Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 9(5) pp. 110-120, May, 2020 Issue.
Available online http://garj.org/garjas/home

Full Length Research Paper

The concentration of toxic metals in teas: A global systematic review, meta-analysis and probabilistic health risk assessment

Fereshteh Mehri[1], Maryam Adabi[2], Elaheh Talebi Ghane[3], Salman Khazaei[4]*

[1]Nutrition Health Research Center, Hamadan University of Medical Sciences.
[2]Brucellosis Research Center, Hamadan University of Medical Sciences, Hamadan, Iran.
[3] PhD in Biostatistics, Hamadan University of Medical Sciences Hamadan, Iran.
[4]Research Center for Health Sciences, Hamadan University of medical Sciences, Hamadan, Iran.

Accepted 13 May, 2020

Background: The tea next to water is the heavily consumed beverage among the world's population. In current investigation was evaluated the concentration of different metals in teas consumptions through meta-analysis. Methods: The related studies regarding to the concentration of toxic metals in teas were collected from international major databases. A random effect model was used for meta-analysis concentration of Cd, Pb and As in tea among defined subgroups. Results: The mean concentration of toxic metals in the teas was Pb (0.55 mg/kg) > Cd (0.13 mg/kg) > As (0.07 mg/kg), respectively. The highest concentration of metals in green and black tea was related to Pb and As, respectively. Conclusion: Due to the high concentration of metals in different tea samples in many of countries and the health risk for consumersitis need to performing of control plans by governments and farmers for decrease concentration of toxic metals in tea.

Keyword: Toxic metals, Tea, Concentration, Systematic review, Meta-analysis

INTRODUCTION

The tea next to water is the heavily consumed beverage among the world population, which is prepared from leave of Camellia sinensis plant and cultivates in certain areas ofChan, Japan, and Indian (Antoine Jet al., 2017). According to processes of fermentation, teas categorize to the three popular types (green, oolong, and black). Nearly 75-80 % of total tea consumption is related to black tea (Al-Othman et al., 2012). Economic and social impotent of tea is obvious from the fact that about 18 to 20billion cups of tea are consumed daily in the world (Fernández-Cáceres et al., 2001). Tea has complex matrix and is rich of antioxidant compounds such as flavonoids, polyphenols that are benefit to human health. Antioxidant compounds available in tea act asa scavenger of reactive free radicals and can reduce risk of heart diseases like stroke, heart attack and various types of cancer like oral, pancreatic and prostate in human (Karak and Bhagat 2010). In addition to antioxidant properties, this high consumptiondrinking has macro elements such as sodium, potassium, phosphorus, and manganese, which activates numerous enzymes in the

*Corresponding Author's Email: salman.khazaei61@gmail.com

human body (Shen and Chen 2008). However, tea might be contaminated with heavy metalsand posed a serious threat to human (Nkansah et al., 2016). It is observed of many studies that more than 90% of human exposure to metals is associated with the consumption of contaminated food (Shen and Chen 2008; de Oliveira et al., 2018; Zhu et al., 2013; Zhang et al., 2018). Recently, remarkable increase in industrial development, agricultural activities, urbanization and mining in different parts of the world led to increase in amount of metals like lead (Pb), cadmium (Cd) and arsenic (As) in different samples of foods (Heshmati et al., 2020). It is worthy to note that, addition to, type and specie of metals, intensity, frequency, duration, and routes of exposure, half-life, biodegradable property, cumulative nature of metals, and also kind of body tissue like fat and doneof human are of effective parameters in toxicity of metals (Khaneghah et al., 2019). The different amounts of metals in various foodsrelatedtofactories such as climatic conditions, geographical location, handling, storage, and processing (Popović et al., 2017; Zhelev et al., 2019; Sofuoglu and Kavcar 2008). As mentioned of previous investigations, the toxicity effects reported due to chronic exposure to metals are the carcinogenicity, genotoxicity, mutagenicity, neurotoxicity, endocrine disorders, and teratogenicity. Exposure with various amounts of pb could lead to decrease in cognitive function , IQ deficits in young children and change in blood pressure level in the adults (Mason et al., 2014). On the other hand, due to the structure similarity of Pb to calcium (Ca), Pbaccumulates in the bone and causes calcium deficiency in the body (Brown and Margolis 2012). Current studies have showed Cd in addition disease (Itai-Itai) can lead to cancer of prostate, lung, and bladder in human (Abbasi et al., 2009; Ensafi et al., 2006).Chronic exposure to As may lead to cancer of kidney, lung, and skin lesions (Gomez et al., 2007). Since the one of the most concerns in terms of food safety is the contamination of food products by metals that attend to have attracted attention from many researchers around the world (Gomes et al., 2019), and also, due to the lack of a global meta-analysis regarding the toxic metals in tea, the current investigation for first was conductedin order to estimate the concentration of different metals (Pb, Cd, and As) in tea consumptions among different countriesthrough a systematic review and meta-analytic approach.

MATERIAL AND METHODS

Search Strategy:

This meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Fig 1) (Liberati et al., 2009). A comprehensive literature searches was done of the following international electronic bibliographic databases including: Scopus, Web of Science, PubMed and Embase from inception to Feb 01, 2020. In addition to identify additional relevant studies, hand searches were also performed. Key search terms included terminology for Scopus: ((ti/ab (“metals”) OR ti/ab (“heavy metals”))) OR ti/ab (“metal(oid)s”)AND ((ti/ab (“tea”) ((ti/ab (“green”) OR ((ti/ab (“black”)OR ((ti/ab (“plant”); Medline: Search(((“Metals”[Mesh]) OR (((heavy metals [Ti/Ab]) OR metals [Ti/Ab]) OR metal(oid)s [Tit_Abs]))) AND (((((((Plant [Ti/Ab]) OR tea[Ti/Ab]) green [Ti/Ab]) black[Ti/Ab]); Embase: (‘metals’:abt OR ‘heavy metals’:abt OR’ metal(oid)s:abt) AND ‘tea’:abt OR plants'. Also, the reference lists of collected articles were investigated to attain additional articles based on similar studies performed.

Extraction of data and inclusion / exclusion criteria

The inclusion criteria in this study were including: (1) full-text published in the English language;(2) cross-sectional study; (3) reporting of mean and/or range concentration of toxic metals in black and green tea. In this regard, books, workshops, reviews, clinical trial researches, experimental studies were excluded (Salahinejad and Aflaki 2010; Piskin et al., 2013; Özden and Özden 2018). The collected data of each study were including the year of study; country; type of teas; sample size; average;standard deviation and range of toxic metals concentration. Aiming to unify units, all unit of concentration of toxic metals including µg/kg, ppb and ng/g were changed to mg/kg-dry-weight.

