The concentration of the potentially toxic element (PTEs) in black tea (Camelia sinensis) consumed in Iran" a systematic review, meta-analysis, and probabilistic risk assessment study

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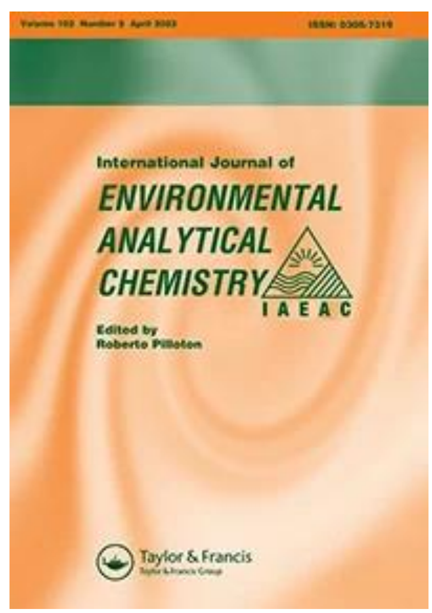

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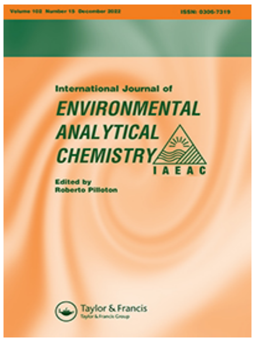

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ABSTRACT

The contamination of tea as one most widely consumed beverage in Iran with the potentially toxic elements (PTEs) leads to adverse health effects. In the current study, a meta-analysis and probabilistic risk assessment regarding PTEs concentration in tea samples from Iran were performed using international databases (PubMed and Scopus) and national databases (SID, Irandoc, and Magiran) from 2005 to 1 June 2022. Data were analysed using the random-effects model based on Iranian and imported tea subgroups, and a probabilistic health risk assessment was conducted using the Monte Carlo simulation (MCS). The highest THQ in adults and children due to consumption of Iranian tea was related to As (0.0635) and As (0.2964), respectively, and the highest THQ in adults and children due to consumption of imported tea was related to Cu (0.0266) and Cu (0.1242), respectively. TTHQ in adults and children's consumers due to PTEs ingestion via consumption of Iranian tea was 0.21 and 1.01, respectively, and TTHQ due to PTEs ingestion via consumption of imported tea was 0.22 and 0.94, respectively. Therefore, non-carcinogenic risk in children due to consumption of Iranian tea was higher than 1 value. The mean CR for content of inorganic As in adults and children via consumption of Iranian tea was 2.89E-5 and 1.35E-4, respectively, and the mean CR for inorganic As in adults and children via consumption of imported tea was 9.44E-6 and 4.42E-5 respectively. Hence adults and children, due to both Iranian and imported tea consumption, are at considerable carcinogenic risk. It is recommended to carry out continuous monitoring plans at country customs and reduce sources of tea contamination to PTEs in agricultural fields.

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1. Introduction

The chemical environment of contamination [1–8], followed by food contamination [9–13], has become a main global health concern. Tea is one of the most consumed and popular beverages in Asian countries, especially Iran. The average global tea consumption is 6.3 billion kg per year, estimated at 1.5 kg per year per each Iranian [14], which can be attributed to the health benefits of tea in the prevention of some diseases, including headache, depression, cancer, Alzheimer's, Parkinson's, vascular diseases, and enhancement of immune defence [15–17].

