Environmental Science and Pollution Research (2018) 25:1033–1043
https://doi.org/10.1007/s11356-017-0863-8

TREND EDITORIAL

What do we know about exposure of Iranians to cadmium? Findings from a systematic review

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Received: 12 July 2017 / Accepted: 28 November 2017 / Published online: 19 December 2017

Abstract
Cadmium is an important environmental contaminant. High consumption of chemical fertilizers and industrial activities in recent decades has caused people to be worried about exposure to cadmium. There is no policy for environmental and biological monitoring of exposure to cadmium in the general population in Iran. This study was aimed to review cadmium content in consuming foods and biological samples in Iran, systematically. We developed a comprehensive search strategy and used it to search on Web of Science, Scopus, Science Direct, and Scientific Information Database until 28 December 2016. The totals of 285 articles were identified and finally 31 original papers were selected. Cadmium contamination was found in Iranian food groups such as rice, cereal and legumes, canned tuna fish, vegetables, fruit juice, and egg. This study showed that cadmium amount in 75% of the consumed rice samples (domestic and imported) was higher than the maximum limits approved by institute of standards and industrial research of Iran. Lettuce samples in Yazd were recorded the highest concentration of cadmium compared to other studies. In addition, high amount of cadmium was observed in the blood of the general population. Regarding the cadmium contamination in food and blood samples in Iran, policies must be adopted to reduce exposure to cadmium through different matrices as much as possible.

Keywords Exposure · Cadmium · Food · Blood · Urine · Iran

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Introduction

Cadmium (Cd) is an environmental contaminant which is released into the environment in inorganic form through volcanic activity, forest fires, weathering of rocks, and windblown transport of soil particles as natural sources. Anthropogenic sources are including manufacture and application of nickel-cadmium batteries, usage of phosphate fertilizers, copper and nickel smelting, and waste incineration and disposal can cause cadmium emission (Jenny-Burri et al. 2015; EFSA 2012). The rapid developments of urbanization and industrial activities have led to an increase in cadmium concentration of the environment (Kim and Wolt 2011). The general population are exposed to cadmium from different sources. The 90 W% of exposure to Cd in non-smoking general population accounts through food. Smoking and food are the main environmental source of non-occupational exposure. Also, in non-smoking general population, less than 10% of total exposure to Cd occurs through inhalation of ambient air and drinking water (EFSA 2012).

High concentrations of cadmium were presented in offal products such as the liver and kidney, molluscs and crustaceans, fish and sea foods, cereals such as rice and wheat, green leafy vegetables, potato, and root vegetables (Sapunar-Postruznik et al. 1996; Nasreddine et al. 2010; Vromman et al. 2010; Kim and Wolt 2011; Arnich et al. 2012; Chen et al. 2014; Kim et al. 2014; Zhang et al. 2016).

The Joint FAO/WHO expert committee on food additives withdrew the provisional tolerable weekly intake (PTWI) of 7 μg kg BW^{-1} $week^{-1}$ in 2010 and they established an amount of 5.6–5.8 μg kg BW^{-1} $week^{-1}$ or 25 μg kg^{-1} BW^{-1} $month^{-1}$ as provisional tolerable monthly intake (FAO/WHO 2011). This value represents permissible human weekly exposure to those contaminants unavoidably associated with consumption of otherwise wholesome and nutritious foods. In Iran, the Institute of Standards and Industrial Research of Iran (ISIRI) established 7 μg kg BW^{-1} $week^{-1}$ as PTWI and it has not been revised since 2010 (ISIRI 2010).

Absorption rate of cadmium in human is 3–5%. Absorbed Cd retains mainly in the kidney with a biological half time of around 10–30 years (Yuan et al. 2014; Ilmiawati et al. 2015; Zhang et al. 2016). The urinary (uCd) and whole blood (bCd) cadmium concentration are good indicators of chronic and recent exposures, respectively. The half-life of cadmium in blood is estimated to be 2–3 months (Farzin et al. 2008; Ilmiawati et al. 2015). Cadmium is primarily toxic for the kidney and increases the risk of cancer. It can accumulate in the placenta and transfer to the fetus. And also, it can induce bone damage and osteoporosis (EFSA 2012).

High consumption of chemical fertilizers and industrial activities in recent decades has caused people to be worried about exposure to cadmium. Since there is not any policy for environmental monitoring and biomonitoring of Cd in the general population of Iran, we designed a systematic review on exposure of Iranian to cadmium through foods and biological samples.