Quality Assessment and Statistical analysis

Two independent authors (FM and SK) reviewed the retrieved studies. The kappa statistics (95%) was used to identify the inter-authors reliability. The third author (MA) was considered as arbiter to resolve any disagreements. The Q-test and I^2 test were performed to assess between-study heterogeneity and considered significant if I^2 index>50%. A random effect model was used for meta-analysis concentration of Cd, Pb and As in tea among defined subgroups (tea type and continent). Data were analyzed by the Stata software, version 14 (Stata Corp, College Station, TX, USA) at a significance level of 0.05.

Risk assessment

The non-carcinogenic risk because of ingestion of metals via consumption of teas was consideredby the following equation

$EDI = C \times IR \times EF \times ED / BW \times ATn$ (1)

Based on mentioned equation, C is mean concentration of metals in teas (mg/kg); IR, ingestion rate of teas (kg/n-day); EF, exposure frequency (350 days/year); ED, exposure duration (children=6 years and adults=30 years); BW, Body weight (children=15 kg and adults=70 kg); ATn

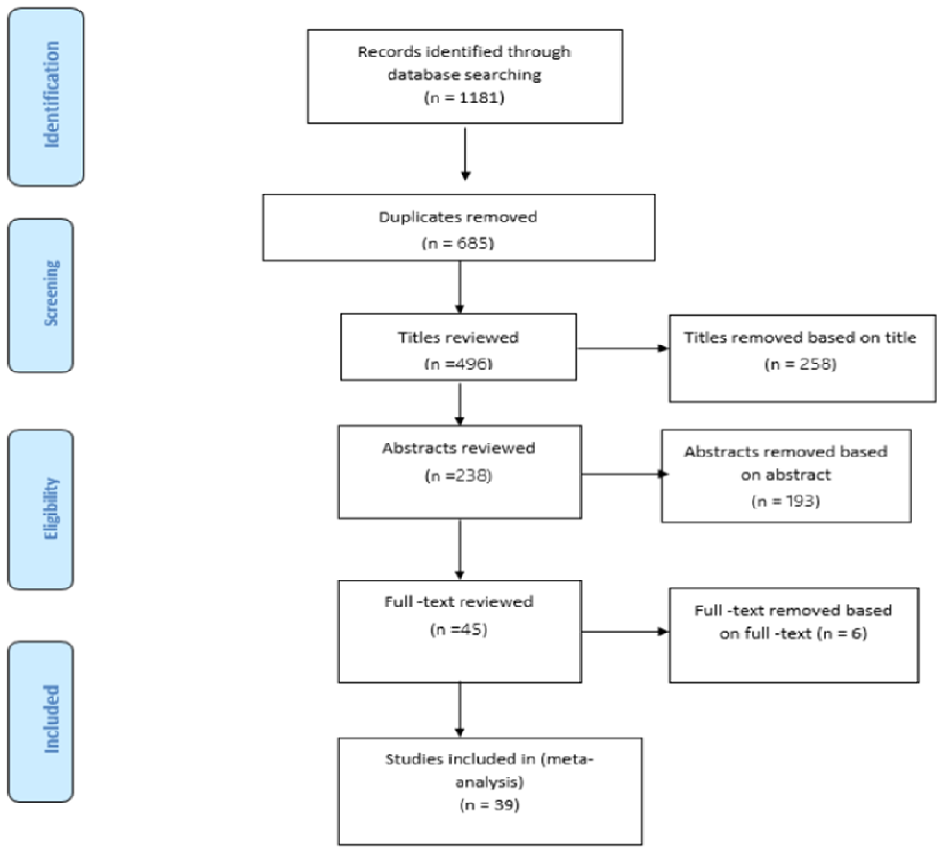

Figure 1: Selection process evidence searches and inclusion

(EF×ED), average time exposure (children= 2190 days and adults=10,950 days). The average world ingestion rate of tea is 750 g/n d, (Helgilibrary 2011).

Target hazard quotient (THQ) due to intake metals in teas was estimated by the following equation((Rezaee et al., 2012).:

THQ = EDI / RfD (2)

In this equation, EDI estimated daily intake; RfD, oral reference dose. Rfd of Pb, Cd, As, was 0.003, 0.001, 0.003mg/kg/day, respectivel (Antoine et al., 2017).

$$\text{TTHQ} = \sum_{i=1}^{n} \quad THQi \quad \text{Equation (4)}$$

TTHQ show the sum of the each THQfor whole metal analyzed in tea samples((Antoine et al., 2017). If TTHQ was lower than 1, health hazard was considered acceptable for health human (Qin et al., 2015).

Uncertainty analysis

In order to raise preciseof risk assessment via considering uncertainties,Monte Carlo simulated (MCS) method was utilized.. MCSis a precise method for considering parameters affecting uncertaintiesand provides accurate health risk . To conduct this method,the Oracle Crystal Ball software (version 11.1.2.4.600) was used. In this method, the parameters like the concentration of metals(C), ingestion rate (IR) and body weight (BW) were considered as lognormal distribution (Qin et al., 2015; Zhu etal., 2019), the number of repetitions was at10,000 and percentile 95% of THQ, TTHQ, and ILCR was considered cut point of human health risk (Qu et al., 2012)..

RESULTS

Retrieve studies process and characteristics of studies

To conduct systematic review process by searching,1,181 papers were retrieved from Web of Science (n=187), Scopus (n=607), Embase (n=93) and PubMed (n=294) databases publications from1 Jan1973 to 1 Sep2019. In the first step, 685 articleswere excluded via Endnote software (EndNoteX7.7.1; Bld 10036) because of repetition. Based on the title of retrieved articles, 496papers were considered suitable for study and 258articles were excluded. Based on abstract, 238 articles were reviewed, and then 193 articles were excluded. The Full text of45 articles were reviewed, and finally, 39 papers were included(2, 6-9, 12, 14, 22, 32-61)(Fig. 1). The study characteristics and results are displayed in Tables 1-3S (Supplementary).In regard of Cd, included studies were

