Research Article

Detection and assessment of Dimethyl phthalate and Antimony migration in different drinking water samples under various storage temperatures in Al-Diwaniyah city

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Abstract

The widespread use of plastic-packaged drinking water has raised increasing concerns regarding the migration of hazardous chemical contaminants under high temperature conditions. this experimental study aimed to assess the effect of storage temperatures on the migration of dimethyl phthalate (DMP) and antimony (Sb) into drinking water packaged in polyethylene terephthalate(PET) ,polypropylene (PP) and high density polyethylene (HDPE) containers in AL-Diwaniyah city,Iraq. A total of 36 drinking water samples were collected from local markets, nine of these samples were transferred into clean sterilized glass bottles and sent directly to the laboratory to investigates about presence of DMP and Sb at markets temperatures (18°C). While, 27 samples were exposed to three temperature conditions (25 °C, 35 °C, and 45 °C) ,also sent to the laboratory with the aim of assessing the effect of different storage temperatures on the migration of these contaminants. DMP concentrations are determined using high-performance liquid chromatography (HPLC).while, Sb concentrations were determined by atomic absorption spectroscopy (AAS).The findings showed a highly significant increase ($P \leq 0.001$) in both DMP and Sb concentration with increasing temperatures across all plastic types. the concentration of DMP in PET plastic reached to (15.618±0.373 µg/L)at 45°C,in PP plastic reached to (16.922±1.048 µg/L) at 45°C.while, in HDPE plastic reached to the highest recorded level (17.319±0.391µg/L) at 45°C. the concentration of Sb in PET plastic reached to (17.133 µg/L) at 45°C,in PP plastic reached to (42.800±0.721µg/L) at 45°C. While, HDPE, exhibited the highest overall migration at elevated temperatures, reached to (50.267±0.306 µg/L) at 45°C.this study concluded that elevated environmental temperatures significantly increase the leaching of organic and inorganic pollutants from plastic packaging into drinking water, potentially exceeding global conservation standards and causing public health risks. these findings emphasize the urgent need for stricter storage policies, improved packaging materials, and enhanced public awareness of safe bottled water storage in hot climates .

Key-words: Drinking water, dimethyl phthalate (DMP) , antimony (Sb) , HPLC , AAS, plastic types, polyethylene terephthalate (PET), polypropylene (PP) and high-density polyethylene (HDPE)**.**

Introduction

Water represents an essential life resource, because it functions as a necessary building block for cell structures and as the medium through which essential biochemical processes occur. The drinking water must satisfy established physical and chemical and biological criteria to ensure it is safe for consumption. The definition of drinking water encompasses all water that people can safely use for both drinking and home activities, while bottled drinking water designates packaged natural or treated water that meets Iraqi specifications according to regulatory standards (Jabbar & Al-Kasser, 2024).

People obtain drinking water from groundwater sources and boreholes and other water sources, which undergo treatment through filtration and reverse osmosis processes to guarantee safe drinking water(Mohammadi et al., 2024). People have become more worried about drinking water safety and quality because of existing safety precautions. The U.S. Environmental Protection Agency has reported that approximately one-third of global water sources now contain organic pollutants (Vasseghian et al., 2021). Areas with unreliable municipal water systems have driven people to consume countries

now consume bottled water at high rates because of their inadequate infrastructure systems and the rising demands of urbanization bottled water at increasing rates. People from low- and middle-income (Pal et al., 2025).

Plastic pollution represents an environmental challenge which exceeds the problem of chemical contamination. The continuous increase in plastic production driven by fossil fuel use has resulted in the buildup of plastic waste and the distribution of plastic additives throughout the entire plastic production process(Cowger et al., 2024).The widespread use of plastic products which include bottled water containers leads to environmental contamination while people face possible exposure to dangerous substances(L. K. Singh et al., 2025).

The plastic industry has created deep effects on contemporary society while becoming essential for everyday existence. Plastic production has undergone rapid growth during the last thirty years which scientists now refer to as the "Plastic Age" because current yearly plastic output reaches 400 million tons and experts predict that this amount will double by 2050 if current patterns continue (Mansuri et al., 2023).

