLW) for a period of 2, 4, 8, 12 and 16 weeks. However, the greatest leaching effect was observed in PET bottled water placed sunlight conditions for sixteen weeks with concentrations of; DEHP (2.1-11.2) µg/L, DEP (0.98-3.87) µg/L, DBP (2.98-13.8) µg/L. The results from this study indicated that, under various storage conditions, DEP, DBP and DEHP from PET bottles may leach more into the drinking water over a period of time under different storage conditions. The result additionally gave indication that DEHP; a known endocrine disruptor, with anti-androgenic and possible human carcinogen effects, exceeded the 6 µg/L USEPA Maximum Contamination Level (MCL) in drinking water, and also greater than 8 µg/L which is the indicated MCL by the World Health Organization (WHO).

Keywords: phthalates, PET bottled water, leaching, storage conditions, health risks, drinking water

1. Introduction

Water is a worldwide resource that is frequently taken for granted and exploited, particularly in third-world countries where knowledge is not easily accessible or distributed. As abundant as it may appear, water is one of the world's rarest elements in its pure state (Omole and Longe, 2008). It can become contaminated when found in mineral-rich areas, making it unfit for human consumption, or it can become contaminated as a result of anthropogenic activities. Water is so essential to life that it can only be lived without for a few days. People use it for drinking, sanitation, and agricultural activities to produce food. As a result, water is critical for man's life in order to ease hunger, maintain hygiene, and provide sustenance. Nonetheless, access to drinking water is becoming increasingly difficult in most developing countries. Even though 70% of the earth's surface is covered by water, most of it is undrinkable. This problem is more endemic in Africa. According to estimates given by the World Bank in 2019, it was estimated that 60 million Nigerians lack access to clean water for drinking (Agu et al. 2021). This has resulted in a significant increase in the demand for packaged water, mostly in high-density polyethylene (HDPE) sachets and PET bottles (Akindele and Alimba. 2021). Delta State, which is situated in South-south of Nigeria, is one of the fastest growing metropolises in Africa with an estimated population of four million people (Ugbomeh and Atubi, 2010). For their everyday drinking water needs, around 60% of the population relies on packaged drinking water (Vedachalam et al. 2017). The rainy and dry seasons alternate in Nigeria. People prefer drinking cold water during the dry season because of the higher temperatures; therefore, cold medium must be used to store water. Retailers of bottled water in Delta state have been seen storing

drinking water outside where they can be kept in stacks for retail purposed, where temperatures of up to 37 ℃ have been recorded.

Phthalate esters (PAEs), a group of chemical compounds, are extensively used as additives in plastics. They are known to increase the flexibility of plastics through weak secondary molecular interactions with polymer chains (Koniecki et al. 2011). They are therefore utilized in a varied amount of products like printer ink, packaging, films, paints, adhesives, cosmetics, pharmaceuticals, and medical equipment. These esters are frequently used as plasticizers to increase the softness and flexibility of plastics. Due to the fact that phthalate plasticizers are not chemically bound to materials, they are able to continuously leak out of plastic products into the environment, where they are then spread throughout the ecosystem (Edjere et al. 2016). Potable water may be contaminated by phthalates from various sources. The release of phthalates from water containing-plastic medium is a known source of water contamination in the environment (Bosnir et al. 2007). In many places, potable water is stored in plastic containers such as drums, buckets, tanks, and water bottles. These containers may be made of phthalates which migrate into the water since they are not bonded in the matrix of the plastics (Peijnenburg, 2008). The consumption of these waters is one of the main sources of human exposure to phthalates (Esteki et al. 2021). Despite these numerous researches, there is scarcity of data indicating the potential leaching effect of phthalate esters leaching into water that are stored in bottles in the study area.

The presence of phthalates in the environment can be attributed to the wide variety of applications to which they are utilized. For example, bis-(2-ethyl-hexyl) phthalate (DEHP) is a component of construction materials, some consumer products including children's toys and materials for packaging food, and in a variety of medical equipment including containers for the collection and storage of fluids and blood, and equipment used in blood transfusion (Heudorf et al. 2007). The phthalate di-n-octyl phthalate (DnOP) is primarily plasticizer used in PVC and is found in panels for walls, floors and roofs, certain parts of cars, cable jackets. DnOP is found in footwear, ink, varnishing and painting materials, colouring pigments, lubricants, and adhesives, etc. (Aziz and Bashir, 2020).