Table 1 S. Main characteristic included in our study for pb metal

Author	Year	Type of tea	Country	N of sample	Mean	SD	Range	Method	LOD
Al-Othman et al.,	2012	Black	Saudi Arabia	10	5.9	2.41	BDL-8.7	(FAAS)	NM
Zhang et al.,	2018	Black	China	10	.93	.19	0.56- 1.26	ICP-AES	0.2
Srogi et al.,	2006	Black	Italy	7	9	4	0.10-27.32	FAAS	NM
Milani et al.,	2016	Black	Brazil	9	.16	.02	0.13-0.20	ICP-MS	0.013
Lv, H. P et al.,	2013	Black	China	56	2.32	.73	0.66–4.66	ICP-AES	NM
Salahinejad et al.,	2010	Black	Iran	11	1.41	.706	0.92- 2.92	ICP-AES	0.04
Shokrzadeh et al.,	2005	Black	Iran	10	6.09	2.01	4.78- 5.99	AAS	NM
Zhu et al.,	2013	Black	China	80	.62	.21	0.380–0.867	ICP-MS	0.01
Karimi et al.,	2008	Black	Iran	10	2.31	.29	2.08 - 2.59	AAS	NM
Narin et al.,	2004	Black	China	14	.17	.07	0.08- 0.27	FAAS	0.1
Nasri et al.,	2017	Black	Iran	7	.13	.4	0.04 - 10.12	AAS	NM
Rubio et al.,	2012	Black	Spain	36	.65	.71	NM	ICPS	NM
Zhang et al.,	2011	Black	China	20	.32	.16	0.13 -0.49	AAS	NM
Sofuoglu et al.,	2008	Black	Turkey	50	.017	.013	0.003- 0.065	ICP-AES	NM
Seth et al.,	1973	Black	Indian	10	.007	.002	0. 002-0. 012	AAS	NM
Árvay, J. et al.,	2015	Black	Slovakia	10	1.387	.54	NM	GF-AAS	NM
Prki? et al.,	2017	Black	Croatia	11	.103	.054	0.053 – 0.25	FAAS	0.07
Yousefi et al.,	2017	Black	Iran	32	.19	.12	0.01 – 0.45	ICP-OES.	NM
Nkansah et al.,	2016	Black	Ghana	15	.16	.6	0.10- 0.40	AAS	0.01
Prki et al.,	2018	Black	Croatia	19	.925	.231	0.561- 1.28	AAS	0,08
Hosseni et al.,	3013	Black	Iran	20	.368	.184	0.016-0.108	GFAAS	0.15
Oliveira et al.,	2018	Black	US	16	.64	.11	0.26- 1.90	ICP-MS	NM
Ozdwn et al.,	2015	Black	Turkey	15	4.6	2.1	3.22-5.98	ICP-OES	0.1
Jin et al.,	2005	Black	China	20	2.21	1.04	0.11- 4.55	GFAAS	NM
Rubio et al.,	2012	Black	Spain	36	.22	.13	NM	ICPS	NM
Rashid et al.,	2016	Black	Bangladesh.	10	.089	.004	0.03- 0.13	GF?AAS	0.052
Ashraf et al.,	2008	Black	Saudi Arabia	17	1.7	.81	0.3 -2.2	ICP-AES	NM
Jin et al.,	2005	Black	China	17	2.2	1.5	0.59- 4.49	AAS	NM
Shaltout et al.,	2016	Black	Saudi Arabia	7	.35	.15	0.23 - 0.53	ICP-MS	0.48
Tokaliolu et al,	2012	Black	Turkey	30	1.5	.55	0.02 - 3.01	ICP-MS	NM
Zhang et al.,	2017	Black	China	30	.82	.74	NM	AAS	0.54
Kalianin et al.,	2013	Black	Serbia	24	.75	.375	0.73-0.77	GFAAS	NM
Cao et al.,	2010	Black	Yunnan	36	.47	.61	0.01–2.4	ICP-AES	0.22
Ghuniem et al.,	2019	Black	Egypt	35	0	0	NM	ICP-OES	NM
Naghipour et al.,	2016	Black	Iran	54	2	.9	0.5-3.5	ICP-AES	NM
Zazouli et al.	2010	Black	Iran	10	11.42	2.28	8.38- 15.48	AAS	NM
Nejatolahi et al.,	2014	Black	Iran	60	.44	.14	0.28-0.56	AAS	NM
Oliveira et al.,	2018	Green	US	14	.76	.12	0.36- 1.70	ICP-MS	NM
Baronet e al.,	2016	Green	Italy	16	.55	.35	0.10-1.08	AAS	0.1
Árvay, J. et al.,	2015	Green	Slovakia	14	.875	.59	NM	GF-AAS	NM
Milani et al.,	2016	Green	Brazil	9	.2	.12	0.05- 0.37	ICP-MS	0.005
Othman et al.,	2011	Green	Saudi Arabia	20	3.28	1.2	0.23 – 6.3	ICP-MS	0.3
Podwika et al.,	2018	Green	Poland	27	.049	.03	0.006-0.15	AAS	NM
Baronet e al.,	2016	Green	Italy	14	.47	.07	0.30-0.57	AAS	0.1
Popovi? et al.,	2018	Green	Serbia	9	.21	.08	NM	FAAS	0.48

Table 1S. Continue

Ghuniem et al.,	2019	Green	Egypt	35	1.23	.5	NM	ICP-OES	NM
Li et al.,	2015	Green	China	26	.92	.42	0.12–2.24	ICP-AES	NM
Peri-Gruji et al.,	2009	Green	Serbia	12	2.9	1.4	1.4- -4.4	FAAS	0.1
Brzezicha-Cirocka et al	2016	Green	Poland	41	.45	.38	0.09–1.38	AAS	0.004
Tsushida et al.,	1997	Green	Japan	139	.49	.23	0. 11- 1. 93	AAS	NM