The extensive adoption of plastic products throughout the world has created environmental damage and health risks which now require worldwide action to resolve plastic pollution. People continuously interact with plastics from various sources which include food that has been contaminated and packaging materials that leak (such as water bottles and medical devices) and personal care products and synthetic textiles(M et al., 2021;Cook & Halden, 2020).

Bottled water has thus become a ubiquitous commodity, driven by urbanization, convenience, and perceived safety advantages over tap water (Y. Zhang et al., 2024). The bottled water industry produces plastic containers from materials that include polyethylene terephthalate (PET) and high-density polyethylene (HDPE) and polypropylene (PP) and polycarbonate (PC)(Da Silva Costa et al., 2021).

PET bottles are widely preferred because they provide both transparent material and lightweight design with gas barrier capabilities. However, the bottles release acetaldehyde , antimony, phthalates and bisphenol A (BPA) when used at high temperatures (Baz et al., 2023).

The production and processing of polymeric materials involve using various additives that improve flexibility and stability and resistance and color (Alshehri et al., 2022).The polymer matrix contains many additives that lack chemical binding and these additives will migrate into water during extended storage or environmental factors like heat and sunlight (Razali et al., 2021).The water inside the bottle interacts with its container, causing substances to move into the water that could pose health risks (Nur, 2025a).

Phthalates represent the primary plastic-derived pollutants because they exist as essential components for plastic product manufacturing(Neves et al., 2023). phthalates, a potential hazardous material because it exist in most products people use today (Khalili Sadrabad et al., 2023; Bhandari et al., 2021). Chemical manufacturers use phthalates to create flexible and strong plastics while BPA functions as a building block for making polycarbonate plastics and epoxy resins. People throughout the world become exposed to these chemical substances which manufacturers make for various consumer products (Basso et al., 2022; Wang et al., 2022).

The presence of endocrine-disrupting chemicals in the environment increases hazards which lead to greater human exposure. People become exposed to these substances through three different ways which include eating and breathing and touching surfaces that have contact with food packaging materials and cosmetic products and pharmaceutical drugs and pesticide application and industrial product distribution (Pan et al., 2024).

Chemical manufacturers use phthalates under the name phthalic acid esters PAEs as plasticizers for industrial purposes which include producing food packaging materials (Chakraborty et al., 2022). The chemical dimethyl phthalate belongs to the group of phthalates which people frequently use(Shah et al., 2024).The chemical compounds make plastic materials more flexible because they diminish the strength of the connections between the polymer chains(Idowu et al., 2026). The chemical properties of PAEs permit them to move from plastics into water and other substances because they exist as free chemicals rather than becoming part of the plastic structure.

PAEs are environmental contaminants that exist as widespread contaminants which industrial activities and human activities have released into groundwater and river water and various aquatic ecosystems (Mehraie et al., 2024).The presence of these contaminants has made some water sources unsafe for human consumption. The U.S. Environmental Protection Agency has established a

maximum contaminant level (MCL) of 6 µg/L for certain phthalates in drinking water(Mohammadi et al., 2024).The toxic properties of multiple phthalates which include DMP and DEP and DEHP have resulted in their classification as priority pollutants because of their widespread detection in the environment (B. Liu et al., 2024).

Phthalates function as endocrine-disrupting chemicals EDCs because they disrupt the normal functioning of hormonal systems (Monisha et al., 2023; Moreno et al., 2020; Ren et al., 2022). The health effects which result from exposure to these compounds include diabetes and obesity and thyroid dysfunction and autism spectrum disorders and multiple types of breast cancer and liver cancer and skin cancer and testicular cancer(Lite et al., 2022).

The body processes these substances through its metabolic system after which they exit the body through urine and feces and sweat. The body absorbs these substances through the intestine before they transform into conjugated forms within the gastrointestinal system and liver (Runkel et al., 2022).