Several human health conditions are linked to phthalate exposure. Among these are endocrine disruptions, fertility delay, impaired development in foetuses, elevated risk of developing allergic reactions, asthma, and carcinogenicity. In humans, the effects of phthalates on reproduction are of utmost importance, as such, the present tolerable daily intake (TDI) values recommended by the European Union Scientific Committee for Toxicity, Ecotoxicity and the Environment (CSTEE) for phthalates including DEHP, DBP and BBP are based on reproductive toxicity studies (Karaconji et al. 2017). Human exposure to phthalates is known to occur *via* ingestion, inhalation, and dermal absorption. Phthalates are present in drinking water and food substances (Fierens et al. 2012), cosmetics and have been detected in breast milk (Guerranti et al. 2013). Effects of exposure may include imbalances in hormonal and metabolic systems together with development problems and reproductive system defects (Eveillard et al. 2009). Phthalates are known to contribute to asthma through increases in inflammatory cells within the lungs and bronchial fluids. Reduction in sperm volume, semen quality, decreases in the amounts of testosterone produced and reduction in luteinizing hormone levels are some other adverse effects recorded in males (Clara et al. 2010). Low-molecular-weight phthalates are reported to cause an improvement in the motor skills of male children, while high-molecular-weight phthalates decrease alertness and orientation in girls (Yolton et al. 2011). Elevated risk levels of pre-term births occurrence and endometriosis incidences have been linked to phthalate exposure, also phthalates have been implicated in insulin resistance and increased risk of diabetes (Dirtu et al. 2013).

This study aims to assess the leaching of specific PAEs in drinking water samples stored in bottles in the Effurun region, focusing on the influence of ambient temperature, sunlight exposure, and cold storage conditions on the concentration of leached PAEs. The research is crucial as the local population heavily relies on bottled water as their primary source of potable water, often purchased and stored in bulk by retailers. The novelty of this investigation lies in its examination of PAE leaching behaviour in a region with limited access to clean drinking water, underscoring its importance for public health considerations. Understanding the impact of storage conditions on PAE leaching is essential, given prevalent consumption patterns and storage practices in Effurun. The findings will provide valuable insights to mitigate potential health risks associated with PAE exposure from bottled water consumption in regions facing challenges in accessing safe drinking water.

2. Materials and Methods

2.1 Sample Collection

Four popular brands of PET bottled table water were purchased from a table water factory located in Otokutu, Udu Local Government Area of Delta State. The samples were purchased and collected from their factories on

the day of production in August 2021. The bottled water samples were compounded into and stored at different storage conditions; refrigeration temperature of 4 ℃ where samples were tagged CW, ambient storage in a room at the Advanced laboratory of the Federal University of Petroleum Resources (FUPRE) at temperatures between 26 ℃ to 29 ℃ and samples were tagged AM, and sunlight at an open space in the car pack at the College of Science at FUPRE at temperatures between 27 ℃ to 37 ℃ and tagged SLW. All bottles were stored at each location for 16 weeks prior to analysis.

2.2 Chemicals and Reagents

Two distinct internal standards were employed in this study, each serving specific purposes in GC-MS measurements and the extraction process. For GC-MS measurements, the certified traceable EPA standards Phthalate Esters Mix in hexane were utilized, consisting of DMP (99.9%), DEP (99.9%), DBP (97.6%), BBP (98.7%), and BEHP (99.7%). In contrast, a separate set of standards, namely Phthalate Esters Mix in methanol, was employed for recovery studies during the extraction phase. This mix comprised DMP (99.9%), DEP (97.6%), DBP (99.3%), BBP (99.9%), and BEHP (99.7%). The choice of these specific internal standards underscores the nuanced requirements of GC-MS measurements and the extraction process, addressing the need for accuracy and precision in each phase of the analytical procedure. Additional reagents, such as Butyl benzoate (BB) and sodium chloride, were sourced from BDH and Sigma-Aldrich, respectively. Furthermore, high-purity solvents, including Dichloromethane and Methanol (HPLC grades), as well as analytical grade Hexane, were procured from Fisher Scientific (Loughborough, UK). Ultrapure water generated by a Milli-Q Integral water purification system (Millipore, USA) was employed to meet stringent quality standards.

2.3 Preparation of Stock and Working Solutions

As working solutions, hexane was used to generate a stock solution of the Phthalate Esters Mix standards (40 g/mL) (DMP, DEP, DBP, BBP, and DEHP) and an internal standard (100 g/L) butyl Benzoate (BB) from which further concentrations were prepared by serial dilution of the stock solution. Prior to use, all solutions were kept at 4 ℃ in the dark.

2.4 Analytical Procedure

Sample Extraction and Gas Chromatographic Analysis

Phthalates, including Dimethyl phthalate (DMP), Diethyl phthalate (DEP), Dibutyl phthalates (DBP), Benzyl butyl phthalate (BBP), and Di-(2-ethylhexyl) phthalate (DEHP), were identified in preserved water samples. To prepare these analytes for Gas Chromatography-Mass Spectrometry (GC-MS) examination, they were pre-concentrated in dichloromethane and enriched in n-hexane. The pre-concentrated samples were stored in amber glass vials with Teflon caps to prevent natural attenuation from ultraviolet light.