Table 2S. Main characteristic included in our study for Cd metal

Author	Year	Type of tea	Country	N of sample	Mean	SD	Range	Method	LOD
Tsushida et al.,	1997	Black	Japan	139	.04	.002	0.013-0.098	AAS	NM
Narin et al.,	2004	Black	China	14	.02	.04	0.01-0.03	FAAS	0.06
Shokrzadeh et al.,	2005	Black	Iran	10	.6	.23	0.09- 1.09	AAS	NM
Srogi et al.,	2006	Black	Italy	7	.27	.12	0.06-0.49	FAAS	NM
Ashraf et al.,	2008	Black	Saudi Arabia	17	1.1	.51	0.3 -2.2	ICP-AES	NM
Sofuoglu et al.,	2008	Black	Turkey	50	.0002	.0002	0.002-0.079	ICP-AES	NM
Yaylali-Abanuz Et al.,	2009	Black	Turkey	10	.06	.02	0.02 - 0.12	AAS	0.01
Yaylali-Abanuz Et al.,	2009	Black	Turkey	10	.74	.27	0.27 - 1.86	AAS	0.002
Cao et al.,	2010	Black	China	36	.02	.0002	0.01–0.03	ICP-AES	0.011
Zazouli et al.	2010	Black	Iran	10	.67	.51	0.13 - 1.92	AAS	NM
Salahinejad et al.,	2010	Black	Iran	11	.66	.33	Nd-0.78	ICP-AES	0.003
Al-Othman et al.,	2012	Black	Saudi Arabia	10	.15	.08	BDL-0.7	(FAAS)	NM
Prkic et al.,	2013	Black	Croatia	7	.21	.13	0.02- 0.38	ETAAS	NM
Lv, H. P et al.,	2013	Black	China	56	.06	.02	0.023–0.13	ICP-AES	NM
Hosseni et al.,	2013	Black	Iran	20	.03	.01	0.005- 0.069	GFAAS	0.18
Zhu et al.,	2013	Black	China	80	.02	.01	0.010–0.032	FAAS	0.005
Árvay, J. et al.,	2015	Green	Slovakia	14	.16	.08	NM	GF-AAS	NM
Árvay, J. et al.,	2015	Black	Slovakia	10	.4	.07	NM	GF-AAS	NM
Ozdwn et al.,	2015	Black	Turkey	15	.39	.19	0.32-0.47	ICP-OES	0.1
Li et al.,	2015	Green	China	26	.06	.02	0.025–0.11	ICPMS	NM
Orisakwe et al.,	2015	Black	Nigeria	20	.1	.05	0.01-0.25	AAS	0.01
Baronet e al.,	2016	Green	Italy	16	.04	.03	0.01-0.08	AAS	0.1
Shaltout et al.,	2016	Black	Saudi Arabia	7	.03	.02	0.01 - 0.05	ICP-MS	0.48
Rashid et al.,	2016	Black	Bangladesh	10	.27	.003	0.05- 1.14	GF-AAS	0.026
Milani et al.,	2016	Black	Brazil	9	.01	.03	0.010-0.02	ICP-MS	0.001
Naghipour et al.,	2016	Black	Iran	54	.33	.16	0.07-0.6	ICP-AES	NM
Brzezicha-Cirocka et al	2016	Green	Poland	41	.01	.004	0.003–0.01	AAS	0.003
Nkansah et al.,	2016	Black	Ghana	15	.36	.18	0.10- 1.50	AAS	0.007
Baronet e al.,	2016	Green	Italy	14	.03	.01	0.01-0.05	AAS	0.1
Milani et al.,	2016	Green	Brazil	9	.01	.0001	0.004-0.01	ICP-MS	0.001
Prkic et al.,	2017	Black	Croatia	11	.02	.02	0.011-0.131	FAAS	0.08
Zhang et al.,	2017	Black	China	30	.05	.03	NM	AAS	1.1
Nasri et al.,	2017	Black	Iran	7	.06	.02	0.01 - 0.12	AAS	NM
Yousefi et al.,	2017	Black	Iran	32	.19	.12	0.01 – 0.45	ICP-OES.	NM
Oliveira et al.,	2018	Green	US	14	.04	.01	0.01-0.04	ICP-MS	NM

Table 2S. Continue

Zhang et al.,	2018	Black	China	10	.06	.01	0.04 - 0.08	ICP-AES	0.02
Oliveira et al.,	2018	Black	US	16	.05	.01	0.01-0.19	ICP-MS	NM
Popovic et al.,	2018	Green	Serbia	9	.34	.02	NM	FAAS	0.11
Prkic et al.,	2018	Black	Croatia	19	.53	.22	0.082- 0.805	AAS	0.07
Ghuniem et al.,	2019	Green	Egypt	35	.09	.03	NM	ICP-OES	NM
Ghuniem et al.,	2019	Black	Egypt	35	0.4	0.2	NM	ICP-OES	NM

Table 3S. Main characteristic included in our study for As metal

Author	Year	Type of tea	Country	N of sample	Mean	SD	Range	Method	LOD
Shaltout et al.,	2016	Black	Saudi Arabia	7	.12	.04	0.07- 0.19	ICP-MS	3.07
Nasri et al.,	2017	Black	Iran	7	.16	.8	0.04 - 0.28	AAS	NM
Karimi et al.,	2008	Black	Iran	10	.09	.02	0.08 - 0.12	AAS	NM
Zhang et al.,	2017	Black	China	30	.15	.1	NM	AAS	1.46
Zhu et al.,	2013	Black	China	80	.06	.02	0.009–0.124	ICP-MS	0.036
Lv, H. P et al.,	2013	Black	China	56	.15	.03	0.07–0.25	ICP-AES	NM
Popovi et al.,	2018	Green	Serbia	9	.21	.08	NM	FAAS	0.48
Popovi et al.,	2018	Green	Serbia	9	.04	.01	NM	FAAS	0.45
Milani et al.,	2016	Black	Brazil	9	.02	.01	0.018-0.04	ICP-MS	0.013
Oliveira et al.,	2018	Black	Us	16	.22	.02	0.05-0.36	ICP-MS	NM
Rashid et al.,	2016	Black	Bangladesh	10	1.21	0	0.19- 2.06	GF-AAS	0.046
Nkansah et al.,	2016	Black	Ghana	15	1.66	.83	1.40- 2.00	AAS	0.004
Naghipour et al.,	2016	Black	Iran	54	.07	.03	0.03-0.1	ICP-AES	NM
Zhang et al.,	2018	Black	China	10	.29	.06	0.18- 0.453	ICP-AES	0.05
Cao et al.,	2010	Black	China	36	.17	.06	0.08–0.36	ICP-AES	0.038
Sofuoglu et al.,	2008	Black	Turkey	50	0	.07	0.016-0.053	ICP-AES	NM
Barman et al.,	2019	Black	India	497	.11	.05	0.01 - 0.37	AAS	0.005
Nejatolahi et al.,	2014	Black	Iran	60	.21	.08	0.17-0.29	AAS	NM
Ashraf et al.,	2008	Black	Saudi Arabia	17	1.1	.52	0.3 -2.2	ICP-AES	NM
Milani et al.,	2016	Green	Brazil	9	.04	.01	0.029-0.06	ICP-MS	0.005
Oliveira et al.,	2018	Green	Us	14	.18	.07	0.01- 0.70	ICP-MS	NM

published between 1997 and 2019, the sample size of included articles varied from 7 to 139 with a total of 956 samples. For Pb, included studies were published between 1973 and 2019, the sample size of included articles varied from 7 to 139 with a total of 1240 samples and for As, included studies were published between 2008 and 2018.The sample size of included articles varied from 7 to 497 with a total of 1005 samples. Rank order of countries according to the number ofstudies were: Iran(51.28%)~China (51.28%) >Saudi Arabia (23.07%) >Turkey(20.47%) >Brazil (15.38%)~Us(15.38%) >Serbia (12.82%)> Egypt (10.25%)~Italy(10.25%)~Slovakia (10.25%)> Bangladesh(7.69%)~Croatia(7.69%)~ Ghana(7.69%)~ Poland(7.69%)>India(5.12%)~Spain(5.12%) >Nigeria (2.56%)~Yunnan (2.56%)(Tables 1-3S).

The concentration of toxic metals in teas based onteas types and continents

The results of Cochran's Q test and I^2 statistics suggested a significant heterogeneity among the included studies for Cd (Q=3205.92, df =40, p<0.001 and I^2=100%), Pb (Q=11373.46, df =48, p<0.001 and I^2=99.6%) and As (Q=2585.79, df =19, p<0.001 and I^2=99.3%). In order to reduce the heterogeneity, we performed subgroup analysis based on teas types and continents (Tables1, 2). The concentration of Pb was higher in green tea and according continents, the highest and lowest concentration was belonging African countries and American countries, respectively (0.703 mg/kg vs. 0.44 mg/kg). Accordingly, the concentration of Cd in black tea was 0.09 mg/kg (0.082 mg/kg, 0.098 mg/kg) and in green tea was 0.08 mg/kg

Table 1. Meta-analysis of concentration of toxic metal (mg/kg) based on kind of tea.