Phthalates exposure leads to major health problems which include endocrine disruption, reproductive toxicity, metabolic disorders and immunological effects (Russo et al., 2022;Costa & Cairrao, 2024). Epidemiological studies have shown that these compounds increase the risk of respiratory disorders which includes asthma and developmental abnormalities(Geetha, 2021a).

The growing concern about trace metals extends beyond organic contaminants to include antimony Sb as a rising environmental threat. The use of antimony compounds as catalysts for PET production leads to their potential contamination of bottled water through migration which occurs at high temperature conditions (Baz et al., 2023).

The rising global demand for bottled water has increased public health concerns about long-term exposure to antimony through its health hazards (World Health Organization, 2022).Antimony exposure results in gastrointestinal disturbances which lead to various negative health effects (Mehdar, 2024a).

The systematic investigation of these contaminants becomes essential because people increasingly rely on plastic-packaged drinking water which displays chemical migration potential based on plastic type and storage conditions while BPA and DMP and antimony reveal documented health risks. Public health protection and water quality control require evaluation of drinking water contamination through drinking water evaluation and assessment of plastic type and temperature effects on their migration and associated changes in physicochemical characteristics.

Materials and Methods

The study seting

The current study was conducted in Al-Diwaniyah city, located in the southern part of Iraq , approximately 158 to 160 kilometers from Baghdad. The city contains fertile farmland which receives irrigation from the Euphrates River. people depends on drinking water from different sources which include bottled water ,cups and RO water system that made from plastic. The region endures extremely high summer temperatures which frequently surpass 45 °C. These conditions create a risk of plastic-related pollutants migrating from the containers into drinking water supplies.

The Study Design

Field and laboratory Experimental study design was used to achieve study's aims

Sample Collection and Experimental Conditions

Thirty six Samples of drinking water packaged in bottles made from polyethylene terephthalate (PET) plastic, cups made from polypropylene (PP) plastic and RO containers made from high-density polyethylene (HDPE) plastic were randomly collected from local markets during 0ctober 2025. the temperatures of these markets were measured field by using a portable temperature meter. nine of these samples were transferred into clean sterilized glass bottles to prevent secondary contamination, then placed in cooler box and sent directly to the laboratory to investigate of presence (DMP and Sb) at markets temperature (18 °C).

While, twenty seven of these samples were underwent to three controlled temperatures included(25°C, 35°C and 45°C) for duration of one week to evaluate different storage conditions. then, the samples were transported to sterilized glass bottles and sent directly in a cooler box to the laboratory analysis to investigate the impact of these temperatures on concentrations of these contaminants.

Selection criteria:

Inclusion Criteria

- Plastic drinking water bottles

- Plastic drinking water cups
- plastic RO containers water

Exclusion criteria

- Expred,unsealed,damaged,or lacked labeling drinking water were excluded .

Instruments and Equipments

Table (3-1) Instrument and equipments used in study

No	Instruments and equipments	Company and Country
1	High Performance Liquid Chromatography (HPLC)	CECIL , Britain
2	Atomic Absorption Spectrometry (AAS)	novAA 350 analytik jena , Germany
4	Glass bottles 50ml	India
5	Refrigerator	Turkey
6	Cooler box	China
7	Thermo-Hygrometer	DYWSJ, china

Table (3-2) Chemicals used and their manufacturer company used in the study

No	Chemicals	Company and Country
2	Dimethyl phthalates standard for HPLC	Bdh for hplc , England
3	Antimony Standard (Sb) for AAS	Jena , Germany
4	Methanol (MeOH)	England
5	Trifluroacetic Acid TFA	England
6	Acetonitrile CAN	England
7	Deionized Water DI water	England

Laboratory Analysis for dimethyl phthalate and antimony

in the laboratories of the scientific center for chemical analysis located in Baghdad , High-Performance Liquid Chromatography (HPLC) was used for the determination of bisphenol A and dimethyl phthalate**,** while Atomic Absorption Spectroscopy (AAS) was employed for the determination of antimony concentrations**.**

Determination of Dimethyl Phthalate

Water samples were analyzed for the quantitative determination of dimethyl phthalate (DMP) using High-Performance Liquid Chromatography (HPLC) according to the operating conditions as described below:

1. Mobile Phase Preparation

The mobile phase was prepared as a mixture of methanol (MeOH) and deionized water in a ratio of 90:10 (v/v)**.** The mobile phase was filtered and degassed prior to use to ensure stable flow and optimal chromatographic performance. The mobile phase was filtered through a 0.45 µm membrane filter and degassed prior to use. the flow rate was 1.0 mL/min.