The GC-MS measurements were conducted meticulously. Initially, a measured volume of the water sample (0.5 L) was weighed into a 0.5 L calibrated Erlenmeyer flask. Subsequently, 1ml of Cyclohexane internal Standard solution and 9ml of Cyclohexane were added. The mixture underwent thorough stirring for approximately two hours using a glass-coated magnetic stirring rod, leading to the extraction of the analytes. The solvent extract was then isolated in a 10 ml vial through a separatory funnel, resulting in a 0.5 L sample volume in a 10 ml Cyclohexane extract. Similarly, a 0.5 L aliquot of the blank sample (Nanopure water) underwent the same extraction procedure as the water sample.

The separation of analytes in both the blank and sample-derived extracts was achieved through capillary gas chromatography with temperature programming. The chromatographically separated phthalate esters were subjected to detection and measurement using a Mass Spectrometer. This process employed the large volume injection (LVI) method, introducing 100 µl of the sample solvent extract at a rate of approximately 4.6 µl/sec into the injector. The injector, starting at an initial temperature of 78 ℃, gradually increased at a rate of 5 ℃/sec to 300 ℃, allowing complete volatilization of the solvent into the analytical column. Simultaneously, the oven's initial temperature was maintained at 70 ℃ and, upon injection, increased to 300 ℃ at a rate of 20 ℃/min. The injector's temperature normalization was swiftly achieved with the use of a liquid Nitrogen Cryo cooling unit. Phthalate separation and detection were performed using a 30 m BGB5 Column and an HP5973 mass spectrometer, respectively. The analytical quantification was conducted with the aid of Agilent Chromstation software (Bachema, 2021).

2.5 Quality Control

All glassware was immersed in 10% nitric acid, then washed with detergent, rinsed with deionized water, dried, and sealed with aluminium foil before being stored. Glassware was also pre-rinsed with acetone before use. Separating funnels with Teflon stopcocks, glass vials and volumetric flasks with Teflon closures, and glass

syringes were utilized during sample handling. Plastic materials were not used at all. To check for possible contamination and interferences, laboratory reagents and instrumental blanks were analyzed with each batch of samples (5 samples) as a blank. The sensitivity of the gas chromatography-mass spectrometer (GC-MS) was evaluated for drift across batches of 5 samples using a midway calibration reference (4 ppm). To compensate for analyte loss during sample preparation, an internal standard was used. The drinking water samples were analyzed three times. The limits of detection (LOD) and quantification (LOQ) were determined, as well as the accuracy (recovery study), precision (between-run and within-run), and linearity. LOD and LOQ were determined as follows: LOD = 3.3(Sy/S) and LOQ = 10(Sy/S) (Shrivastava et al. 2011), where Sy is the standard deviation of the calibration curve's y-intercepts and S is the calibration curve's slope for concentration levels 1.0 - 8.0 g/L. To validate the results obtained for DMP, DEP, DBP, BBP, and DEHP, recovery tests were performed at concentration levels of 4.0, 6.0, and 10.0 g/L. A linearity study was also conducted, with five concentration levels and five repetitions. Five repeated analyses of water spiked with DMP, DEP, DBP, BBP, and DEHP standards at concentrations of 1.0, 2.0, and 4.0 g/L were used to determine the method's precision (intra-assay), which was expressed as a percentage of relative standard deviation (%RSD).

2.6 Statistical Analysis

Microsoft Excel was used to calculate the mean, standard deviation and variance of the different Phthalate concentrations from the GC-MS analysis, while XLSTAT, an add in to excel was used to calculate the Multivariate Analysis of Variance (MANOVA), Wilks test, Kruskal-Wallis test, and Friedman's test.

3. Results and Discussion

3.1 Phthalates Contamination in PET Bottled Water Samples

As shown in Figure 1, there was an exponential increase in the concentration of Bis(2-ethylhexyl)phthalate (DEHP), Dibutylphthalate, and (DBP), Diethylphthalate (DEP), with concentrations of 2.2 µg/L in the first week and increasing to 4.38 µg/L in the sixteenth week, 3.2 µg/L in the first week and increased to 5.74 µg/L in the sixteenth week, 1.07 µg/L in the first week and increasing to 2.48 µg/L in the sixteenth week respectively in the bottle water analyzed under different ambient storage. This insinuates that there was leaching of phthalates in the bottle water at the different ambient storage.

