



Brief Communication

Migration of Phthalates From Polyethylene Terephthalate Bottles into Beverages: A Health Policy Brief



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ABSTRACT

Background: Phthalate compounds are among the harmful compounds that, under certain conditions, can migrate from the inner wall of polyethylene terephthalate (PET) bottles into the beverage in which they are contained.

Objectives: This policy brief aims to discuss and investigate the factors influencing the release of phthalates from PET bottles into beverages.

Materials & Methods: Following a narrative review approach, scientific studies and reports were sourced from reputable national and international databases. Key findings were analyzed to identify the most critical factors affecting phthalate migration.

Results: The primary parameters influencing the migration of phthalates include the concentration of phthalates in bottle production, storage temperature, exposure to sunlight, duration of storage, and the reuse of bottles.

Conclusion: This study highlights modifiable factors that impact the migration of phthalates from PET bottles. Health authorities should educate the public and beverage vendors to implement safe storage and usage practices, as outlined in this health policy brief.

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Introduction

In recent decades, the widespread use of plastics in daily life and the inevitable human interaction with plastic products and their harmful components that alter the human endocrine system have raised concerns. Endocrine-disrupting chemicals (EDCs) are a large group of natural and synthetic substances that interfere with the normal functions of the endocrine system. These chemical compounds include environmental estrogens (xenoestrogens) such as phytoestrogens or artificial chemicals such as alkylphenols and phthalates [1]. These xenoestrogenic compounds are a diverse group that bind to estrogen receptors, mimic estrogenic effects, and may have adverse effects on human health [2, 3].

Phthalates (also called phthalic diesters) are a group of related organic chemicals commonly used as plasticizers in the plastics industry. Polyvinyl chloride (PVC) and other polymers such as rubber and styrene, commonly have plasticizers added to them to make them flexible and elastic. The five most commonly used phthalates in the plastics industry include: Di-(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), diisononyl phthalate (DINP), diisodecyl phthalate (DIDP), and benzyl butyl phthalate (BBP) [4]. Because phthalates are not tightly bound to plastic, they can migrate into water or food over time when they come into contact with the plastic container [5]. BBP, DEHP, and DBP are listed as EDCs [6]. Human exposure to phthalates can lead to health problems including breast cancer, reproductive hormonal disorders, obesity, and impaired function of enzymes involved in sexual cell maturation [7, 8].

In Iran, polyethylene terephthalate (PET) bottles are widely used in the production of mineral water and various beverages due to their low cost and easy availability. Most commonly, plastic containers are used as drinking water bottles, and the unfavorable storage conditions of these bottles in factories and distribution warehouses (in direct sunlight) increase the temperature inside the water bottles, which can increase the likelihood of migration of compounds such as phthalates from the bottle wall into the water contained.

This health policy brief identifies the factors influencing phthalate migration and provides recommendations to reduce the associated risks through effective public health policies and practices.

Materials and Methods

To develop this policy brief, we first conducted a comprehensive search of reputable national and international databases, including [Google Scholar](#), [ScienceDirect](#), [Scopus](#), [PubMed](#), [Iranian Research Institute for Information Science and Technology \(IranDoc\)](#), [Comprehensive reference for Iranian Scientific and Specialized Journals \(Magiran\)](#) and [ISC \(Islamic World Science Citation\)](#). Relevant keywords such as “polyethylene terephthalate”, “beverages”, “migration”, “bottle”, “phthalate”, “concentration”, “liquids”, and “storage” were used in the search and combined (and/or) to conduct a comprehensive search. This search included scientific reports and studies on the subject from the last two decades. We then used the key findings from these studies to determine which method of storing PET bottles is best to prevent the formation of phthalate compounds. Finally, by modeling the measures taken in other countries, we have made important recommendations to prevent the migration of phthalates from the walls of bottles into drinks

Results

Various studies have been carried out around the world to detect phthalates in PET bottled beverages. [Table 1](#) summarizes the phthalate concentrations observed in diverse studies, highlighting their variability based on storage conditions and bottle reuse.

Factors affecting the migration of phthalates from the bottle wall into the beverage have been reported in some studies. In a study conducted by Keresztes et al. (2013) in Hungary, the migration of phthalates from PET bottles into drinking water was investigated. The results showed that the levels of DIBP, DBP, BBP, and DEHP in the water contained in the tested bottles were in the range of >3-200, >6.6-800, >6-100, and >16-170 ng/L, respectively. Among the phthalates studied, DEHP was the most prevalent in the samples [7]. A study by Moreira et al. (2014) in Brazil examined DBP migration from plastic materials to food during the microwaving process. The results showed that the levels of DBP in the food samples were in the range of >0.08-7.5 µg/L, and that increasing the heating time and the frequency of using plastic containers increased the phthalate content in food [15]. A study by Jeddi et al. (2015) investigated the levels of phthalates in bottled water under common storage conditions. The results showed that increasing the storage temperature and duration increased the migration of phthalates from the bottle wall into the water [16]. [Table 2](#) presents a compilation of results from diverse research