The benefits of tea consumption can be associated with the presence of compounds such as flavonoids, flavonols, caffeine, minerals, vitamins, trace elements, theobromine, and antioxidants [18]. However, tea can become contaminated with potentially toxic element, including heavy metals, during the growing, harvesting, processing, drying, processing, and packaging periods. In addition, soil, air, and water pollution, as well as pesticides, can affect the level of tea contamination [15,19]. In other words, the type and amount of potentially toxic element, especially heavy metals, in tea are different under the influence of the above factors [18]. Due to the high consumption of tea, the presence of PTEs in this drink can endanger human health. The most important heavy metals identified in tea are Iron (Fe), Zinc (Zn), Copper (Cu), Chromium (Cr), Lead (Pb), Cadmium (Cd), Nickel (Ni), and Mercury (Hg) [20–23]. Some PTEs, such as Fe, Zn, and Cu, are essential trace elements for human health; however, if their concentration exceeds the maximum allowable limit, they can accumulate in living systems [24–27]. In contrast, Cr, Pb, As, Cd, Ni, and Hg are toxic metals [28]. For example, exposure to Cd can lead to kidney disorders, high blood pressure, infertility, lung, bone marrow, stomach, and prostate cancers [29,30]. High concentrations of Pb in the body can prevent the synthesis of haemoglobin, kidney and cardiovascular system failure, autism, damage to the central nervous system, and high blood pressure [31,32]. Ni is most common adverse effects on humans are allergic reactions, shortness of breath, chronic bronchitis, headache, delirium, kidney and blood problems, and lung and sinus cancer [33]. Hg can damage the liver, brain, respiratory system, skin, eyes, and central nervous system [34].

Despite numerous studies on the concentration of PTEs in tea, no systematic review and meta-analysis regarding the concentration of the potentially toxic elements (PTEs) in black tea in Iran were published. Therefore, this study was designed to meta-analyse the concentration of PTEs in Iranian and imported tea and probabilistic health risks.

2. Materials and methods

2.1. Search strategy

According to the PRISMA protocol [35], a search on international databases (Scopus and PubMed) and national databases (SID, Irandoc, and Magiran) were conducted for the period 2005 to 1 June 2022 to retrieve citations that investigated heavy metals in tea consumed in Iran. The search was conducted according to the following terms: 'Trace element' OR "Metal OR 'Heavy metal' OR 'Elements' OR 'Potential toxic element' OR 'Toxic element' AND 'Black tea' OR 'Tea' AND 'Iran'. Disagreement between two authors for select of papers was resolved with the final opinion of the senior author [36].

2.2. Inclusion and exclusion criteria and extraction of data

Our criteria for inclusion of paper were 1) English and Persian language paper, 2) Descriptive studies, and 3) investigated concentration of heavy metals in tea. The experimental studies, unclear data studies, review, clinical trial, and thesis were excluded. The data, sample size, province, type of tea (Iranian or imported), and concentration (Mean, standard deviation, lowest and highest) were extracted [37].

2.3. Meta-analysis

A meta-analysis of the concentration of heavy metals in tea was conducted based on average and standard error. The data heterogeneity was detected by the I^2 index [38,39]. Depending on the I^2 index, random-effects model (> 50%) or fixed-effects model (< 50%) used to meta-analysis. Stata 14.00 software was used for meta-analysis.

2.4. Health risk assessment

In the current study, the non-carcinogenic risk of As, Cd, Pb, Ni, Hg, Cu, and Fe and the carcinogenic risk of As in consumers due to consumption of Iranian and imported tea were estimated using the Monte Carlo simulation (MCS). The distribution type of concentration and ingestion rate was selected as Log-normal and normal for body weight [40–42]. All equations of non-carcinogenic and carcinogenic risks were presented in Table 1.

3. Results and discussion

3.1. The level of PTEs based on metals types

Twenty-eight papers with 73 records reports were included in the current meta-analysis Figure 1 and Table S1. As seen at Table 2, the rank order of PTEs based on concentration was Fe (90.211 mg/kg) > Cu (16.881 mg/kg) > Ni (7.223 mg/kg) > Pb (1.305 mg/kg) > Cd (0.239 mg/kg) > As (0.228 mg/kg) > Hg (0.034 mg/kg). Findings obtained were lower than the standard limits suggested by Iran Iranian standard organisation (Pb: 10 mg/kg, Cd: 3 mg/

Table 1. Equations and description in our study.