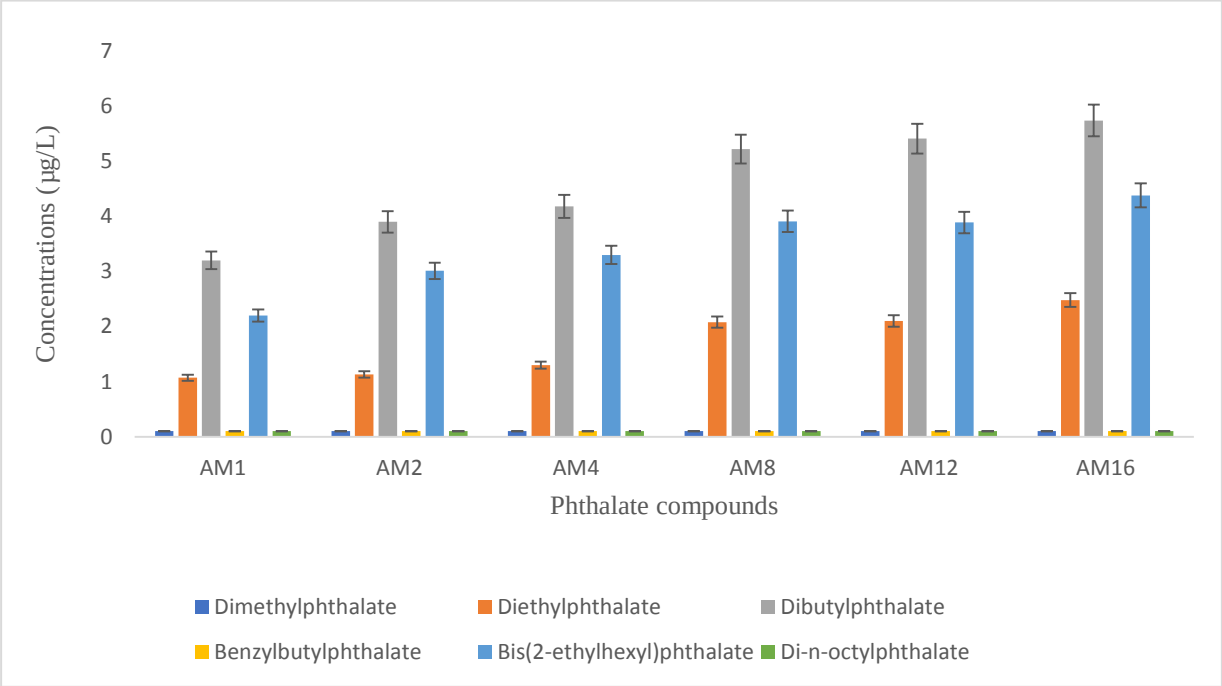

Figure 1. Concentration of Phthalate esters bottled water under ambient storage conditions

Take note: AM means ambient conditions, while the numbers 1, 2, 4, 8, 12, and 16 indicate the number of weeks of storage.

The concentration of phthalate compounds in this study was considerably higher in concentration from bottled water stored in ambient conditions in Tehran, Iran, where the concentrations had a mean of 0.76 ± 0.19 µg/L (Abtahi et al. 2019), and 1.963 ± 0.160 µg/L in Tianjin, China (Wang et al. 2021).

The concentration of phthalate compounds in bottled water stored in cold temperature conditions are shown in Figure 2 below.