Table 1. Concentration levels of phthalates in liquids stored in PETbottles across various studies

Year of Study	Analyzed Food	Analysis Method	Compounds	Concentration	Reference
2004	Whole milk	GC-MS	DBP	7.3–50.3 µg/kg	[9]
			BBP	1.11–2.93 µg/kg	
			DEHP	15.1–27.2 µg/kg	
2008	Olive oil	GC-MS/MS	DBP	<LOD –490 µg/kg	[10]
			BBP	<LOD –1750 µg/kg	
			DEHP	<LOD–4700 µg/kg	
2005	Cow milk	GC-MS	DBP	4.07–9.79 µg/kg	[11]
			BBP	<LOD	
			DEHP	8.4–282.9 µg/kg	
2010	Olive oil	GC-ion trap	DBP	<LOD–175 µg/kg	[12]
			BBP	87–211 µg/kg	
			DEHP	198–240 µg/kg	
2003	Mineral water	GC-MS	DBP	0.32–0.51 µg/L	[13]
			BBP	<LOD	
			DEHP	0.57–0.65 µg/L	
2007	Mineral water	GC-MS	DBP	<LOD	[14]
			BBP	<LOD	
			DEHP	<LOD	



Abbreviation: GC-MS: Gas chromatography coupled to mass spectrometric; GC-MS/MS: Gas chromatography–tandem mass spectrometry; LOD: Limit of detection; GC-ion trap: Gas chromatography with mass spectrometry detector; PET: Polyethylene terephthalate; DBP: Dibutyl phthalate; BBP: Benzyl butyl phthalate; DEHP: Di-(2-ethylhexyl) phthalate.

studies, providing insights into the factors that influence the migration of phthalates.

Discussion

Phthalates are commonly used plasticizers in the plastics industry [4, 6] and are not chemically bound to the polymer matrix of the plastic. This lack of chemical binding makes them prone to migration into foods or beverages that come into contact with plastic containers [5, 21]. The serious adverse health effects of phthalates have garnered significant attention from researchers and health authorities. The migration process of phthalates from PET bottle walls into their contents depends on various factors, including the concentration of phthalates in the packaging material, the acidity and lipid content of the contents that come into contact with the bottles,

and the duration of the liquid's contact with the bottle wall (storage time), the temperature of the environment in which the bottles with liquids are stored, and whether or not they are exposed to sunlight [5, 16, 22–25].

The unique chemical properties of DEHP, DBP and BBP may contribute to their migration behavior into the bottle contents. These compounds exhibit a higher tendency tendency to migrate into food or beverages under various real-world conditions. In addition, the contact time between the PET bottle and its contents can be a significant factor in chemical migration. Prolonged contact at higher temperatures can increase leaching and potentially lead to increased phthalate levels in the stored food or beverage. In addition, the properties of the contents in the bottles, such as pH and the presence of additives, also play a crucial role in the migration of

Table 2. Summary of findings from key studies on factors affecting the migration of phthalates from plastic bottles to their contents

Author, Year of Study	Analysis Method	Findings
Seyhan et al. 2022 [17]	ELISA	Storage conditions, particularly high temperatures and sunlight exposure, influence the migration of chemicals from plastic bottles, specifically PET
Sreedhashyam et al. 2022 [18]	LC/APPI/HR-MS	Increased storage time and temperature significantly enhance migration of phthalates and bisphenols from plastic bottles. They provide empirical data on the concentration of various phthalates over time, emphasizing the influence of storage conditions on the release of these compounds into drinking water
Wang et al. 2023 [19]	GC-MS	Increased temperature above 80 °C and the presence of oily food simulants significantly enhance migration rates
Evarist et al. 2024 [20]	HPLC	Temperature and duration significantly influence the migration of phthalate compounds from plastic bottles, particularly PET. They also indicated that reusing these bottles can exacerbate phthalate release, raising safety concerns for drinking water



Abbreviation: ELISA: Enzyme-linked immunosorbent assay; LC/APPI/HR-MS: Liquid chromatography/atmospheric pressure photoionization/high-resolution mass spectrometry; GC-MS: Gas chromatography coupled to mass spectrometric; HPLC: High-performance liquid chromatography; PET: Polyethylene terephthalate.

these compounds. These external elements can influence chemical interactions in PET bottles and influence the leaching process of phthalates into stored food or beverages [5, 26, 27]. Xu et al. (2010) reported that the migration rate of phthalates from the walls of bottles specifically designed for cooking oil was higher than that of bottles specifically designed for bottled water. Among the factors studied, storage temperature and duration were found to have the most substantial impact on migration rates [28].

