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The concentration of phthalates in drinking water in Iran: A systematic review and meta-analysis

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A R T I C L E   I N F O

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Iran

A B S T R A C T

PAE and PC polymers, such as BPA, are utilized to make water bottles. Due to the lack of polymer-chemical interaction, PAE can enter drinking bottles during production, wrapping, and keeping. Phthalates can transfer from the bottle to the water depending on keeping conditions (temperature, time, sunlight intensity), pH, and bottle capacity. Since there haven't been previous studies published on the subject, the aim of this meta-analysis and systematic review research is to determine the level of phthalates in drinking water consumed in Iranian cities. Web of Science, Science of Direct, Scopus, and PubMed, databases have been used in this study. Eight studies were selected from 556 initial publications after screening for duplication and irrelevant information. Articles from January 1, 2000, to February 10, 2024, were found in the mentioned databases. Among the types of phthalates, the concentration of DEHP was reported higher than the others Because its concentration has been reported in seven out of eight studies. The highest concentration of DEHP was reported by Mehraie(2.22 μg/l), Zare Jeddi (0.8 μg/l), Yousefi (0.77 μg/l), Abtahi (0.76 μg/l), Zare Jeddi (0.42 μg/l), Abdolahnejad(0.15 μg/l), and Pourzamani (0.08 μg/l). The highest concentration of DEP, DBP, BBP, and PA was reported by Abtahi (0.77 μg/l) and Esteki (2.25 μg/l), Mehraie(0.93 μg/l), and Pourzamani (0.83 μg/l). The results of this study showed that the most important phthalates measured in drinking water include DEP, DEHP, DBP, BBP, and PA. According to the results of the present studies, the most important factor in the increase of phthalates is the storage conditions of drinking water (temperature, sunlight, and the type of pipe or bottle)

1. Introduction

Polyethylene terephthalate (PET) makes up a substantial portion (64%) of the bottles that are produced, according to the 2018 data. In 2018, the American Chemistry Council (ACC) documented the collection of nearly 0.31 million pounds of post-consumer PC bottles for recovery [1]. PET and high-density polyethylene (HDPE) comprise the majority (97.1%) of the overall weight of commercially produced plastic. In addition, phthalate ester (PAE) is a common material in the production of drinking bottles, while PC polymer compounds, including BPA, are also used. PAE might potentially enter drinking bottles throughout the production, packaging, and storage processes, as it doesn't react chemically with the polymers used [2]. The bottled water business is found in many of the world's regions. The composition and structure of caps on bottles can serve as an essential source of phthalate esters (PAE). Polymer bottle caps comprise high- and low-density polyethylene (LDPE and HDPE) and polystyrene (PS) [3]. According to the studies, BPA has been found in LDPE, HDPE, and PS polymers.

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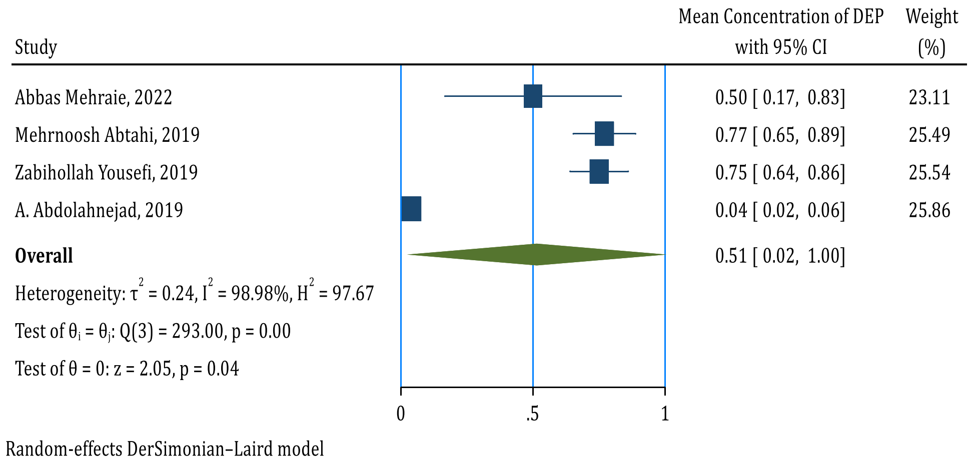

Figure1. combined findings of DEP.