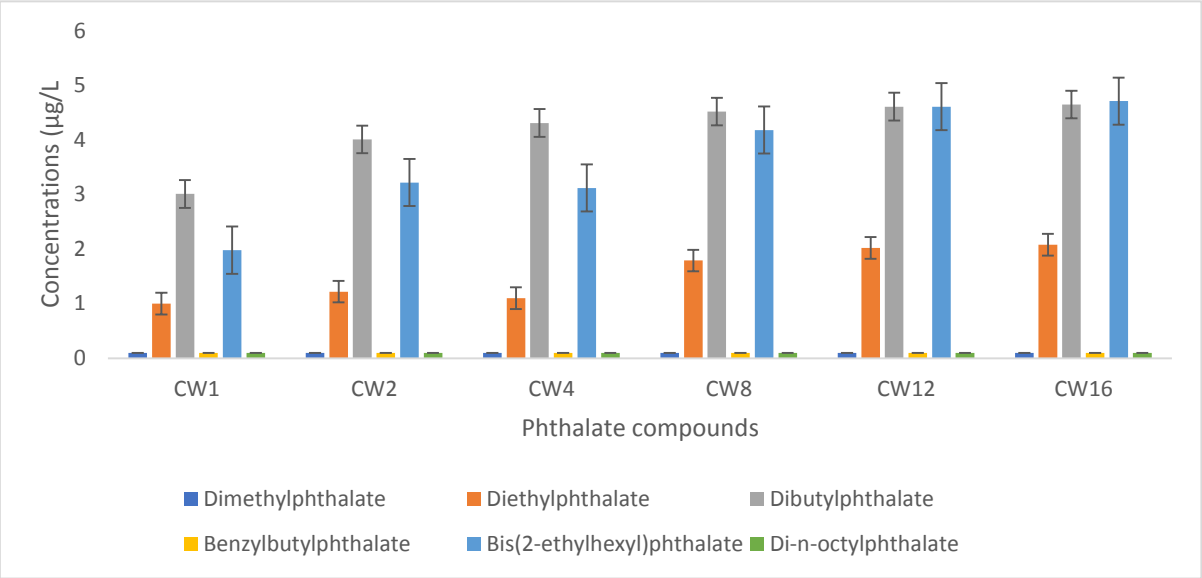

Figure 2. Concentration of Phthalate esters bottled water under cold storage conditions

Take note: CW means cold conditions, while the numbers 1, 2, 4, 8, 12, and 16 indicate the number of weeks of storage.

As shown in Figure 2, Dimethyl phthalate (DMP), Di-n-octylphthalate (Di-n-octylphthalat), and Benzylbutylphthalate (BBP) both had a concentration of less than 0.1 µg/L for the 16 weeks the four PET bottled water samples were placed under cold storage conditions that were analyzed in this study. The concentration of Diethyl phthalate (DEP) increased from 1 µg/L in the first week to 1.22 µg/L, 1.1 µg/L, 1.79 µg/L, 2.02 µg/L, 2.08 µg/L, in the second, fourth, eighth, and sixteenth weeks respectively. Dibutyl phthalate (DBP) recorded a concentration of 3.01 µg/L, 4.01 µg/L, 4.31 µg/L, 4.52 µg/L, 4.61 µg/L, 4.65 µg/L, in the first, second, fourth, eighth, twelfth and sixteenth week of cold storage respectively.

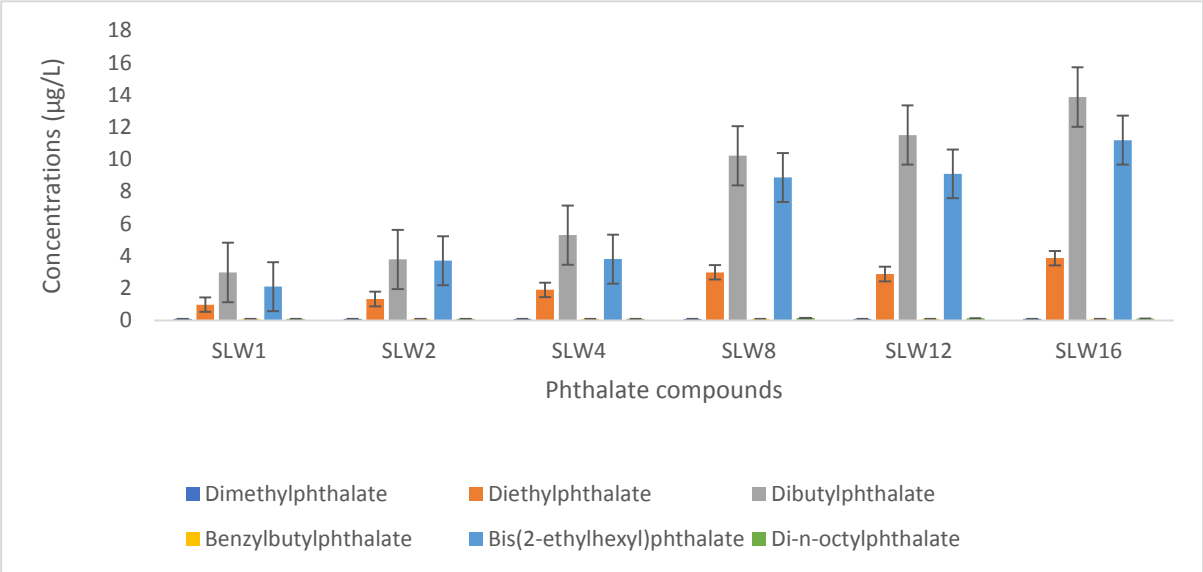

Figure 3. Concentration of Phthalate esters bottled water under sunlight storage conditions

Take note: SW means sunlight conditions, while the numbers 1, 2, 4, 8, 12, and 16 indicate the number of weeks of storage.