Number	Equation	Description	References
1	$EDI = \frac{C_m \times IR}{BW}$	EDI = estimated daily intake C_m = concentration of metal (μg/Kg) IR = ingestion rate (4.13 ± 0.56 g/n-d) BW = Body weight (Adults = 70 kg and children = 15 kg)	[43,44]
2	$THQ = \frac{EDI}{RfD\ or\ TDI}$	THQ = target hazard quotient RfD = oral reference dose: As (inorganic), Cd, Zn, Cu, Fe, Ni, methyl Hg, Mn and Zn is 0.0003, 0.001, 0.3, 0.04, 0.7, 0.011, 0.0001, 0.14, and 0.30 mg/kg-d, respectively. TDI: Tolerable daily intake TDI for Pb is 0.0036 mg/kg-d	[45,46]
3	$TTHQ = \frac{EDI_1}{RfD_1} + \frac{EDI_2}{RfD_2} + \ldots + \frac{EDI_n}{RfD_n}$	EDI_n is the estimated daily intake for *n*th toxicant RfD_n is oral reference dose for *n*th toxicant	[47–49]
4	$CR = EDI \times SF$	Slope factor of inorganic As is 1.5 $(mg/kg\text{-}d)^{-1}$	[50]

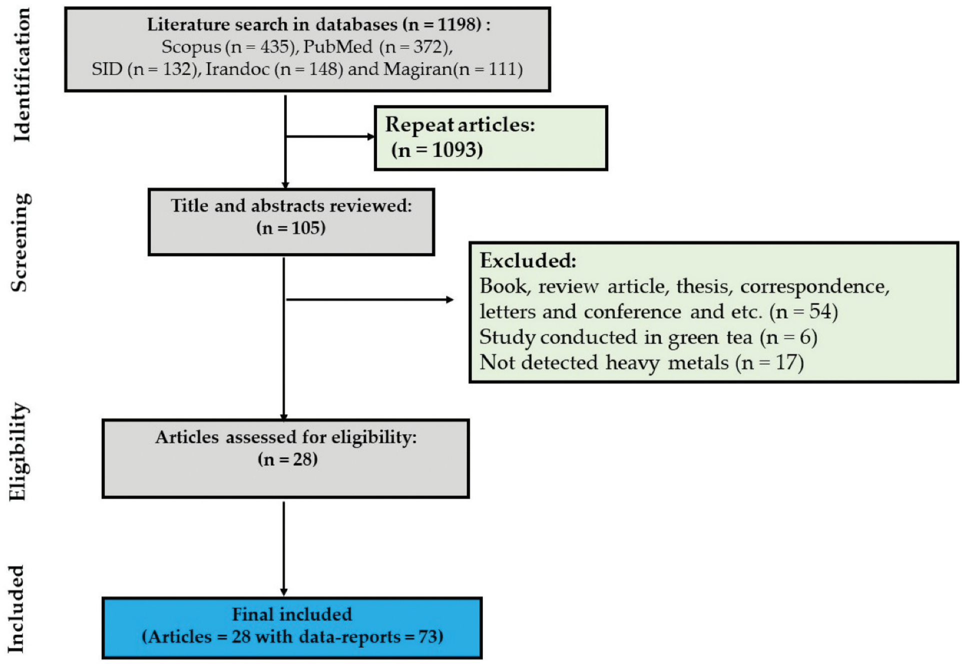

Figure 1. Selection process of papers based on PRISMA.

Table 2. Meta-analysis concentration of PTEs in national and imported black tea in Iran (mg/kg).