Toxic metals	WHO regions	Number study	ES	Lower	Upper	Weight (%)	Statistic	df	P value	I2 (%)
Pd	black	33	0.54	0.51	0.58	69.99	90008.7	35	<0.001	99.6
	green	13	0.779	0.587	0.971	30.01	1771.37	12	<0.001	99.3
Cd	black	32	0.09	0.082	0.098	68.14	3202.05	31	<0.001	100
	green	9	0.08	0.065	0.096	36.86	3108.34	8	<0.001	99.7
AS	black	16	0.149	0.116	0.182	77.61	2147.21	15	<0.001	99.3
	green	4	0.101	0.067	0.134	22.39	94.42	3	<0.001	96.8

Table 2. Meta-analysis of concentration of toxic metal (PTEs) (mg/kg) in teas based on WHO regions

Toxic metals	WHO regions	Number study	ES	Lower	Upper	Weight (%)	Statistic	df	P value	I^2 (%)
Pd	Asia	26	0.661	0.613	0.708	48.59	8018.07	25	<0.001	99.7
	Europe	17	0.558	0.472	0.644	35.25	1705.86	16	<0.001	99.1
	Africa	2	0.703	0	1.75	2.73	36.76	1	<0.001	97.3
	America	4	0.44	0.114	0.766	13.43	594.87	3	<0.001	99.5
Cd	Asia	19	0.103	0.085	0.12	48.79	833356.5	18	<0.001	100
	Europe	14	0.131	0.114	0.149	29.27	3779.41	13	<0.001	99.7
	Africa	4	0.224	0.137	0.311	6.86	113.93	3	<0.001	97.4
	America	4	0.028	0.003	0.063	15.09	381.88	3	<0.001	99.2
AS	Asia	13	0.159	0.129	0.188	59.79	930.15	12	<0.001	98.7
	Europe	3	0.075	0.014	0.136	16.8	56.69	2	<0.001	96.5
	Africa	0	-	-	-	-	-	-	-	-
	America	4	0.114	0.023	0.206)	23.41	1237.05	3	<0.001	99.8

(0.065 mg/kg, 0.096 mg/kg). The highest concentration of Cd in tea was in African countries and lowest in American countries (0.224 mg/kg vs. 0.028 mg/kg). In regard of As, black teas had higher concentration (0.149 mg/kg vs. 0.101 mg/kg) and teas in Asian countries had highest concentration (0.159 mg/kg). As seen of results, the concentration of toxic metals in tea was greatly diverse between different countries.Discrepancy observed could be related to the numerous factors like physicochemical characteristics of heavy metals, condition during plant growth (PH.humidity of soil, water), altitude of sea level, speed of rainfall,different bioavailability of metals (Shi et al., 2008; Yongsheng et al., 2011; Chaoua et al., 2019), and characteristics of soil used for cultivation tea. Generally, It is obvious that chemical properties of soil including pH (Li et al., 2013), level of carbon (Lei et al., 2013), amount of nitrogen (Oh et al., 2008), potassium sulfur (Kamau et al., 2008), and phosphate fertilizers have effect role in metals uptake viatea plants (Ananthacumaraswamy et al., 2003); Yaylali-Abanuz and Tuysuzin their studies indicated that there was a significant negative relation between soil pH and uptake of metals by tea plants (Yaylalı-Abanuz and Tüysüz 2009). As mentioned in previous studies, high concentration of metals in teas may be effective by environmental pollution levelduring plant growth. For sample, Sharafi et al., 2019 in their studies indicated, crops cultivate near factories, mines, and highways had high amounts of metals (Sharafi et al., 2019). As a result, the metals pattern in tea shows the geography conditions of different countries and the natural environments in which tea plants are grown.

Processing of tea production

Meta-analysis regardingto concentration of toxic metal (mg/kg) based on kind of tea was presented in Table 1. The ranking of metals concentration in black and green tea was Pb> As >Cd, respectively. The highest contamination in black tea was related to Asmetal whereas in green tea was related to Pbmetal. These differences in concentration of metals may be dependent on processing of tea production (Heshmati et al., 2020; Mehri et al., 2019). It is

Table 3. Uncertainty analysis for TTHQ of metals in children and adult due to consumption of tea in various countries

	Adults				Children			
	Percentile 95%				Percentile 95%			
Country	AS	Cd	Pb	TTHQ	AS	Cd	Pb	TTHQ
Bangladesh	0.045	0.037	-	0.066	0.212	0.172	-	0.307
Brazil	0.002	0.002	0.082	0.068	0.007	0.008	0.382	0.314
China	0.006	0.009	0.740	0.440	0.030	0.041	3.458	2.057
Croatia	-	0.072	0.285	0.259	-	0.337	1.325	1.207
Egypt	0.101	0.057	0.521	0.495	0.466	0.264	2.443	2.312
Ghana	0.006	0.076	0.235	0.100	0.030	0.359	1.095	0.468
Indian	-	-	0.004	0.003	-	-	0.019	0.012
Iran	0.007	0.075	1.095	0.651	0.033	0.351	5.113	3.036
Italy	-	0.013	2.458	0.766	-	0.062	11.422	3.595
Japan	-	0.005	0.221	0.181	-	0.023	1.030	0.844
Nigeria	-	0.021	-	0.011	-	0.100	-	0.050
Poland	-	0.002	0.172	0.119	-	0.009	0.804	0.556
Saudi Arabia	0.048	0.141	2.319	1.111	0.224	0.661	10.900	5.186
Serbia	0.007	0.046	0.865	0.479	0.033	0.216	4.051	2.235
Slovakia	-	0.045	0.639	0.422	-	0.207	2.990	1.970
Spain	-	-	0.346	0.158	-	-	1.614	0.737
Turkey	0.001	0.043	0.980	0.454	0.006	0.203	4.535	2.121
US	0.009	0.007	0.314	0.262	0.043	0.034	1.466	1.226
Yunnan	0.009	0.008	0.555	0.176	0.041	0.036	2.560	0.817

quite clear that content of metal varies among teas andan assortment of synergistic factors can be involved in these diversities. Besides to age and content of leaves of tea that used in packaging process, degree of maturing, storage and also the ways of fermentation have basic role in contamination sources of tea. As mentioned in previous studies, green tea is produced by young leaves, vapor of water, dry and fry without fermentation, in contrast to black tea, which it is produced by older leaves, dry via air along with fermentation (Szymczycha-Madeja et al., 2012; Mosleh et al., 2014; Matsuura et al., 2001). Also, In addition contamination sources during the production of tea,agricultural activities, use of fungicides and fertilizers in process of cultivation,handling and storage of teacan be the most important parameters in the presence of metals intea plants (Falahi and Hedaiati 2013).