For PET bottled water stored in sunlight conditions, the concentration of DMP and BBP in the sixteen weeks of storage was less than 0.1 µg/L. This concentration was also recorded for DnOP in the first, second, and fourth weeks. However, during the eighth, twelfth and sixteenth weeks of storage, there was a slight increase in the concentration at 0.15 µg/L, 0.14 µg/L, and 0.12 µg/L respectively. The concentration of DEP were 0.98 µg/L, 1.33 µg/L, 1.9 µg/L, 2.99 µg/L, 2.88 µg/L, 3.87 µg/L for the first, second, fourth, eighth, twelfth, and sixteenth weeks of storage at sunlight conditions respectively. The concentration of DBP for the period of storage under sunlight conditions recorded the highest values at 2.98 µg/L, 3.79 µg/L, 5.3 µg/L,10.23 µg/L, 11.52 µg/L, and 13.88 µg/L for the first, second, fourth, eighth, twelfth, and sixteenth weeks of storage respectively. DEHP recorded values of 2.1 µg/L, 3.71 µg/L, 3.81 µg/L, 8.88 µg/L, 9.11 µg/L, and 11.2 µg/L for the period of storage respectively.

Under cold storage conditions, the trend of results could suggest that the mobility of the phthalates was higher at that specific incubation time (week 16) and storage temperature (4 ^{0}C). Yousefi, et al. (2019) while investigating the phthalate content of water stored in about 110 PET bottles suggested that the refrigeration temperature of 4 ^{0}C provided better conditions for the storage of bottled water, as the researchers detected minimal level of phthalates released from the bottle into the water at this temperature. A comparison of these data indicates that phthalates migrated from the PET bottles into the water even at storage temperatures lower than 4 0C (-10 0C). Among the observed dissolved phthalate chemicals, the water samples held at the sixteenth week of the incubation period had the highest DEHP concentrations. An identical trend was reported in respect of elevated DEHP values for stored water samples by Kanchanamayoon et al. (2012) and Yousefi, et al. (2019) respectively.

Similarly, the presence of DEHP in bottled water was reported by other studies which found that it was the most abundant phthalate in bottled water under cold, ambient and sunlight storage conditions (Amiridou & Voutsa, 2011; Greifenstein, et al. 2013; Keresztes et al. 2013; Schmid et al. 2008). In contrast, Saleh et al. (2011) found that BBP was the most abundant phthalate ester in three storage conditions (-4 ℃, room temperature, outdoor conditions) and the highest values (4.592 ± 3.081 µg/L) were detected at 4 ℃(Al-Saleh et al. 2011). The results of this investigation (Saleh et al. 2011) showed that the leaching pattern of phthalates among Saudi Arabian bottled water is somewhat different from that reported in other studies. The concentration of BBP in bottled water at low and high tempetemperaturesenerally much higher than that reported in the present (Amiridou & Voutsa, 2011; Cao, 2008; Keresztes Szilvia et al. 2013). The results for DnOP and BBP under ambient condition shows that at all time frames tested for, there was no increase or any leaching effect of DnOP and BBP into the water the results of this study correspond with the study carried out by Xu et al. (2020) which also show no leaching effect or presence of this phthalates.

3.2 Effect of Storage and Time on Leaching of Phthalates in PET Bottled Water

A Manova test was conducted to illustrate the different concentrations of Phthalate compounds over time when PET bottled water was stored in different storage conditions. As shown in Fig. 4 and Fig. 5 below, DEP, BBP, and DEHP showed increasing concentration under the three different storage conditions and duration and represent the entire dataset.