PTEs	Type of tea	Number study	ES	Lower	Upper	Weight (%)	Heterogeneity statistic	Degrees of freedom	p-value	I2
As	National	16	0.323	0.292	0.355	65.30	5233	15	<0.001	99.70%
	Imported	5	0.106	0.058	0.155	22.98	3154	4	<0.001	99.90%
	NM[1]	3	0.053	0.028	0.079	11.72	140	2	<0.001	98.60%
	Overall	24	0.228	0.209	0.247	100.00	9067	23	<0.001	99.70%
Cd	National	33	0.271	0.231	0.311	71.06	19,203	32	<0.001	99.80%
	Imported	9	0.243	0.191	0.295	21.45	3597	8	<0.001	99.80%
	NM	3	0.042	0.036	0.048	7.49	6	2	0.045	67.80%
	Overall	45	0.239	0.212	0.265	100.00	24,831	44	<0.001	99.80%
Pb	National	40	1.303	1.171	1.435	69.96	300,000	39	<0.001	100.00%
	Imported	13	1.427	0.977	1.877	22.82	180,000	12	<0.001	100.00%
	NM	4	0.856	0.114	1.598	7.22	1161	3	<0.001	99.70%
	Overall	57	1.305	1.183	1.426	100.00	580,000	56	<0.001	100.00%
Ni	National	20	7.991	6.894	9.088	79.80	750,000	19	<0.001	100.00%
	Imported	3	4.428	3.573	5.284	12.11	51	2	<0.001	96.10%
	NM	2	3.823	3.49	4.157	8.09	4	1	0.053	73.20%
	Overall	25	7.223	6.247	8.199	100.00	750,000	24	<0.001	100.00%
Methyl Hg	National	3	0.066	0.025	0.107	39.16	1598	2	<0.001	99.90%
	Imported	2	0.025	0.000	0.074	30.34	1586	1	<0.001	99.90%
	NM	2	0.012	0.008	0.016	30.50	49	1	<0.001	98.00%
	Overall	7	0.034	0.026	0.042	100.00	7368	6	<0.001	99.90%
Cu	National	37	16.275	15.736	16.815	76.92	170,000	36	<0.001	100.00%
	Imported	11	18.037	14.467	21.607	21.00	5112	10	<0.001	99.80%
	NM	1	19.46	18.435	20.485	2.08	0	0	.	.%
	Overall	49	16.881	16.352	17.411	100.00	210,000	48	<0.001	100.00%
Fe	National	4	87.691	14.668	160.714	50.13	18,924	3	<0.001	100.00%
	Imported	3	95.898	14.906	176.89	37.32	3539	2	<0.001	99.90%
	NM	1	83.42	77.129	89.711	12.55	0	0	.	.%
	Overall	8	90.211	38.764	141.658	100.00	36,470	7	<0.001	100.00%

kg, Cu: 50 mg/kg, As: 0.15 mg/kg, Hg:0.02 mg/kg) [51]. Consistent with the findings, the level of PTEs in the studied black teas was very diverse between countries and compared to the standard level, which can be related to several factors such as the ability of the bioaccumulation and bioavailability of metals in the tea plant, nature of the tea plant species, biological form of cultivation, situation during plant growth of tea (humidity of soil, PH and water content), the composition of the irrigation water and soil, storage condition and processing technologies [52]. Each of these parameters can play an effective role in the content of metals in black tea consumed in Iran. Chemical properties of soil compounds, including pH level [53], level of carbon [54], amount of nitrogen [55], potassium sulphur [56], and type and amount of phosphate fertilisers, have an influence on metals level uptake via tea plants [57]. In a study conducted by Tuysuz and Yaylali-Abanuz, they showed a significant negative correlation between the pH of the soil and the uptake of various metals by tea plants. An increase in pH causes a reduction in the solubility of the Pb metal in soil [58]. It is observed that the higher level of Fe, Cu, and Zn elements, as compared with PTEs such as Pb, Cd, As, and Hg in black teas is related to their higher transfer rate [29,59,60]. PTEs such as Cu, Fe, and Cd have higher mobility properties than other PTEs such as Pb and Cd; hence, Cu, Fe, and Cd can quickly accumulate at the tea plant's roots [61,62]. Storage conditions and processing technologies are the significant factors in the concentration of PTEs. For example, the washing stage and pH environment in processing performed on tea leaves in industrial factories are important factors that affect the level of PTEs [63]. The content and age of tea plant leaves used in the production process, maturing, storage, and packing stage besides the fermentation methods have an effective role in contamination level in black tea [64]. The soil irrigated with wastewater had higher metals concentration than the soil irrigated with groundwater [65]. While the soil irrigated with wastewater contain a higher level of PTEs than the clean water and groundwater [66,67]. The different wastewater of domestic or industrial due to composition or, electrical conductivity can directly effect on bioavailability and then bioaccumulation of PTEs in crops [68]. Using various phosphate fertilisers and pesticides (fungicides) may lead to contamination of tea plants with PTEs [16]. Using ammonium sulphate fertiliser in agriculture can raise the content of the soil and increase the adsorption and mobility of the PTEs in the soil. In this regard, the soil fertilisation via ammonium sulphate is the important factor affecting the Cd absorption in the leaves of tea plants [58].