2. Stationary Phase

Separation was carried out using a C18 reversed-phase (ODS) column**.** The column dimensions were 25 cm × 4.6 mm**.** The column was equilibrated with the mobile phase before sample injection. The injection volume was set to 20 µL, using UV–Visible detector at wavelength 230 nm and the total retention time for each analysis was 10 minutes**.**

3. Preparation of Standard Solutions

A DMP standard solution (5 ppm) was used, prepared according to the laboratory method file (DMP. mtd**).** The standard solution was injected under the same chromatographic conditions as the samples to ensure accurate quantification.

4. Quantification of DMP

The concentration of DMP in the water samples was determined using the peak area method (Area/Area%)**.** Quantification was performed by comparing the peak area of the samples with that of the DMP standard solutions under identical chromatographic conditions.

Determination of Antimony

The concentration of antimony in water samples was determined using Atomic Absorption Spectroscopy(AAS)**,**which based on the characteristic absorption spectrum of the elements to be measured. The analysis was performed using an air–acetylene flame as the atomization source and an antimony hollow cathode lamp (Sb-HCL) as the radiation source**.**

Calibration was performed using standard solutions with concentrations ranging from 0.000 to 0.2 mg/L. The calibration curve showed excellent linearity with a correlation coefficient (R^2) of approximately 0.9999. The method demonstrated high sensitivity and precision, with low limits of detection and quantification, making it suitable for trace-level determination of antimony in drinking water samples.

Statistical analysis

All data are analyzed by the SPSS software (V.28 Inc., Chicago, USA) and Microsoft Excel 2019. This study used (T-test) for an independent sample between two groups for quantitative variables and Analysis of Variance (F-test) (ANOVA) for more than two groups. Pearson's correlation is used to determine correlation between variables. All values are expressed as the mean value ± of the standard deviation (SD). P- value of less than (0.05) and (0.01) were significant.

Results

Table 1: illustrates the migration levels of DMP from PET, PP and HDPE plastic into water across four different temperatures: 18°C, 25°C, 35°C, and 45°C. the increase in DMP concentrations with temperature was a highly significant for all plastic types($P \leq 0.001$) . PET showed the lowest migration at lowest temperatures starting with no detected levels (0.000±0.000 µg/L) at markets temperature(18°C). However, it shows a sharp spike at 35°C (13.029±2.644 µg/L) and 45°C (15.618±0.373 µg/L). PP Showed a steady and significant increase in DMP migration as temperature rises, Leaching increases from(1.263±2.188 µg/L) at markets temperature(18°C) to (16.922±1.048 µg) /L at 45°C. HDPE follows a very similar trajectory to PP, Started at (1.890±0.856 µg/L) at markets temperature(18°C) and reaches the highest recorded level (17.319±0.391µg/L) at 45°C.

the LSD values indicates that all pairwise differences between temperature levels are significance differences.

Table 1: Mean Concentrations (±SD) of DMP (µg/L) for PET ,PP and HDPE plastic at Temperatures of 18°C, 25°C, 35°C, and 45°C

Parameter	Plastic type	Temperature	Mean±SD	Minimum	Maximum	F	P-value	LSD
DMP	PET	18	0.000±0.000	0.000	0.000	98.994	≤0.001*	1.863
		25	2.119±0.452	1.730	2.614			
		35	13.029±2.644	10.003	14.896			
		45	15.618±0.373	15.401	16.048			
	PP	18	1.263±2.188	0.000	3.789	62.073	≤0.001*	3.821
		25	12.347±1.800	10.346	13.835			
		35	14.537±0.387	14.213	14.965			
		45	16.922±1.048	15.804	17.881			
	HDPE	18	1.890±0.856	1.063	2.773	122.468	≤0.001*	2.237
		25	10.910±1.598	9.317	12.512			
		35	14.886±1.031	13.708	15.622			
		45	17.319±0.391	16.904	17.681			
	*. The mean difference is significant at the 0.05 level.							