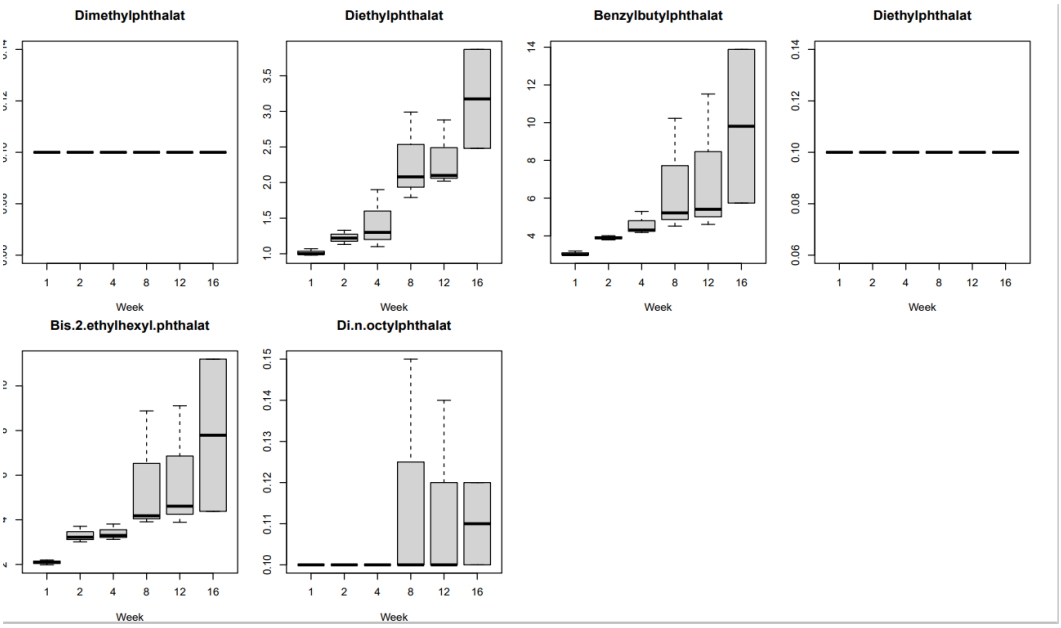

Figure 4. Box plots showing differences in weeks

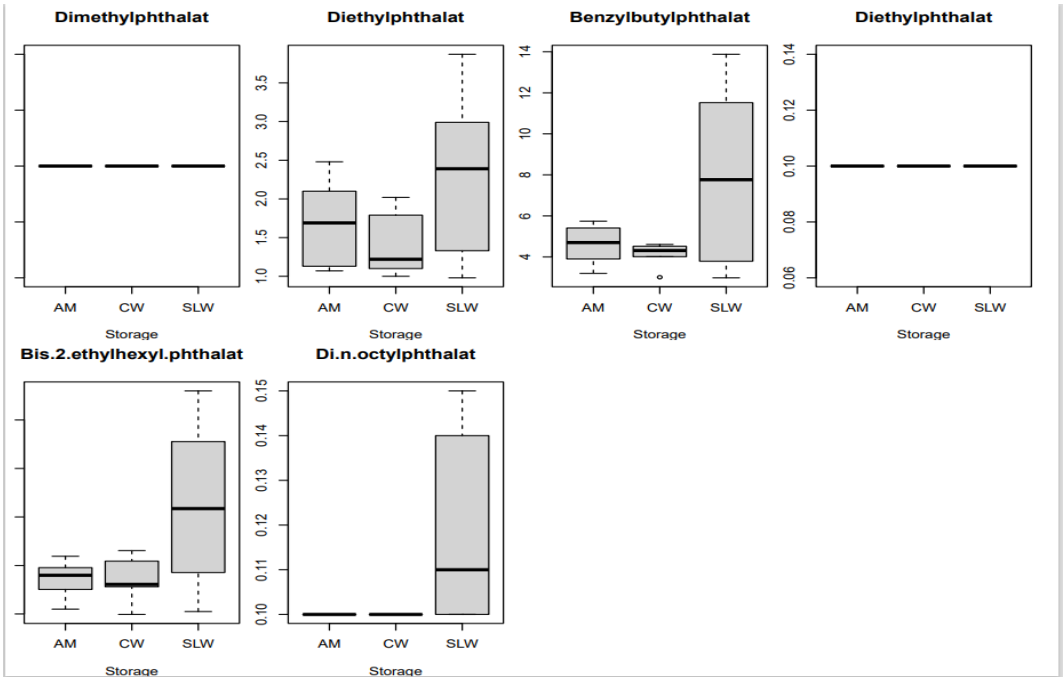

Figure 5. Boxplots showing phthalates compounds under different storage conditions

Take note: AM means ambient storage conditions, CW means cold storage conditions, and SLW means sunlight conditions respectively.

There was no difference recorded in the concentration of DMP, DnOP, and DEP, in the duration of the research. This shows the possibility of leaching effects of some phthalate compounds under the three storage conditions in consideration.

From the Manova test conducted between the independent variables (storage and week), the Wilk test (Shown in table 1 below) type shows that there is a significant difference among the means of the dependent variables from the results at 0.05 confidence level (p value =9.756e-08).

Table 1. Wilk-Statistical Test

Terms	**Storage (0.32)**	**Week (0.39)**	**Residuals**
Resp 1	2.3973	7.75936	0.96744
Resp 2	50.38385	67.68677	41.09299
Resp3	35.69174	41.26258	24.92407
Resp 4	0.0013	0.00083	0.00166
Deg. Of Freedom	2	5	9

*Resp 1: Diethylphthalate, Resp 2: Dibutylphthalate, Resp 3: 2.ethylhexyl.phthalate, Resp 4: Di.n.octylphthalate.

The result of the effect size test shows that the effect of week (0.39) is more than the effect of storage (0.32) which results to variation in mean.

Table 2. Kruskal-Wallis Statistical test

Kruskal-Wallis test / Two-tailed test:	
K (Observed value)	5.990
K (Critical value)	26.296
DF	16
p-value (one-tailed)	0.988
Alpha	0.05

The Kruskal-Wallis test (shown in table 2 above) showed significant differences between storage conditions, posthoc results only revealed a difference between PET bottled water stored in sunlight and the other conditions.

The Friedman test (Table 3) showed a significant difference ($p<0.001$) between time periods of measurements (From the first week to the sixteenth week of storage), post-hoc results showed that DEP, DEHP, and DBP concentrations had significant differences between all-time intervals.