Health risk assessment

The non-carcinogenic risk assessment of toxic metals by consumption of the black and green teas in different countries was indicated in Table3.The results showed that accounted TTHQ amounts for adult groups in all investigated countries,except Saudi Arabia country,were lower than 1 whichindicated no acceptable health risk for tea consumers. TTHQ amounts accounted for children groupsin countries like Saudi Arabia > Italy > Iran > Egypt > Serbia > Turkey > China > Slovakia >US>Croatia respectively were higher than 1 whilein other countries was lower than 1.Therefore, consumers are at the considerable non-carcinogenic health risk in countries with risk higher than one. TTHQ level in children was higher in comparison with adult that may be due to lower BW,which can make children to be at higher hazard risk. This finding was similar to previous studies(77-79). It is worth noting different amount of TTHQ among countries can be related to pattern and rate of consumption, consumption frequency, concentration of toxic metal and body weight (Barone et al., 2016; Atamaleki et al., 2019).

CONCLUSIONS

This study was first systematic review and meta-analysis regarding the concentration of the toxic metals in teas according to types of teas and continentsin the world.On-carcinogenic health risk in regarding to the adults and children was assessed. The results of 39 papers showed that the ranking of metals concentration in black and green was Pb> As > Cd. The highest contamination in black tea was related to Asmetal whereas in green tea the highest level of contamination was related to Pbmetal. According to continents, the higher and lower concentration of toxic metals was related to Pb in Africa and Cd in America. Some parameters such as physicochemical characteristics of heavy metals, agricultural activities, status during plant growth (Ph. and humidity of soil, water), and also handling, storage, and processing practices play critical roles among these diversities. The health risk assessment indicatedrisk pattern was different in various countries and TTHQ level in children was higher in comparison with adult, hence, performing of control plans should be considered by governments as well as farmer for decrease concentration of toxic metals in black and green tea.

Conflict interest

All authors express that they have any conflict of interest.

REFERENCES

Abbasi S, Farmany A, Gholivand MB, Naghipour A, Abbasi F, Khani H (2009). Kinetic-spectrophotometry method for determination of ultra trace amounts of aluminum in food samples. Food chemistry. 2009;116(4):1019-23.

Al-Othman ZA, Yilmaz E, Sumayli HMT, Soylak M (2012). Evaluation of trace metals in tea samples from Jeddah and Jazan, Saudi Arabia by atomic Absorption Spectrometry. Bulletin of Environmental Contamination and Toxicology. 2012;89(6):1216-9.

Ananthacumaraswamy S, Hettiarachchi L, Dissanayake S (2003). Soil and foliar sulfur status in some tea plantations of Sri Lanka. Communications in soil science and plant analysis. 2003;34(11-12):1481-97.

Antoine JMR, Fung LAH, Grant CN (2017). Assessment of the potential health risks associated with the aluminium, arsenic, cadmium and lead content in selected fruits and vegetables grown in Jamaica. Toxicology Reports. 2017;4:181-7.

Árvay J, Hauptvogl M, Tomáš j, Harangozo L (2015). Determination of mercury, cadmium and lead contents in different tea and teas infusions (Camellia sinensis, L.). Potravinarstvo. 2015;9(1):398-402.

Ashraf W, Mian AA (2008). Levels of selected heavy metals in black tea varieties consumed in Saudi Arabia. Bulletin of Environmental Contamination and Toxicology. 2008;81(1):101-4.

Atamaleki A, Yazdanbakhsh A, Fakhri Y, Mahdipour F, Khodakarim S, Khaneghah AM (2019). The concentration of potentially toxic elements (PTEs) in the onion and tomato irrigated by wastewater: a systematic review; meta-analysis and health risk assessment. Food research international. 2019;125:108518.

Barone G, Giacominelli-Stuffler R, Storelli MM (2016). Evaluation of trace metal and polychlorinated biphenyl levels in tea brands of different origin commercialized in Italy. Food and Chemical Toxicology. 2016;87:113-9.

Başgel S, Erdemoğlu SB (2006). Determination of mineral and trace elements in some medicinal herbs and their infusions consumed in Turkey. Science of the Total Environment. 2006;359(1-3):82-9.

Brown MJ, Margolis S. Lead in drinking water and human blood lead levels in the United States. 2012.

Brzezicha-Cirocka J, Grembecka M, Szefer P (2016). Monitoring of essential and heavy metals in green tea from different geographical origins. Environmental Monitoring and Assessment. 2016;188(3).

Chaoua S, Boussaa S, El Gharmali A, Boumezzough A (2019). Impact of irrigation with wastewater on accumulation of heavy metals in soil and crops in the region of Marrakech in Morocco. Journal of the Saudi Society of Agricultural Sciences. 2019;18(4):429-36.

Chen SL, Li C, Chen AH, Shao Y, Li JW, Liu SB (2015). Editors. Determination of eight metal elements in polygonatum tea by microwave digestion-AAS. Resources, Environment and Engineering - 2nd Technical Congress on Resources, Environment and Engineering, CREE 2015; 2016.

de Oliveira LM, Das S, da Silva EB, Gao P, Gress J, Liu Y (2018). Metal concentrations in traditional and herbal teas and their potential risks to human health. Science of the Total Environment. 2018;633:649-57.

Ensafi AA, Khayamian T, Benvidi A, Mirmomtaz E (2006). Simultaneous determination of copper, lead and cadmium by cathodic adsorptive stripping voltammetry using artificial neural network. Analytica chimica acta. 2006;561(1-2):225-32.

Fakhri Y, Atamaleki A, Asadi A, Ghasemi SM, Mousavi Khaneghah A (2019). Bioaccumulation of potentially toxic elements (PTEs) in muscle Tilapia spp fish: a systematic review, meta-analysis, and non-carcinogenic risk assessment. Toxin Reviews. 2019:1-11.

Falahi E, Hedaiati R (2013). Heavy metal content of black teas consumed in Iran. Food Additives & Contaminants: Part B. 2013;6(2):123-6.

Fernández-Cáceres PL, Martín MJ, Pablos F, González AG (2001). Differentiation of tea (Camellia sinensis) varieties and their geographical origin according to their metal content. Journal of Agricultural and Food Chemistry. 2001;49(10):4775-9.

Ghasemidehkordi B, Malekirad AA, Nazem H, Fazilati M, Salavati H, Shariatifar N (2018). Concentration of lead and mercury in collected vegetables and herbs from Markazi province, Iran: a non-carcinogenic risk assessment. Food and chemical toxicology. 2018;113:204-10.

Gholami Z, Abtahi M, Golbini M, Parseh I, Alinejad A, Avazpour M (2019). The concentration and probabilistic health risk assessment of nitrate in Iranian drinking water: a case study of Ilam city. Toxin reviews. 2019:1-10.