Consequently, the adhesive utilized to attach bottle labels might contribute to PAE in samples from bottled drinking water. PAE compounds are among the hydrophobic organic compounds that are very insoluble in water under normal conditions (25 degrees Celsius) but have a high affinity for alcohols and fats [4]. Therefore, we conclude that if humans are exposed to PAEs even at low levels, their health can be endangered, and if this exposure is long-term, it can be a severe threat to health. PAEs have been identified as having adverse effects on the well-being of humans, including the manifestation of indications such as tremors in the limbs, pulmonary disruption in kids, inflammation of the eyes, and disturbance of the hormonal system [5–7]. Bottled water was first in the main category of commercial drinks in Western Europe and then became a natural drink worldwide. Within the bottler industry, the main emphasis is on the manufacturing and packaging of two different kinds of water: Mineral drinking water consists of a type of water containing minerals [8]. It is drunk for health needs. Drinking water refers to the water source suitable for use, originating from groundwater, boreholes, and other sources. This water requires purification by different techniques such as filtering, elimination, and reverse osmosis [9]. In 2018, worldwide water consumption in bottles exceeded one hundred trillion gallons, with the average person's consumption reaching over forty-two gallons (158,987 liters). Since estrogenic phthalates, a type of organic substance, have been regularly detected in bottled water, it creates concerns with the widespread belief that bottled water is superior to tap water regarding smell, safety, and portability. Phthalates, harmful to human wellness, have significant adverse effects on public health, garnering increasing concern [10,11]. The Environmental Protection Agency (EPA) sets the Maximum Contamination Limit Goal (MCLG) for phthalates at zero, following the Maximum Contaminant Level (MCL) in drinking water set at 6 micrograms per liter. Nevertheless, the Lethal Concentration 50 (LC_{50}) of phthalates in drinking water is not mentioned. Phthalates are widely used as polymers in various items, including wall covers, wires, cable covers, toys, packaging for food, blood baggage, etc. Phthalates are also used to transform rigid polyvinyl chloride polymers into flexible and pliable plastics, such as chewing rubbery dolls and other loose goods [12]. Phthalates are found in several chemical compounds. Among these compounds, DEHP and DBP have estrogenic effects. This activity can be hidden entirely and removed through purified anti-estrogens if BBP and DBP are estrogenic for salmon. Phthalates represent significant hazards to the well-being of humans and are susceptible to adverse effects and problems [13]. Some consequences include endocrine anomalies, neurological disorders of development, reproduction, and cardiovascular problems. DEHP, for example, has an impact on the reproductive system of men, producing damage. It is notable that DEHP additionally hurts estrogen-sensitive tissues, leading to their injury [14]. Other phthalates may cause issues with reproduction, such as abnormalities in the bladder, vas deferens in the seminal vesicles, the prostate, and outer genitalia, a condition known as testicle harm [15]. The movement and migration of phthalates from the bottle to the water can be affected by multiple variables, including storage conditions (such as temperature, length of time, daylight intensity), pH, and bottle volume. Rising the temperature increases the migration of phthalates from the bottle to the water. Similarly, raised time in storage additionally speeds up the migrating of phthalates. It is essential to note that acidic situations increase the release of phthalates [16]. The utilization of phthalate-free polyethylene bottles for bottling drinking water has risen. The movement of dangerous organic substances, especially phthalates and alkylphenols, is important because of varying storage circumstances. Investigating the level of phthalates in drinking water consumed in Iranian cities is the aim of this meta-analysis and systematic review research since there haven't been any previously published studies on the subject.

2. Material and method

2.1. Search strategy

The search was carried out based on all articles published until the twentieth of December 2023, to assess the levels of phthalates in drinking water in Iran. Databases, including Scopus, Web of Science, Iran Doc, Mag Iran, Science Direct, and PubMed, have been searched to locate original papers on this topic. PubMed's Mesh terms were also utilized when choosing English keywords. Truncation was used at the end of some phrases to enhance search sensitivity. Absolute keywords for article searches in PubMed were: ((((((((((((((((((((((("Phthalate, Dibutyl"[Title/Abstract]) OR ("Di-n-Butyl Phthalate"[Title/Abstract])) OR ("Di n Butyl Phthalate"[Title/Abstract])) OR ("Phthalate, Di-n-Butyl"[Title/Abstract])) OR ("Butyl Phthalate"[Title/Abstract])) OR ("Phthalate, Butyl"[Title/Abstract])) OR ("Phthalate, Diethylhexyl"[Title/Abstract])) OR ("Bis(2-ethylhexyl)phthalate"[Title/Abstract])) OR ("Dioctyl Phthalate"[Title/Abstract])) OR ("Phthalate, Dioctyl"[Title/Abstract])) OR ("Di-2-Ethylhexylphthalate"[Title/Abstract])) OR ("Di 2 Ethylhexylphthalate"[Title/Abstract])) OR ("DEHP"[Title/Abstract])) OR ("DEP"[Title/Abstract])) OR ("BBP"[Title/Abstract])) OR ("DBP"[Title/Abstract])) OR ("PA"[Title/Abstract])) OR ("butyl benzyl phthalate"[Title/Abstract])) OR ("benzyl butyl phthalate"[Title/Abstract])) OR ("BBPHT"[Title/Abstract])) OR ("MEHP"[Title/Abstract])) OR ("mono(ethylhexyl) phthalate"[Title/Abstract])) OR ("tributyl tin phthalate"[Title/Abstract])) AND ((((("Water, Drinking"[Title/Abstract]) OR ("Potable Water"[Title/Abstract])) OR ("Water, Potable"[Title/Abstract])) OR ("Bottled Water"[Title/Abstract])) OR ("Water, Bottled"[Title/Abstract]))) AND ("Iran"[Title/Abstract]).

