

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 Copyright © 2020 Global Advanced Research Journals

Full Length Research Paper

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

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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

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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 as 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 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) fulltext 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

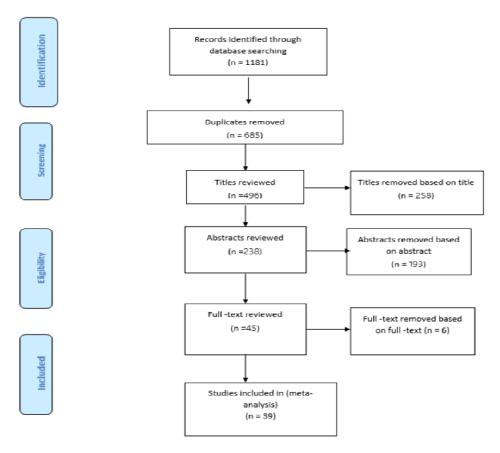


Figure 1: Selection process evidence searches and inclusion

(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).

 $TTHQ = \sum_{i=1}^{n} THQi$ 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 of 45 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	.01	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.,	2010	Black	Iran	60	.44	.14	0.28-0.56	AAS	NM
Oliveira et al.,	2014	Green	US	14	.76	.14	0.36- 1.70	ICP-MS	NM
Baronet e al.,	2018	Green	Italy	14	.70	.12	0.10-1.08	AAS	0.1
Árvay, J. et al.,	2016	Green	Slovakia	14	.875	.55	0.10-1.08 NM	GF-AAS	NM
Milani et al.,	2015	Green	Brazil	9	.075	.12	0.05- 0.37	ICP-MS	0.005
Othman et al.,	2018	Green	Saudi Arabia	9 20	3.28	1.2	0.03- 0.37	ICP-MS	0.005
Podwika et al.,	2011		Poland	20	.049		0.23 - 6.3	AAS	0.3 NM
Baronet e al.,	2018	Green		27 14		.03 .07			0.1
		Green	Italy Sorbia		.47		0.30-0.57	AAS	
Popovi? et al.,	2018	Green	Serbia	9	.21	.08	NM	FAAS	0.48

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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	1.44.4	FAAS	0.1
Brzezicha-Cirocka et	2016	Green	Poland	41	.45	.38	0.09–1.38	AAS	0.004
al									
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 number according the ofstudies were: to Iran(51.28%)~China (51.28%) >Saudi Arabia (23.07%) >Turkey(20.47%) >Brazil (15.38%)~Us(15.38%) >Serbia (12.82%)> (10.25%)~Italy(10.25%)~Slovakia Egypt (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 I² statistics suggested a significant heterogeneity among the included studies for Cd (Q=3205.92, df =40, p<0.001 and I²=100%), Pb (Q=11373.46, df =48, p<0.001 and I²=99.6%) and As (Q=2585.79, df =19, p<0.001 and I²=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

Toxic metals	WHO regions	Number study	ES	Lower	Upper	Weight (%)	Statistic	df	P value	l2 (%)
-	Ŭ	,	0.54	0.54	0.50	· · · ·	00000 7	05	0.001	
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 1. Meta-analysis of concentration of toxic metal (mg/kg) based on kind of tea.

 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	l 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

				Adults				Children
		Percer	ntile 95%				Pe	ercentile 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

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

quite clear that content of metal varies among teas and an 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 which indicated 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 continents in 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.

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