3.2. The concentration of PTEs based on origin of tea

The content of PTEs in the Iranian and imported teas was different (Table 2). Our findings indicated that the pooled concentration of Methyl Hg (0.066 mg/kg), As (0.323 mg/kg), Ni (7.991 mg/kg), Cu (18.037 mg/kg), Fe (95.898 mg/kg) in Iranian black tea was higher than imported tea (0.025 mg/kg), (0.106 mg/kg), (4.428 mg/kg), (16.275 mg/kg) and (87.691 mg/kg), respectively. While the pooled concentration of Cd and Pb in Iranian black tea (0.271 mg/kg) and (1.303 mg/kg) was almost equal to imported tea (0.243 mg/kg) and (1.427 mg/kg) respectively.

The mean level of As and Cd in Iranian black tea were 0.09 and 2.5 mg/kg, respectively [15]. In another investigation, the mean level of Cd and As in imported black tea were defined as 0.72 and 0.05 mg/kg, respectively [69]. Similarly, the mean level of Cd, Pb, Cu, and Fe in Iranian black tea were reported as 0.63, 1.72, 8.85, and 41.34 mg/kg, respectively [60].

The main sources of PTEs contamination in Iranian and imported teas are strongly dependent on geographic characteristics, including the weather conditions, annual rainfall, air pollution and as well as, and agricultural activities such as using of fertilisers and pesticides, different industrial and urban activities, proximity to roads, the mines, factories, and highways [70]. In this context, the low level of PTEs in some counties can be attributable to the agricultural soil's physicochemical properties and the region's weather conditions [71]. For example, various PTEs concentration teas plant mainly due to different climatic conditions in Japan (moister) compared with China and other Asian countries was noted [72]. The existence of mining and industry activities in the region close to planting plants, besides local dispersion in soil profiles can rise concentration of PTEs in tea plants. Cu contamination was higher than other PTEs in tea plants cultivated around a copper mine [72]. In another study, Argentina's rural or suburban regions have an extensive groundwater network polluted with unique As metals. Therefore, different plants that grow in these areas are more contaminated with As than in other areas [73]. A study conducted in Mengel, Konrad stated that Cd availability in soils was influenced completely by adding rock phosphate because rock phosphate is useful annually in several soils used for tea plants [74]. Contamination of pb in the soils of parts near the roads was noted because of emissions of tetraethyl lead from exhaust vehicles was higher than in other areas [75]. Amouei et al. stated high level of Pb in Iranian black tea can be associated with the high traffic in this region, the alkalinity of the soil, the rise of cation exchange capacity, and the high volume of organic carbon and clay particles percentages of the soil [76].

4. Risk assessment

Non-carcinogenic risk

When, THQ and/or TTHQ > 1, exposed population are considerable non-carcinogenic risk [77,78]. The rank order of THQ of PTEs in Iranian tea for adults was As (0.0635) > Ni (0.0429) > Methyl Hg (0.0389) > Cu (0.0240) > Pb (0.0214) > Cd (0.0160)> Fe (0.0074) and for children was As (0.2964) > Ni (0.2000) > Methyl Hg (0.1817) > Cu (0.1120) > Pb (0.0997) > Cd (0.0746) > Fe (0.0345) (Figure S1). The rank order of THQ of PTEs in imported tea for adults was Cu (0.0266) > Ni (0.0238) > Pb (0.0234) > As (0.0208) > Methyl Hg (0.0148) > Cd (0.0143) > Fe (0.0081) and for children was Cu (0.1242) > Ni (0.1108) > Pb (0.1091) > As (0.0973) > Methyl Hg (0.0688) > Cd (0.0669) > Fe (0.0377) (Figure S2). Differences in concentrations of PTEs and their RfD were the reasons for the variation among THQ of Iranian and imported tea [79–81]. TTHQ in adults and children's consumers due to ingestion of PTEs in Iranian tea was 0.21 and 1.01, respectively, and also TTHQ because of ingestion of PTEs in imported tea was 0.22 and 0.94, respectively (Figure 2). Hence, TTHQ in children due to consumption of Iranian tea is higher compared with 1 value.