Table 1
Studies of phthalates measured in drinking water in Iran.

Date	City	Sample Size	Phthalates	Concentration(μg/l)	SD	Reference
2014	Tehran	24	DEHP	0.418	0.196	[17]
			DBP	0.114	0.088	
			BBP	0.043	0.018	
2016	Tehran	6	DEHP	0.802	0.225	[18]
			DBP	0.302	0.107	
			BBP	0.003	0.0011	
2019	Sari	110	DEP	0.75	0.08	[19]
			DEHP	0.77	0.11	
			DBP	1.78	0.43	
2019	Isfahan	33	DEP	0.014	0.011	[20]
			DEHP	0.149	0.032	
			DBP	0.023	0.0068	
			BBP	0.039	0.0094	
2019	Tehran	40	DEP	0.77	0.06	[21]
			DEHP	0.76	0.19	
			DBP	1.06	0.23	
			BBP	0.096	0.1	
2021	Isfahan	15	DBP	2.251	1.51	[22]
			PA	0.026	0.012	
2022	Tehran	40	DEP	0.5	0.17	[23]
			DEHP	2.22	0.76	
			DBP	0.5	0.21	
			BBP	0.93	0.3	
2023	Isfahan	7	DEHP	0.077	0.095	[24]
			DBP	0.039	0.021	
			PA	0.831	0.013	

Keywords in the web of science were (((((AB= ("Phthalate ")) AND AB= ("Concentration")) AND AB= ("DEP")) AND AB= (DEHP)) AND AB= ("Drinking Water ")) AND AB= (Iran).

2.2. Inclusion and exclusion criteria

Only articles with subsequent features were chosen for inclusion in this systematic review.

- Articles that are entirely text accessible
- Articles that only measured the amount of Phthalate in the drinking water of cities in Iran.
- Articles that are only published in English or Persian.
  - o However, items that did not meet the requirements were not included in the article
- Presentation (PowerPoint)
- Book
- Conference Paper
- Email to the editor
- Reviews articles

2.3. Literature search

The papers on preparing research and choosing items are based on the flow diagram of the Recommended Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) shown in Fig. 1. Articles were found throughout the initial search. Following the initial screening, 556 documents with appropriate search terms were identified. Out of these, 485 papers that hadn't been associated were excluded based on an analysis of their titles and abstracts. Following a comprehensive examination of the whole article, 27 studies have been removed from inclusion due to insufficient presentation of data. The current overview includes research in which researchers have collected the desired information throughout many years and cities. Everyone was treated as an independent investigation. In the end, 8 studies were included in the meta-analysis.

2.4. Process of gathering data

The appropriate papers were evaluated using specific criteria to determine whether they met the requirements outlined in the article's title and summary. Afterward, every one of the qualifying documents was separately reviewed by separate colleagues, who subsequently extracted and reported the data in the designated collecting form in this approach:

- First author.
- Publication year of the research paper.
- Sampling location (city).
- Declare.
- Statistical analysis method.
- A type of phthalate.

- Average Standard deviation (SD),
- Assessment of the levels of phthalates in drinking water

2.5. Statistical analysis

We utilized the software known as STATA for the objective of carrying out statistical analysis of data. The effect size can be calculated by estimating the mean of various phthalate levels. The essential data needed for research papers includes summary statistics, including the mean, standard deviation, and sample size. The heterogeneity analysis is done using Cochrane's Q statistics, in which a low P-value shows the presence of heterogeneity. In addition, the Iˆ2 index is utilized to assess the level of heterogeneity, with $I^2 < 40\%$ showing insignificant heterogeneity and $I^2 > 75\%$ suggesting considerable heterogeneity. A random-effects systematic review is done using the DerSimonian-Laird technique to consider heterogeneity. When no heterogeneity exists, a model with fixed effects is utilized.