Table 2: illustrates the migration levels of Sb from PET, PP and HDPE plastic into water across temperatures18°C, 25°C, 35°C, and 45°C. the results in this table showed a highly significant differences in Sb concentrations with temperature increase for most plastic types($P \leq 0.001$). concentration of Sb in PET plastic increased from(6.067±0.153 µg/L) at market temperature(18°C) to a peak of (17.133 µg/L) at 45°C. PP started with the highest initial migration at market temperature(18°C) (11.733±1.102µg/L),showing a steady increase, reaching (42.800±0.721µg/L) at

45°C. While, HDPE, exhibited the highest overall migration at elevated temperatures, values rise sharply from (5.200±0.265µg/L) at market temperature(18°C) to a peak of (50.267±0.306 µg/L) at 45°C. The LSD values (2.052, 4.886 and 9.632) confirms that all differences between temperature groups are significant differences.

Table 2 Mean Concentrations (±SD) of Sb (µg/L) for PET, PP and HDPE Plastic at Temperatures of 18°C, 25°C, 35°C, and 45°C.

Parameter	Plastic type	Temperature	Mean±SD	Minimum	Maximum	F	P-value	LSD
Sb	PET	18	6.067±0.153	5.900	6.200	67.312	≤0.001*	2.052
		25	11.567±1.716	10.000	13.400			
		35	14.100±0.361	13.800	14.500			
		45	17.133±0.907	16.300	18.100			
	PP	18	11.733±1.102	11.000	13.000	895.386	≤0.001*	4.886
		25	21.967±0.961	21.100	23.000			
		35	36.967±0.153	36.800	37.100			
		45	42.800±0.721	42.000	43.400			
	HDPE	18	5.200±0.265	4.900	5.400	1993.673	≤0.001*	9.632
		25	16.933±0.473	16.400	17.300			
		35	40.367±1.484	39.100	42.000			
		45	50.267±0.306	50.000	50.600			
	*. The mean difference is significant at the 0.05 level.							

Correlation Analysis

To evaluate the correlations between temperature, plastic-related contaminants(DMP and Sb) in drinking water samples, Pearson correlation analysis was performed. the results for PET,PP and HDPE plastic types are presented in tables(3,4 and 5).

Table 3: showed that temperature has a strong positive significant correlations with DMP(r = 0.861)and Sb (r = 0.768),showing that rising temperatures lead to more PET materials leaking both organic and inorganic pollutants.

DMP showed a strong positive significant correlation with Sb (r = 0.876) ,suggesting that both

contaminants get released at the same time when environmental conditions reach similar temperatures.

Table 3: Pearson correlation coefficient between temperature and plastic-related contaminants (DMP and Sb) in water samples packaged in PET plastic.

For PET	DMP (µg/L)	Sb (µg/L)
TEM.	0.861*	0.768*
DMP (µg/L)	1.000	0.876*
*. Significant correlation at P ≤0.05		

Table 4: showed that temperature has strong positive correlations with DMP(r = 0.863) and Sb (r = 0.981). also showed a strong positive correlation between DMP and Sb (r = 0.891) .

Table 4: Pearson correlation coefficient between temperature and plastic-related contaminants (DMP and Sb) in water samples packaged in PP plastic.

For PP	DMP (µg/L)	Sb (µg/L)
TEM.	0.863*	0.981*
DMP (µg/L)	1.000	0.891*
*. Significant correlation at P ≤0.05		

Table 5: showed that Temperature has a strong positive correlations with DMP(r = 0.922)and Sb (r = 0.987). also showed a strong positive correlation between DMP and Sb(r = 0.932).