5. Carcinogenic risk

The mean CR in children and adults because of ingestion of Iranian tea level of inorganic As was 2.89E-5 and 1.35E-4, respectively (Figure S3). The mean CR in adults and children due to inorganic As ingestion in imported tea was 9.44E-6 and 4.42E-5 respectively (Figure S4). If, CR > 1.00E-06, exposed population are considerable carcinogenic risk [82].

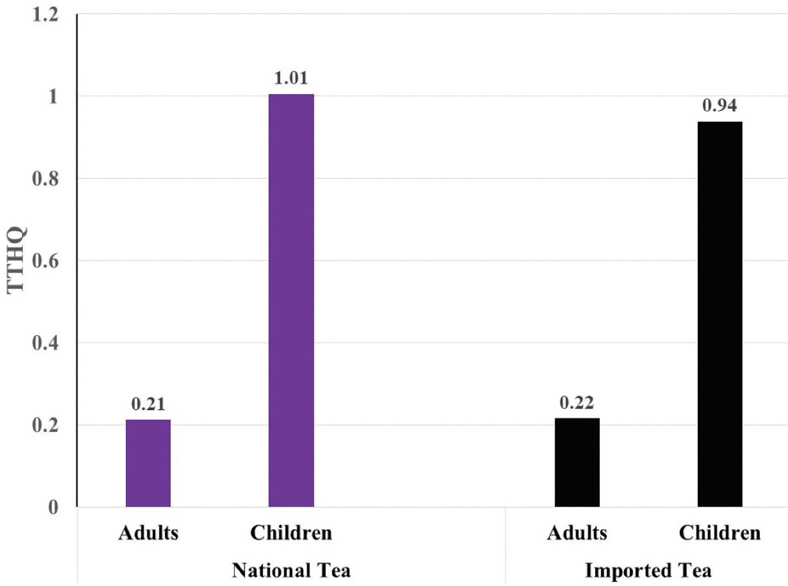

Figure 2. TTHQ in adults and children due to consumption of national and imported tea.

Therefore, CR for adults and children due to both Iranian and imported tea are at considerable carcinogenic risk.

6. Conclusion

This study was designed to meta-analysis the concentration of PTEs in black tea in Iran and probabilistic risk assessment. Pooled Fe, Cu, and Ni concentrations in consumed tea were higher than in other PTEs. The concentration of Methyl Hg, As, Ni, Cu, and Fe, in Iranian black tea, was higher than in imported tea. Consumption of Iranian tea resulted in non-carcinogenic risk to children as marginally. Adults and children were posed to non-acceptable carcinogenic risk due to consumption of Iranian and imported tea consumption. It is recommended to carry out continuous monitoring plans at country customs and agricultural fields to reduce the concentration of PTEs in black tea in Iran.

Note

1. Not mentioned

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Consent to Participate

The authors declare their Consent to Participate in this article.

Consent to Publish

The authors declare their Consent to Publish this article.

Authors contributions

Search in databases was conducted by **Somayeh Hoseinvandtabar and Hasti Daraei**; Screening of obtained articles based on title, abstract and full text by **Somayeh Hoseinvandtabar**; Data extraction by **Somayeh Hoseinvandtabar**; Meta-analysis of data and risk assessment by **Yadolah Fakhri**; write and edit the manuscript by **Yadolah Fakhri, Trias Mahmudiono, Hasti Daraei, Fereshteh Mehri, Amin Mousavi Khaneghah.**

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