3. Result

In Iran, eight investigations evaluated bottled water phthalate concentrations. The research has been restricted to three cities: Tehran, Isfahan, and Sari. The details of their studies are reported in Table 1, including the authors' names, year of research, sample size, type,

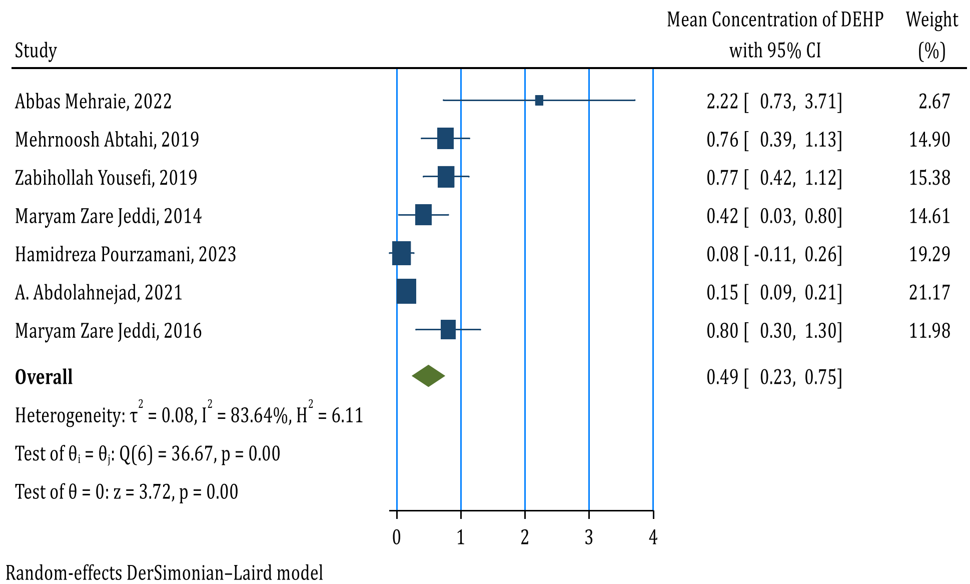

Fig. 2. combined findings of DEHP.

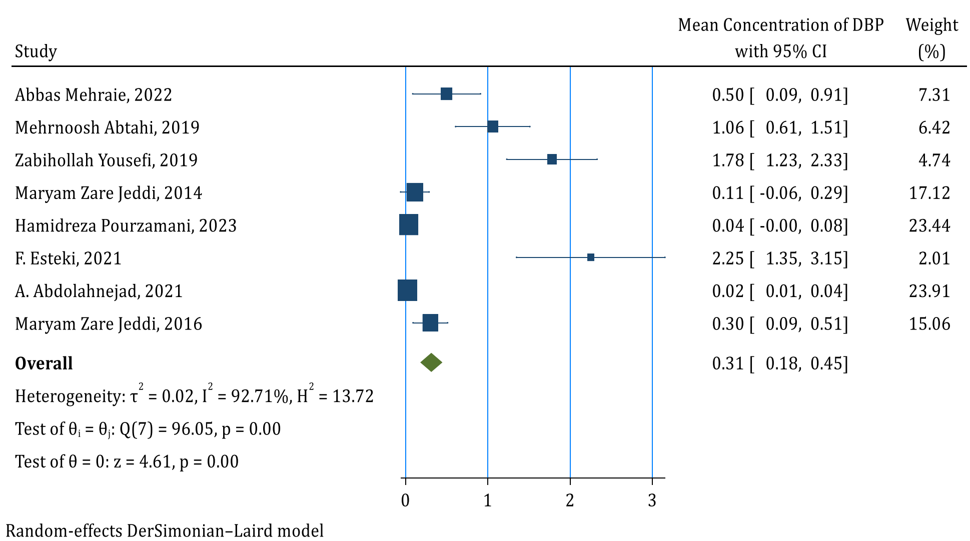

Fig. 3. combined findings of DBP.

concentration, and standard of measured phthalate division. Four out of eight studies were conducted to measure phthalates in drinking water in Tehran. These studies were performed every three years from 2014 (Zare Jeddi et al.), 2016 (Zare Jeddi et al.), 2019 (Abtahi et al.), and 2022 (Mehraie et al.). Isfahan City (Esteki, Abdolahnejad, Pourzamani) was the focus of three investigations, while Sari City had just one study done (Yousefi et al.). The highest sample volume (110) was reported in Sari. The smallest sample volume was also written in Tehran [6] and Isfahan [7]. The phthalates in drinking water measured in the present studies included DEHP, DBP, BBP, DEP, and PA. The highest and lowest reported concentrations of PA belonged to Pourzamani (0.831) and Esteki (0.026). Pourzamani and Mehraie reported the lowest (0.077) and highest (2.22) concentrations of DEHP in drinking water, respectively. Abtahi et al. reported the highest concentration of DEP (0.77), and Abdolahnejad et al. reported the lowest concentration (0.041) in drinking water. Sari (1.78) and Isfahan (0.023) had the highest and lowest DBP concentrations in their drinking water, respectively. Mehraie reported the greatest level of BBP in bottled water at 0.93 ppb, but Zare Jeddi observed the lowest value at 0.003 ppb.