Table 5: Pearson correlation coefficient between temperature and plastic-related contaminants (DMP and Sb) in water samples packaged in HDPE plastic

For HDPE	DMP (µg/L)	Sb (µg/L)
TEM.	0.922*	0.987*
DMP (µg/L)	1.000	0.932*
*. Significant correlation at P ≤0.05		

Discussion:

The results in table 1 showed that the increase in DMP concentrations with temperature was a highly significant for all plastic types, a trend that is well supported through the latest toxicological and materials studies.The determined increase in DMP concentration from 18°C to 45°C (reached 17.319 µg/L in HDPE) is consistent with the findings by (Angnunavuri et al., 2022),who stated that the storage temperature of HDPE-packaged water semigration stage. where the first sharp spike of DMP leaching from PET at temperatures above 35°C,which becomes traceable inside,is constant with the behavior of semicrystalline polymers, where accelerated chain motion near their glass transition regions accelerates diffusion of components. this confirmed by(Mastanjević et al., 2025) in bottled beverages studies.

the fast release rate between 18°C and 25°C suggest that the initial surface layer leaching is observed in a diffusion-controlled manner, which tends to equilibrium at better temperatures. It reflects the observations of recent studies on pipe materials, where water temperature was established as the most important variable controlling the kinetic launch of phthalate esters into the aqueous phase(Zhang et al., 2023) .

The results in table 2 showed a highly significant differences in Sb concentrations with temperature, concentrations increasing sharply as the temperature increases from 18°C to 45°C.these findings are in agreement with recent studies.leaching of chemical additives from polymer matrices in aqueous environments as reported by(Kiyataka et al., 2024) who confirmed that Sb migration from PET bottles increases significantly upon exposure to thermal stress (60°C), while(Mehdar, 2025) and (Geetha, 2021) determined that long-term heat exposure promotes Sb release, due to the extended molecular inner structure of the plastic.

Although PET is widely established as a source of Sb due to its use as a polymerization catalyst, the very high migration levels found in HDPE and PP suggest the presence of flat Sb-based components. pigments may be responsible for leaching under thermal conditions. this is aligns with the study by (Eti et al., 2023),who found that simulations at extreme temperatures (70°C) can cause extensive heavy steel migration from many food-grade nitroplastics, far exceeding typical environmental garage platforms.

The results presented in table 3 indicate that temperature showed a strong positive correlations with organic DMP and inorganic Sb pollutants leaching from PET water bottles. these results are consistent with recent studies emphasizing that thermal stress accelerates the transfer kinetics of chemical compounds from the plastic matrix to the embedded water.(Khanniri et al., 2024) suggested that the migration of phthalic acid pollutants (including DMP) is significantly accelerated by storage conditions, showing extreme correlation with the highest concentrations found at accelerated temperatures (40°C).

Similarly, the leaching behavior of antimony (Sb) is consistent with the findings of (Mehdar, 2024) and (Kishi et al., 2024),who documented that increasing temperature acts as a primary factor for increase Sb leaching, possibly approaching regulatory limits under extreme temperature conditions. the strong correlation between DMP and Sb ($r = 0.876$) suggests a simultaneous co-discharge mechanism, a phenomenon supported through(Nur, 2025), who mentioned that increased temperature causes a simultaneous increase of inorganic and organic pollutants in the wastewater packages that lead to drinking water to ambient temperature is an important issue in chemical protection because it allows the simultaneous leakage of various pollutants.

The results in table 4 showed that temperature has strong positive correlations with DMP and Sb . also showed a strong positive correlation between DMP and Sb (r = 0.891) in polypropylene (PP) water samples, these high correlation coefficients imply that elevated storage temperature acts as an essential catalyst for organic and inorganic pollutants migration from the polymer matrix to the water . Furthermore, the strong positive correlation between DMP and Sb indicates that these contaminants are released exclusion current pollution temperature. Incredibly regulated by a common diffusion-controlled migration mechanism, where rising temperature booms the kinetic strength of polymer chains, thus reducing the activation energy needed to diffuse additives and residues into water. studies have proven that excessive temperature significantly accelerates the release of catalytic agents and plasticizers from many polymers(Carneado etal.,2023;Nur, 2025).