Table 3. Friedman's Statistical test

Friedman's test:		
Q (Observed value)	54.288	
Q (Critical value)	26.296	
DF	16	
p-value (one-tailed)	**<0.0001**	***
Alpha	0.05	

Besides the fact that storage conditions, and duration of exposure affected phthalate migration into water. Results of DEP, DBP, and DEHP monitoring showed that significant differences were observed from the first and sixteenth weeks of exposure. According to our findings after sixteen weeks of storage in different conditions a significant increase was observed in the concentration of phthalates concentrations. In other words, as the storage

time prolonged, regardless of the storage condition and brand of the bottled water, concentrations of phthalate esters increased (as shown in Figure 1-3).

3.3 Possible Human Health Risk Potentials on Phthalate Concentration Under Different Storage Conditions

The investigation into phthalate leaching from thermoplastic products has brought attention to potential risks impacting the endocrine system. Of particular concern is the heightened sensitivity of children to phthalate exposure during their early developmental stages (Chou, et al. 2009).

In this study under ambient storage conditions, an exponential increase in concentrations of DEHP, DBP, and DEP over 16 weeks was observed. The concentrations escalated from 2.2 μg/L to 4.38 μg/L for DEHP, 3.2 μg/L to 5.74 μg/L for DBP, and 1.07 μg/L to 2.48 μg/L for DEP. These results suggest a significant leaching of phthalates into bottled water under ambient storage conditions.

Comparisons with studies in Tehran, Iran, and Tianjin, China, indicate considerably higher concentrations in the current study. The mean concentrations of phthalate compounds in this investigation surpassed those reported in Tehran (0.76 ± 0.19 μg/L) and Tianjin (1.963 ± 0.160 μg/L) for ambient storage conditions (Chou et al. 2009; Al-Saleh et al. 2011).

Under cold storage conditions, certain phthalates, including DMP, Di-n-octylphthalate, and BBP, remained at concentrations below 0.1 μg/L throughout the 16-week period. However, DEP and DBP displayed increasing concentrations over time, reaching 2.08 μg/L and 4.65 μg/L, respectively, by the sixteenth week.

For sunlight storage conditions, some phthalates maintained low concentrations, such as DMP and BBP (below 0.1 μg/L) over 16 weeks. Di-n-octylphthalate (DnOP) displayed increased concentrations in later weeks. Notably, Diethyl phthalate (DEP) and Dibutyl phthalate (DBP) recorded higher concentrations, reaching 3.87 μg/L and 13.88 μg/L, respectively, by the sixteenth week.

Given these results, it is crucial to assess the potential human health risks associated with phthalate concentrations under various storage conditions. Previous studies, such as those by Evandri et al. (2000) and Biscardi et al. (2003), highlighted genotoxic effects and chromosomal abnormalities in PET bottled water exposed to sunlight and temperature. Moreover, the cancer risk associated with DEHP exposure, as indicated by Jeddi et al. (2015), was found to be higher at elevated temperatures, surpassing permissible levels and suggesting potential health concerns for vulnerable populations. Consequently, there is a pressing need for proactive measures, including centralized water distribution in the Effurun metropolis, to mitigate potential health-related issues stemming from phthalate exposure.

4. Conclusion

The study demonstrated significant leaching of phthalates, particularly DEHP, DBP, and DEP, over a 16-week period under different storage conditions. The concentrations observed, especially under ambient storage, surpassed those reported in other regions, indicating a potential health risk associated with bottled water consumption. The implications of these findings extend to the broader discourse on water safety, emphasizing the need for proactive measures to address the growing reliance on bottled water in regions with limited access to clean drinking water. The elevated concentrations of phthalates, known for their adverse health effects, underscore the urgency of implementing strategies to mitigate potential risks. Considering the genotoxic effects, chromosomal abnormalities, and increased cancer risk associated with phthalate exposure from previous studies, it becomes imperative to prioritize water quality management. The Effurun metropolis, like many other areas facing similar challenges, should explore centralized water distribution systems as a means to ensure safer drinking water sources. This study contributes valuable insights to the understanding of phthalate contamination in regions with limited access to clean water. It emphasizes the importance of tailored solutions and proactive interventions to safeguard public health from potential risks associated with phthalate exposure through bottled water consumption.

Ethical Approval

This manuscript has not been submitted to any other journal for publication. All data generated from this research were gotten from the experiment carried out. This research did not include experimental studies involving animals, human data, or tissue.

Consent to Participate

Not applicable

Consent to Publish

Not applicable

Authorship contribution Details

Please see the specific contributions made by each author below.

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Competing Interests

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Availability of data and materials

The authors affirm that the article contains the information needed to support the study's findings.

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