Fig. 1 shows the combined findings of four primary studies in Tehran, Sari, and Isfahan, reporting the mean level of DEP in Iran. The mean concentration of DEP has been calculated to be 0.51. Since I^2= 98.98%, the main research is heterogeneous, and the Random-effect approach. The highest concentration of DEP in 4 studies conducted in drinking water belonged to Abtahi et al. (Mean=0.77; CI: 0.64–0.86). The lowest value was determined by Abdolahnejad et al. (Mean=0.04; CI: 0.02–0.06).

Fig. 2 shows the results of 7 primary studies to report the mean DEHP concentration in Iran (the 7 prior studies have been done in Tehran, Sari, and Isfahan). The pooled estimation of the mean concentration of DEHP is 0.49 with a 95% confidence interval (0.23, 0.75). Since I^2=83.64%, main research is heterogeneous, and the Random-effect approach. DEHP measurement has been reported in seven studies in Iran. Its highest concentration (Mean=2.22; CI: 0.73–3.71) was reported in the study of Mehraie et al. Zare Jeddi (Mean=0.80; CI: 0.30–1.30), Yousefi (Mean=0.77; CI: 0.42–1.12), Abtahi (Mean=0.76; CI: 0.39–1.13), Zare Jeddi (Mean=0.42; CI: 0.03–0.80), Abdolahnejad (Mean=0.15; CI: 0.09–0.21), reported a lower amount. Pourzamani et al. reported the lowest concentration of DEHP (Mean=0.08; CI: −0.11–0.26).

Fig. 3 depicts the combined results from 8 primary studies conducted

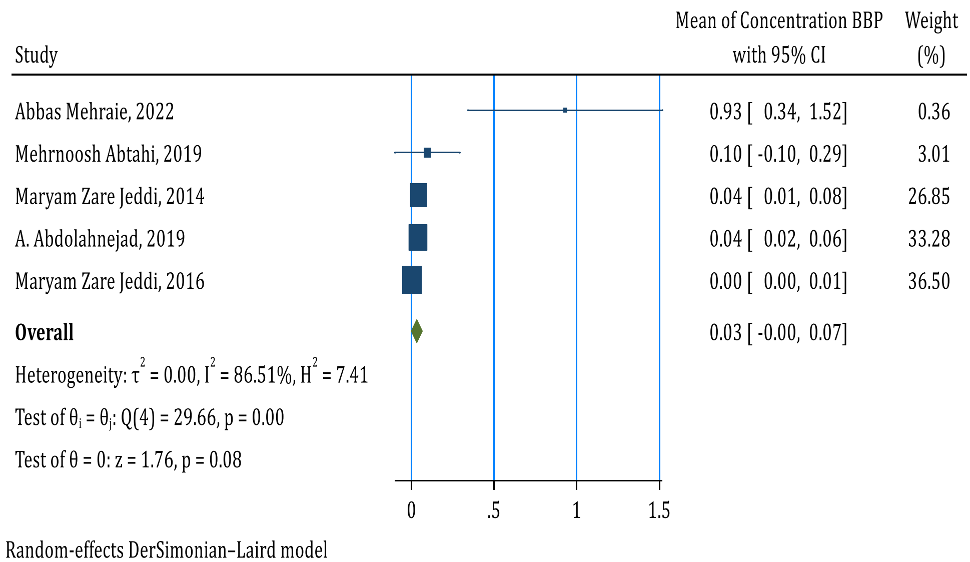

Fig. 4. combined findings of BBP.

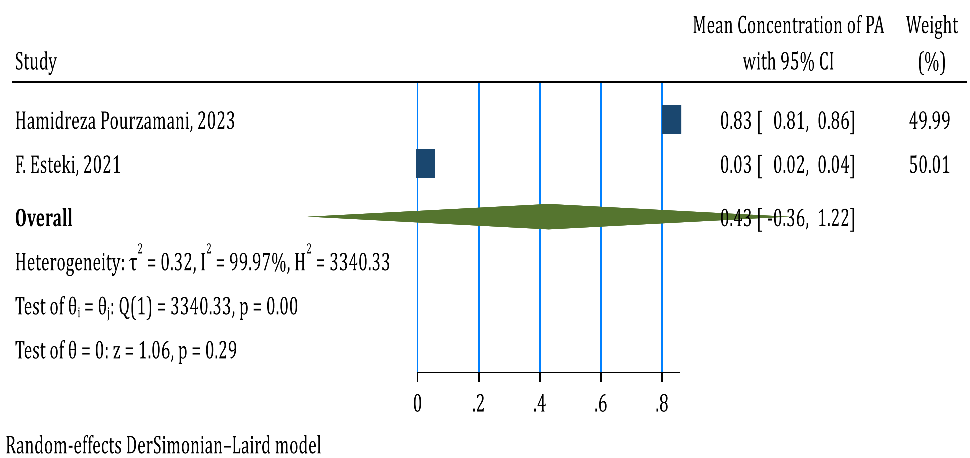

Fig. 5. combined findings of PA.

in Tehran, Sari, and Isfahan, showing the mean level of DBP in Iran. The mean concentration of DBP has been calculated to be 0.31. Considering that the value of I^2 is 92.71%, the main research show heterogeneity. Consequently, a random-effect approach was used.