Similarly, researchers suggested that phthalate migration by DMP follows a temperature-stabilized kinetic version, where increasing thermal energy allows molecules to migrate from the inner plastic to the surface sooner or later(Wang et al., 2023). Inorganic (Sb) and organic (DMP) corresponding data in high columns chemicals, multi-pollutant leaching is often driven through the same environmental stressors, posing a cumulative fitness risk to consumers (Eti et al., 2023).

The results in table 5 showed that Temperature has a strong positive correlations with DMP and Sb . also showed a strong positive correlation between DMP and Sb in water samples stored in HDPE bottles.these results indicate that high temperatures greatly increases the leaching and the migration of the chemical pollutants from plastic matrix into watershed, this consistent with existing study by(Angnunavuri et al., 2022), who indicating that storage temperature is an essential element affecting phthalate levels in drinking water in HDPE packaged water, with longer handling at better temperature. Similarly,(Liu et al., 2024) revealed that increasing ambient temperature acts as the primary factor for the leaching of phthalate esters from various polymers, including HDPE.

The high correlation between DMP and Sb further indicates that the contaminants probably percent normal absorption in the packaging material or follow parallel migration pathways. This consists with(Nur, 2025), who mentioned the co-diffusion and temperature-structured increase of antimony and organic plasticizers in bottled water, indicating that the polymer matrix acts as a multi-source reservoir for the pollutants

In addition,(Tisler et al., 2024) showed that HDPE bottles can release a wide range of organic migrants,reinforcing the idea that multiple contaminants can leach simultaneously under heat stress.

Conclusions

This study showed the essential relationship between environmental heat stress and chemical safety of bottled water, identifying temperature as a main catalyst for leaching of organic and inorganic contaminants. Highly positive significant correlation between increasing temperatures and both dimethyl phthalate and antimony, as thermal expansion of the polymer matrix reduces the activation force required for these pollutants to pass through the water .

Specifically, while PET is often tested for antimony leaching, this study found that HDPE and PP showed much higher Sb migration rates with extended temperatures, reaching 50.267 µg/L and 42.8 µg/L and 42.8 µg/L, respectively, indicating Sb-based stabilizers or pigments used in these plastics are less thermal stability than the detected PET catalysts. Thus, the antimony

concentrations of PP and HDPE do not meet Iraqi and worldwide protection standards at storage temperatures of 25°C and higher, posing a direct toxicological risk to consumers.
The strong positive correlation between DMP and Sb is due to several factors of the simultaneous co-migration mechanism, whereby heat-precipitated structural decomposition allows the joint emission of more than one pollutant. The temperature in it Iraq summers commonly reach 35 to 45 degrees Celsius, these results indicate that bottled water stored in unrefrigerated reservoirs or outdoor environments is particularly susceptible to chemical contamination .

Recommendations

1- Strict storage regulations: In areas with extreme heat, such as Iraq, the purchase and distribution of bottled water in refrigerated and storage facilities (keeping the temperature below 20°C) may be legally mandated .
2- General warning labels: The packaging of bottled water shall have clear "temperature warning" labels advising consumers not to expose bottles to heat or direct sunlight.
3- Review of HDPE/PP Additives: Regulatory Our agencies and manufacturers need to examine the supply of antimony in HDPE and PP plastics (potential pigments) and replace them with stronger, non-toxic alternatives.
4- Revised quality testing: should deal with "stress tests" (testing water after propagation to 40°C), as opposed to the most effective test at room temperature to ensure real-world safety
5- Consumer awareness: Consumers should be encouraged to use high quality glass containers for water storage, especially during the summer months.
6- Environmental Policy: Encourage exemptions for virgin-used plastics over centralized water filtration systems to reduce health risks associated with plastic-water-chemical interactions.