High temperatures can accelerate the degradation of plastic polymers and increase the mobility of chemical additives, resulting in higher phthalate release [21]. This phenomenon is particularly noticeable in scenarios where PET bottles are exposed to high temperatures, such as when stored outdoors in direct sunlight. To assess the safety of PET bottles, it is crucial to understand the extent to which sunlight influences phthalate migration. This issue is particularly relevant in a country like Iran, where observations indicate that some sellers or consumers store excess packaged foods outdoors (usually outside the distribution and sales area) due to limited storage space. Findings from a study by Jeddi et al. (2015) in Iran showed that increasing the storage temperature and duration of mineral water bottles resulted in an increase in the migration of phthalates from the bottle wall into the contained water [16].

It has been proven that increasing temperature and storage time, in addition to phthalates, can also increase the migration of other dangerous compounds from the

bottle wall into the liquids contained. Chapa-Martínez et al. (2016) in Mexico reported that among the variables studied (temperature, pH, and storage time), temperature had the greatest influence on the migration rate of antimony from PET bottles into water. The highest migration occurred at a pH of 7, a temperature of 75 °C and a storage period of 5 days [29]. Kazemi et al. (2012) found that increasing temperatures significantly increase the migration rate of bisphenol A (BPA) and nonylphenol from PET bottles into water [30]. In a study by Nam et al. (2010) in South Korea showed that the migration rate of BPA from a polycarbonate baby bottle into water was 0.03 ppb and 0.13 ppb at 40 °C and 95 °C, respectively, when the bottle was new. However, after 6 months of use at the same temperatures, these values increased to 0.18 ppb and 18.47 ppb. Based on the results of this study, it was found that the migration rate of BPA from bottle to water increased rapidly at temperatures above 80 °C, and the migration rate of BPA from bottle to water was 4.9×10^{-2} ppb at each use [31].

On the other hand, some Iranian consumers, after consuming beverages and liquids from new bottles, reuse them for the same purpose (e.g. drinking water) or for other purposes (e.g. storing vinegar, lemon juice, herbal extracts, pickles, etc.). Therefore, different temperature storage conditions and the type of food stored in the bottles (with pH levels higher or lower than neutral) can affect the release of phthalates [6]. Despite the prevalence of reusing PET bottles in Iran, there is a lack of comprehensive data on how the reuse of these bottles affects

the migration of phthalates from PET bottles into beverages or other stored substances. Therefore, conducting research on this topic is necessary.

Based on the findings, we present several recommendations for the proper production, storage and transportation of PET beverage bottles to reduce the migration of phthalates and other harmful compounds into the beverages. During the production process, manufacturers should prioritize the use of high-quality PET materials with minimal phthalate content to reduce the potential for migration.

Temperature control is crucial for storage and transportation. Bottles should be kept in cool environments to slow down the migration of phthalates. Additionally, exposure of beverage-containing bottles to direct sunlight should be avoided, as higher temperatures can accelerate the release of harmful compounds from the bottles. Distributors and retailers should also be trained on appropriate storage methods, emphasizing the importance of keeping bottles away from heat sources and sunlight.

The duration of storage should also be minimized, as longer contact times between the beverage and the bottle walls increase the risk of phthalate migration. Monitoring the inventory of retailers can help ensure that bottles are not stored for extended periods before reaching consumers. Furthermore, reuse of PET bottles should be reduced whenever possible, especially for storing acidic or fatty substances, as these can increase the leaching of phthalates.

Transportation methods should prioritize temperature-controlled vehicles to maintain a consistent cool temperature throughout transit. Packaging and handling methods should be designed to minimize physical stress on bottles, as this can potentially accelerate the release of compounds from the plastic. By implementing these measures, the risk of phthalate migration from PET bottles into beverages can be significantly reduced, ensuring product safety for consumers.

Conclusion

Previous studies indicate that factors such as increased storage temperature, exposure to direct sunlight, prolonged storage duration (contact time between the beverage and the inner wall of the bottle), and the reuse of bottles significantly contribute to the migration of hazardous compounds, including phthalates, from PET bottle walls into the contained beverages.

To address these risks, it is recommended that health authorities and regulatory bodies implement targeted policies and issue guidelines for beverage manufacturers to ensure proper storage conditions for PET bottles. Furthermore, public education and information campaigns are essential to raise awareness among consumers, distributors, and retailers about the correct storage and usage practices for PET bottles. These efforts will help mitigate the release of harmful substances and enhance the safety of bottled beverages.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of [Kermanshah University of Medical Sciences](#) (Code: IR.KUMS.REC.1399.359).

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Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interpretation of the results and drafting of the manuscript. Each author approved the final version of the manuscript for submission.

Conflict of interest

The authors declared no conflict of interest.

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