Esteki(Mean=2.25; CI: 1.35–3.15), Yousefi(Mean=1.78; CI: 1.23–2.33), Abtahi(Mean=1.06; CI: 0.61–1.51), Mehraie(Mean=0.50; CI: 0.09–0.91), Zare Jeddi(Mean=0.30; CI: 0.09–0.51) and (Mean=0.11; CI: 0.06–0.29), Pourzamani (Mean=0.04; CI: 0.00–0.08), Abdolahnejad (Mean=0.02; CI: 0.01–0.04) reported DBP concentration in their studies; The highest concentration said belonged to Esteki and the lowest concentration belonged to Abdolahnejad.

Fig. 4 presents the combined results of 5 primary investigations in Tehran and Isfahan, showing the mean concentration of BBP in Iran. The mean concentration of BBP has been calculated to be 0.03. Since I^2=86.51%, the main research is heterogeneous, and the Random-effect approach. Mehraie(Mean=0.93; CI: 0.34–1.52), Abtahi(Mean=0.1; CI: −0.1–0.29), Zare Jeddi (Mean=0.04; CI: 0.01–0.08), and Abdolahnejad (Mean=0.04; CI: 0.02–0.06) reported BBP concentration in their studies. The highest and lowest measured BBP belong to Mehraie and Zare Jeddi, respectively.

Only two studies reported PA concentrations. These two studies were conducted by Pourzamani (Mean=0.83; CI: −0.81–0.86) and Esteki (Mean=0.03; CI: −0.02–0.04). Fig. 5 shows the incorporating result of 2 primary studies to report the mean of PA concentration in Iran (the 2 primary studies have been done in Isfahan). The pooled estimation of the mean concentration of PA is 0.43 with 95% confidence interval (-0.36, 1.22). Since I^2=99.97%, the main research is heterogeneous, and the Random-effect approach.

4. Discussion

Phthalate levels in Iranian drinking water were systematically reviewed in the present investigation. A total of 8 studies in Iran were extracted with this aim. Among the accepted studies, the concentration of 5 types of phthalates in drinking water was further investigated, which included DEHP, DEP, DBP, BBP, and PA.

The highest and lowest concentrations of DEP in drinking water belonged to the study of Abtahi (Mean=0.5; CI: 0.17–0.83) and Abdullah Nejad (Mean=0.04; CI: 0.02–0.06), respectively. Al- Four phthalate chemicals were found in home bottled water by Mudhaf et al. A 113.98 ng/l DEP was detected. DEP contained 22.9% of the four phthalates detected [25]. Luks-Betlej et al. detected DEP in Poland and Germany, from water bottle samples [26].

Seven Iranian studies analyzed DEHP. Mehraie et al. had the highest DEHP levels in Iranian drinking water (Mean=2.22; CI: 0.73–3.71), while Pourzamani had the lowest (Mean=0.08; CI: −0.11–0.26). DEHP, an important phthalate element, has been extensively shown to be present at exceedingly high concentrations globally. This result is consistent with previous research done in Taiwan [27]. Canadian drinking water samples have been analyzed for PAE according to Coa. They detected a mean DEHP content of 0.1 μg/L [28]. In Greece, Amiridou and Voutsa concluded that the mean DEHP level in water bottle samples were 0.580 μg/L [29]. The researchers Wu et al. detected no PAEs in Chinese water bottle samples [30]. Luo et al. conducted research in China to evaluate the levels of PAE in mineral and municipal water. DEHP content averaged 0.72 μg/L in natural water and 3.3 μg/L in water from municipalities [31]. Moazzen et al. found that the mean PAE level in Iranian-flavored soft drinks was 3.453 μg/L [32].

The highest and lowest concentrations of DBP in drinking water belonged to the study of Esteki(Mean=2.25; CI: 1.35–3.15), and Abdolahnejad (Mean=0.02; CI: 0.01–0.04), respectively.

Following being kept outdoors for 10 weeks; the samples indicated a slightly higher concentration of phthalates [33]. The highest and lowest concentrations of BBP in drinking water belonged to the study of Mehraie(Mean=0.93; CI: 0.34–1.52), and Abdolahnejad (Mean=0.04; CI: 0.02–0.06), respectively. Saleh et al. found that BBP was the most common phthalate at 4 °C, room temperature, and outdoors. Maximum BBP concentrations (4.592 ± 3.081 μg/L) were reported at 4 °C. [34]. Considering that the MCL level for phthalates in drinking water is defined by WHO and EPA between 6 and 8 μg/L, none of the samples in the present study exceeded the standard [35].