Gomes DAS, Alves JPDS, da Silva EGP, Novaes CG, Silva DS, Aguiar RM (2019). Evaluation of metal content in tea samples commercialized in sachets using multivariate data analysis techniques. Microchemical Journal. 2019;151.

Gomez MR, Cerutti S, Sombra LL, Silva MF, Martínez LD (2007). Determination of heavy metals for the quality control in argentinian herbal medicines by ETAAS and ICP-OES. Food and Chemical Toxicology. 2007;45(6):1060-4.

Hadayat N, De Oliveira LM, Da Silva E, Han L, Hussain M, Liu X (2018). Assessment of trace metals in five most-consumed vegetables in the US: Conventional vs. organic. Environmental Pollution. 2018;243:292-300.

Helgilibrary (2011). Tea ingestion rate. https://wwwhelgilibrarycom/indicators/onion-consumption-per-capita/india/1–3. 2011.

Heshmati A, Mehri F, Karami-Momtaz J, Khaneghah AM (2020). Concentration and Risk Assessment of Potentially Toxic Elements, Lead and Cadmium, in Vegetables and Cereals Consumed in Western Iran. Journal of Food Protection. 2020;83(1):101-7.

Jin CW, Yun FH, Zhang K, Gen DZ, Jian LS, Zheng SJ (2005). Lead contamination in tea leaves and non-edaphic factors affecting it. Chemosphere. 2005;61(5):726-32.

Jin CW, Zheng SJ, He YF, Zhou GD, Zhou ZX (2995). Lead contamination in tea garden soils and factors affecting its bioavailability. Chemosphere. 2005;59(8):1151-9.

Kaličanin B, Velimirović D (2012). The content of lead in herbal drugs and tea samples. Central European Journal of Biology. 2012;8(2):178-85.

Kamau D, Spiertz J, Oenema O (2008). Carbon and nutrient stocks of tea plantations differing in age, genotype and plant population density. Plant and Soil. 2008;307(1-2):29.

Karak T, Bhagat R (2010). Trace elements in tea leaves, made tea and tea infusion: A review. Food Research International. 2010;43(9):2234-52.

Khaneghah AM, Fakhri Y, Nematollahi A, Pirhadi M (2019). Potentially toxic elements (PTEs) in cereal-based foods: A systematic review and meta-analysis. Trends in Food Science & Technology. 2019.

Lei W, Xing-Lun Y, Rachel K, Yu W, De-Li T, Mao Y (2013). Combined use of alkaline slag and rapeseed cake to ameliorate soil acidity in an acid tea garden soil. Pedosphere. 2013;23(2):177-84.

Li L, Fu QL, Achal V, Liu Y (2015). A comparison of the potential health risk of aluminum and heavy metals in tea leaves and tea infusion of commercially available green tea in Jiangxi, China. Environmental Monitoring and Assessment. 2015;187(5):1-12.

Orisakwe OE, Mbagwu HO, Ukpai P, Udowelle NA (2015). Survey of polycyclic aromatic hydrocarbons and lead in Chinese teas sold in Nigeria: levels and health implications. Roczniki Państwowego Zakładu Higieny. 2015;66(3):225-32.

Li M, Zhang X, Pang G, Han F (2013). The estimation of soil organic carbon distribution and storage in a small catchment area of the Loess Plateau. Catena. 2013;101:11-6.

Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Annals of internal medicine. 2009;151(4):W-65-W-94.

Lv HP, Lin Z, Tan JF, Guo L (2013). Contents of fluoride, lead, copper, chromium, arsenic and cadmium in Chinese Pu-erh tea. Food Research International. 2013;53(2):938-44.

Mason LH, Harp JP, Han DY (2014). Pb neurotoxicity: neuropsychological effects of lead toxicity. BioMed research international. 2014;2014.

Matsuura H, Hokura A, Katsuki F, Itoh A, Haraguchi H (2001). Multielement determination and speciation of major-to-trace elements in black tea leaves by ICP-AES and ICP-MS with the aid of size exclusion chromatography. Analytical sciences. 2001;17(3):391-8.

Mehri F, Heshmati A, Moradi M, Khaneghah AM (2019). The concentration and health risk assessment of nitrate in vegetables and fruits samples of Iran. Toxin Reviews. 2019:1-8.

Milani RF, Morgano MA, Cadore S (2016). Trace elements in Camellia sinensis marketed in southeastern Brazil: Extraction from tea leaves to beverages and dietary exposure. LWT - Food Science and Technology. 2016;68:491-8.

Mosleh YY, Mofeed J, Almaghrabi OA, Kadasa NM, El-Alzahrani H, Fuller M (2014). Residues of heavy metals, PCDDs, PCDFs, and DL-PCBs some medicinal plants collected randomly from the Jeddah, central market. Life Science Journal. 2014;11(7):1-8.

Naghipour D, Amouei A, Dadashi M, Zazouli MA (2016). Heavy metal content in black tea and their infusions in North of Iran and estimation of possible consumer health risk. Journal of Mazandaran University of Medical Sciences. 2016;26(143):211-23.

Nejatolahi M, Mortazavi S, Ildoromi A (2014). Levels of Cu, Zn, Pb, and Cd in the leaves of the tea plant (Camellia sinensis) and in the soil of Gilan and Mazandaran farms of Iran. Journal of Food Measurement and Characterization. 2014;8(4):277-82.

Nkansah MA, Opoku F, Ackumey AA (2016). Risk assessment of mineral and heavy metal content of selected tea products from the Ghanaian market. Environmental Monitoring and Assessment. 2016;188(6):1-11.

Oh K, Kato T, Xu H (2008). Transport of nitrogen assimilation in xylem vessels of green tea plants fed with NH4-N and NO3-N. Pedosphere. 2008;18(2):222-6.

Özden H, Özden S (2018). Levels of heavy metals and ochratoxin a in medicinal plants commercialized in Turkey. Turkish Journal of Pharmaceutical Sciences. 2018;15(3):376-81.

Piskin MB, Ozdemir OD, Kipcak AS, Tuğrul N, Derun EM (2013). Some essential element concentrations of Turkish rosehip teas. Advanced Science Letters. 2013;19(11):3148-50.

Podwika W, Kleszcz K (2018). Copper, Manganese, Zinc, and Cadmium in Tea Leaves of Different Types and Origin. 2018;183(2):389-95.

Popović S, Pantelić A, Milovanović Ž, Milinkov J, Vidović M (2017). Analysis of Tea for Metals by Flame and Graphite Furnace Atomic Absorption Spectrometry with Multivariate Analysis. Analytical Letters. 2017;50(16):2619-33.

Prkić A, Jurić A, Giljanović J, Politeo N, Sokol V, Bošković P (2017). Monitoring content of cadmium, calcium, copper, iron, lead, magnesium and manganese in tea leaves by electrothermal and flame atomizer atomic absorption spectrometry. Open Chemistry. 2017;15(1):200-7.

Prkić A, Politeo N, Giljanović J, Sokol V, Bošković P, Brkljača M (2018). Survey of content of cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, sodium and zinc in chamomile and green tea leaves by electrothermal or flame atomizer atomic absorption spectrometry. Open Chemistry. 2018;16(1):228-37.

Qin D, Jiang H, Bai S, Tang S, Mou Z (2015). Determination of 28 trace elements in three farmed cyprinid fish species from Northeast China. Food Control. 2015;50:1-8.

Qu C-S, Ma Z-W, Yang J, Liu Y, Bi J, Huang L (2012). Human exposure pathways of heavy metals in a lead-zinc mining area, Jiangsu Province, China. PloS one. 2012;7(11).

Rashid MH, Fardous Z, Chowdhury MA, Alam MK, Bari ML, Moniruzzaman M (2016). Determination of heavy metals in the soils of tea plantations and in fresh and processed tea leaves: an evaluation of six digestion methods. 2016;10:7.

Rezaee R, Hassanzadeh-Khayyat M, Mehri F, Khashyarmanesh Z, Moallemzadeh H, Karimi G (2012). Determination of parathion, aldicarb, and thiobencarb in tap water and bottled mineral water in Mashhad, Iran. Drug and chemical toxicology. 2012;35(2):192-8.

Antoine JM, Fung LAH, Grant CN (2017). Assessment of the potential health risks associated with the aluminium, arsenic, cadmium and lead content in selected fruits and vegetables grown in Jamaica. Toxicology reports. 2017;4:181-7.

Rubio C, Lucas JRD, Gutiérrez AJ, Glez-Weller D, Pérez Marrero B, Caballero JM (2012). Evaluation of metal concentrations in mentha herbal teas (Mentha piperita, Mentha pulegium and Mentha species) by inductively coupled plasma spectrometry. Journal of Pharmaceutical and Biomedical Analysis. 2012;71:11-7.

Salahinejad M, Aflaki F (2010). Toxic and essential mineral elements content of black tea leaves and their tea infusions consumed in Iran. Biological trace element research. 2010;134(1):109-17.

Seth TD, Hasan MZ, Sircar S (1973). Lead content of indian tea. Bulletin of Environmental Contamination and Toxicology. 1973;9(2):124-8.

Shaltout AA, Abd-Elkader OH (2016). Levels of Trace Elements in Black Teas Commercialized in Saudi Arabia Using Inductively Coupled Plasma Mass Spectrometry. Biological trace element research. 2016;174(2):477-83.

Sharafi K, Yunesian M, Nodehi RN, Mahvi AH, Pirsaheb M (2019). A systematic literature review for some toxic metals in widely consumed rice types (domestic and imported) in Iran: human health risk assessment, uncertainty and sensitivity analysis. Ecotoxicology and environmental safety. 2019;176:64-75.

Sharafi K, Yunesian M, Nodehi RN, Mahvi AH, Pirsaheb M, Nazmara S (2019). The reduction of toxic metals of various rice types by different preparation and cooking processes–Human health risk assessment in Tehran households, Iran. Food chemistry. 2019;280:294-302.

Shen FM, Chen HW (2008). Element composition of tea leaves and tea infusions and its impact on health. Bulletin of Environmental Contamination and Toxicology. 2008;80(3):300-4.

Shi Y-z, Ruan J-y, Ma L-f, Han W-y, Wang F (2008). Accumulation and distribution of arsenic and cadmium by tea plants. Journal of Zhejiang University SCIENCE B. 2008;9(3):265-70.

Shokrzadeh M, Saberyan M, Saeedi Saravi SS (2008). Assessment of lead (Pb) and cadmium (Cd) in 10 samples of Iranian and foreign consumed tea leaves and dissolved beverages. Toxicological and Environmental Chemistry. 2008;90(5):879-83.

Sofuoglu SC, Kavcar P (2008). An exposure and risk assessment for fluoride and trace metals in black tea. Journal of hazardous materials. 2008;158(2-3):392-400.

Soylak M, Narin I, Divrikli U, Saracoglu S, Elci L, Dogan M (2004). Preconcentration-Separation of Heavy Metal Ions in Environmental Samples by Membrane Filtration-Atomic Absorption Spectrometry Combination. Analytical Letters. 2004;37(4):767-80.

Srogi K (2006). Assessment of selected heavy metal contents in medicinal plants, tea leaves and chocolate using atomic absorption spectrometry. Acta Toxicologica. 2006;14(1-2):117-28.

Szymczycha-Madeja A, Welna M, Pohl P (2012). Elemental analysis of teas and their infusions by spectrometric methods. TrAC trends in analytical chemistry. 2012;35:165-81.

Tokalioğlu Ş (2012). Determination of trace elements in commonly consumed medicinal herbs by ICP-MS and multivariate analysis. Food Chemistry. 2012;134(4):2504-8.

Tsushida T, Takeo T (1977). Zinc, copper, lead and cadmium contents in green tea. Journal of the Science of Food and Agriculture. 1977;28(3):255-8.

Yaylalı-Abanuz G, Tüysüz N (2009). Heavy metal contamination of soils and tea plants in the eastern Black Sea region, NE Turkey. Environmental Earth Sciences. 2009;59(1):131.

Yongsheng W, Qihui L, Qian T (2011). Effect of Pb on growth, accumulation and quality component of tea plant. Procedia Engineering. 2011;18:214-9.

Zhang HQ, Ni BF, Tian WZ, Zhang GY, Huang DH, Liu CX (2011). Study on essential and toxic elements intake from drinking of Chinese tea. Journal of Radioanalytical and Nuclear Chemistry. 2011;287(3):887-92.

Zhang J, Ma G, Chen L, Liu T, Liu X, Lu C (2017). Profiling elements in Puerh tea from Yunnan province, China. Food Additives and Contaminants: Part B Surveillance. 2017;10(3):155-64.

Zhang J, Yang R, Chen R, Peng Y, Wen X, Gao L (2018). Accumulation of heavy metals in tea leaves and potential health risk assessment: A case study from Puan County, Guizhou Province, China. International Journal of Environmental Research and Public Health. 2018;15(1).

Zhelev I, Barman T, Barooah AK, Goswami BC, Sharma N, Panja S (2019). Contents of Chromium and Arsenic in Tea (Camellia sinensis L.): Extent of Transfer into Tea Infusion and Health Consequence. Scientific reports. 2019.

Zhu F, Wang X, Fan W, Qu L, Qiao M, Yao S (2013). Assessment of potential health risk for arsenic and heavy metals in some herbal flowers and their infusions consumed in China. Environmental Monitoring and Assessment. 2013;185(5):3909-16.

Zhu Y, Duan X, Qin N, Lv J, Wu G, Wei F (2019). Health risk from dietary exposure to polycyclic aromatic hydrocarbons (PAHs) in a typical high cancer incidence area in southwest China. Science of the Total Environment. 2019;649:731-8.