Temperature, disposable plastic and paper containers, water supply pipelines, and light affect phthalates in drinking water and their transfer to water bottles, as reported by researchers [36]. In warmer months, Abdolahnejad et al. reported mean DEP, DEHP, DBP, and BBP concentrations of 40.38, 150.02, 19.13, and 40.19 ng/l in all samples. However, winter averages were 29.12, 99.22, 16.01, and 69.14 ng/l. In contrast to winter, summer showed higher average levels of all PAEs but BBP. The difference in PAE levels between winter and summer can be attributed to the increasing temperature during the warmer seasons since higher temperatures result in an increase in PAE levels [37]. He et al. reported the highest number of PAEs in September [38]. In their study, Jeddi et al. concluded that the duration of keeping and exposure to direct sunlight both influenced the leakage of phthalates into water bottles. The study showed that DEHP levels in water bottles rose from 0.35 to 0.80 μg/L over 45 days of sunlight storage. Yousefi et al.'s studies determined that the levels of DEHP in any control samples were under the level that had been established. DEHP revealed more levels compared to other phthalate esters after being exposed to higher temperatures and longer periods of storage. Nevertheless, the level was lower compared to that of other phthalates after a five-day period of storage and at colder temperatures. Casajuana et al. found that storage of bottled water in poor conditions (at a temperature of 30 degrees Celsius for a period of 10 weeks) resulted in an elevated level of phthalates, particularly DBP, DEHP, and BBP, in the drinking water. In addition, the level of phthalate in PET bottles for drinking was twenty times higher in comparison with that in water bottles made of glass [39]. Khanniri et al. noticed that at a normal temperature, the level of DEP in assessed water-drinking bottles varied from 0.85 to 0.97 μg/L. After the storage time of 90 days at 40 degrees Celsius, the level of DEP increased to 1.35 μg/L, which increase in level was statistically significant. Furthermore, raising the room temperature to 40 degrees Celsius and lengthening the storage time to 90 days led to a significant increase in average levels of DEHP to 3.44 μg/L, respectively. This research showed that increasing temperatures raised plastic bottle phthalate release into for drinking [17,18]. A new study analyzed phthalate levels in packaged water at 25–42°C over a period of time. Similarly to our studies, it appears that the highest emission of phthalates occurred after 15 days of keeping at a temperature above 42 degrees Celsius [40]. According to a different inquiry, the concentrations of phthalates in water used in bottles at a temperature of 40°C for a period of 6 months revealed an increase [41]. Furthermore, Pourzamani et al. showed a significant rise in the level of DEHP in all PET water bottles samples following being kept for 3 months at temperatures above 45°C. Orabi et al. obtained similar results, confirming that the concentrations of phthalates in PET water samples rose after 180 days of keeping compared to the concentrations observed during the first week of production [42]. Additionally, it was determined that the concentrations of DEHP, DBP, and BBP indicated an increasing trend in mineral water that had been stored at ambient temperature for a duration of 44 days [43]. Also, Guart et al. claimed that the rate of phthalate detected in PET bottled water held at ambient temperature for a year was substantially greater compared to those that were evaluated immediately after manufacture [44]. Abtahi et al. observed these mean total phthalate levels in water consumed from different resources: 0.76 ± 0.19 μg/L in the drinking water supply system, 0.96 ± 0.10 μg/L in water bottles, 1.06 ± 0.23 μg/L in waters on the surface, and 0.77 ± 0.06 μg/L in ground waters. Studies indicate that even brief contact between drinking water and plastics may result in greater concentrations of phthalate exposure, and it is recommended to reduce such contact wherever possible. The transfer of phthalate in disposable paper cups is caused by the plastic's inner layer. Thus, replacing throwaway disposable cups with paper ones isn't a successful way to decrease the probability of phthalate exposure by water consumption. Similarly, to these findings, Martine et al.[45]. indicated the drinking water containers had more phthalates than the water from the faucet. In this study, DBP and DEHP levels in bottled samples of water were almost 50% lower compared to those observed in Iran by Jeddi et al., with concentrations of 0.2 and 0.19 μg/L, respectively. Phthalate amounts in water were similar to those published by Domínguez et al. [46] for Madrid and Martine et al.[45] for Paris, having levels of 0.99 and 0.71 μg/L, respectively. On the contrary hand, Tang et al.[47] detected phthalates in Chinese water bottles in refers up to 96 μg/L. Exposure to lead affected kids' circulating sexual hormone concentrations. A current thorough study by Luo et al.[48] revealed that Thailand, Croatia, and the Czech Republic had the greatest average DEHP refers in bottled water. These countries measured levels of 59.9, 7.9, and 5.8 μg/L, respectively. The sequence of average phthalate levels transferring into bottled water from pipes made of plastic has been identified by Abdolahnejad et al. DEHP>DEP>BBP>DBP. The mean DEP, DEHP, DBP, and BBP levels found in pipe materials were 24.1, 29.98, 19.58, and 20.21 ng/l. DEP, DEHP, DBP, and BBP in plastic containers were 50.21, 168.79, 20.24, and 61.28 (ng/l). PAE compounds like DEHP can be utilized as plasticizers to improve polymers' flexibility, versatility, and resilience. It is easily released into water consumption through bottles and manufacture[29].

Santhi [49] and Serôdio [50] determined that plastic pipe water samples had significantly higher mean BPA and PAE levels compared to other pipe waters. A study carried out with a significant amount of Italian water bottle samples showed a variety of compounds such as DEHP, dimethyl phthalate, DEP, diisobutyl phthalate, and DBP, ranging from 2.11 to 4.81 (ppb). The concentrations of the migrant compounds in glass bottles ranged from 0.13 to 0.36 (ppb). The level of phthalates in products bottled in PET bottles was about 20 times higher compared with those in glass bottles [51]. Detecting phthalates in water bottled immediately following factory production may be caused by three primary reasons: contamination of water in the packaging facility, water treatment facilities, and phthalates in the drinking water (groundwater or tap water) utilized for filling plastic bottles. These findings have been supported by studies conducted by Amiridou and Voutsa [29], as well as Schmid, Kohler, Meierhofer, Luzi, and Wegelin [52]. Casajuana [39], observed that phthalates in PET, PE, and glass bottled water samples were either below or extremely close to detection limits. After 10 weeks of outdoor keeping, the collected samples revealed significantly higher levels of phthalates, with the highest mean concentrations detected at 0.003, 0.432, 0.046, and 0.196 μg/L for DMP, DEP, DBP, and DEHP, respectively. Mukhopadhyay et al.[53] determined that DEHP was the most common ester observed in PET bottled water. They additionally reported that the highest level of leaching appeared after a week of keeping water containing minerals packed in recycled PET at a

Table 2
Limitations and suggestions of the research.

Limitations	Suggestion
The evaluation of phthalate types in drinking water was not performed	Investigating the concentration of phthalates in food, air, and soil.
The comparison of phthalate levels in various brands of bottled water was not conducted	
The study presented heterogeneity.	Investigating the concentration of phthalates in all types of bottled water
A limited number of research was done in Iranian cities.	

temperature of 45 degrees Celsius. In a study done by Mehraie et al., it was found that four various kinds of water bottles (sparkling, flavored sparkling, minerals, and drinking) included a significant amount of DEHP. The concentrations of DEHP in these water bottles varied from 1.51 to 3.04 μg/L. Abtahi et al. did an investigation that showed that DEHP and DMP were the main compounds found in water bottles, and the concentrations of phthalates elevated significantly when exposed to sunlight. Furthermore, Wang et al.[54] noticed that the level of DEHP was higher than that of DBP and BBP in water bottles, barreled water, and drinking water in Tianjin, China. Finally, Table 2 shows the study's suggestions and limitations about the present systematic review and meta-analysis.

5. Conclusion

The present study is a systematic review that examines the amount of phthalates in drinking water. The results of this study showed that the most important phthalates measured in drinking water include DEP, DEHP, DBP, BBP, PA. According to the results of the present studies, the most important factor in the increase of phthalates is the storage conditions of drinking water (temperature, sunlight, and the type of pipe or bottle); In such a way that whenever bottled water is exposed to sunlight or high temperature for a relatively long time, it causes the migration of phthalates from the plastic bottle or tube to the water. To reduce the levels of phthalates in drinking water, it is recommended to store bottled water at low temperatures and away from direct sunlight. Phthalates, which are used as softeners, have the ability to soften and increase the flexibility of plastics. They are widely used in various consumer products, including PVC pipes, vinyl flooring, toys and medical devices. To address the concerns of phthalates, industries are looking for phthalate-free softeners. These alternatives aim to provide substances similar to phthalates while minimizing health and environmental risks. Phthalate-free fabric softeners are usually obtained from renewable sources. which cause more stability and less dependence on fossil fuels.

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Mohammad Sharifi: Writing – review & editing, Visualization. **Mohadese Neisi:** Validation, Supervision. **Mahboobeh Dehvari:** Supervision, Software. **Arefeh Sepahvand:** Resources, Project administration, Writting this article. **Saeed Ghanbari:** Methodology, Investigation. **majid farhadi:** Data curation, Conceptualization. **mohammad javad mohammadi:** Funding acquisition, Formal analysis. **Marzieh Bayat:** Resources, Software.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Consent to Participate

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