Methodology

Literature sources and search strategy

In the present systematic review which was conducted in December 2016, we first formulated the framing question as follows: What is the Cd level in food and biological samples (urine and blood) in the non-smoking general population of Iran? Since the main source of cadmium exposure in the non-smoking general population is food, we searched articles about level of cadmium in foods in Iran. Also, the Iranian articles were selected about the amount of cadmium in biological samples (urine and blood) on healthy non-smoking general population. Population in these studies were without occupational exposure. Based on these subjects, we formulated a comprehensive search strategy to cover all the relevant articles about topics. We searched all available electronic information resources in Web of Science, Scopus, and Science Direct for English language articles and Scientific Information Database for Persian articles. The using search strategy was the same for all databases. In order to find as many articles as possible, the following terms (using Medical Subject Headings (MeSH)) were used until December 28, 2016: ("cadmium AND diet*") OR ("cadmium AND urine*) OR ("cadmium AND blood") in Iran.

After this stage, we considered a set of inclusion and exclusion criteria, which was described as follows:

Inclusion criteria

In this study, we included articles that were published as original articles in peer-reviewed journals about the amount of cadmium in different types of food and biological samples (urine and blood) on healthy non-smoking general population in Iran. In case-control articles, we considered Cd level in the control group. The papers were selected in both languages, English and Persian, without any time limitation.

Exclusion criteria

We excluded book, presentation, review, and letter to the editor about cadmium amount in water, wastewater, air, soil, and biological samples such as hair, nail, saliva, milk human, etc. We did not select the studies that were done on the animals. Also articles about development of methods to determine of cadmium in different media were excluded.

Data collection process

All articles were reviewed by two reviewers independently for title, abstract, and keywords, in the next stage. In some included articles, decision was made based on the whole paper, because we could not decide at that time. Then, we developed a comprehensive data extraction form the included papers. Information were obtained from each article about the following items: first author, year of data collection, location, type of food group and sample size, type of biological (urine, blood) samples, sample size of population, and level of cadmium.

Result

The totals of 285 articles were identified and we excluded 254 studies based on the mentioned criteria. Finally, 31 full texts of relevant articles were included in this review.

The PRISMA flow diagram of this process is shown in Fig. 1. By using the search strategy that was mentioned, we found 24 articles about Cd level in different foods, 27 articles about cadmium levels in urine, and 53 articles about cadmium concentration in the blood in Iran from Web of Science database. By searching in Scopus database about cadmium levels in food, urine, and blood in Iran, we achieved 36, 1, and 16 articles, respectively. Also, we found 37 articles related to the purpose of the Science Direct database. We got to 91 articles with Persian language through searching in the Persian database.

A summary of included articles was depicted in Table 1. Some studies had calculated the estimated weekly intake (EWI) of cadmium through consumption of foods and compared this value to PTWI. The EWI by consumption of rice in Torbat Heidarieh indicated 1.09 to 4.60 (μg kg^{-1} BW $week^{-1}$) (Amiri Qandashtani and Mohamadi Sani 2016). This value was presented between 3.465–5.3 (μg kg^{-1} BW $week^{-1}$) in domestic and 3.747–5.762 (μg kg^{-1} BW $week^{-1}$) in imported rice in Shiraz (Naseri et al. 2015). The weekly intake of Cd from rice in Ghaemshahr was 1.573 (0.461–2.343) (μg kg^{-1} BW $week^{-1}$) (Malidareh et al. 2014). The calculated EWI from Iranian (Tarom) and Indian rice in Golestan province reported, respectively, 3.51 and 3.62 (μg kg^{-1} BW $week^{-1}$) (Shokrzadeh et al. 2014a, b).

Discussion

Exposure to cadmium of different food groups

Cadmium toxicity is well known and the health effects of cadmium exposure have been reviewed recently. Food is the main source of cadmium exposure in the general non-smoking population. The various studies have conducted to determine cadmium in different food types of Iran. ISIRI has not revised the PTWI value since 2010 and it must be changed based on the latest amount expressed by FAO/WHO. In addition, ISIRI must be considered the maximum level of Cd amount for the most consumed food groups.

Rice Cadmium contamination was observed in rice samples that have been cultivated in Iran. This was increased in rice samples that were taken respectively of Lorestan (Falahi et al. 2010), Ghaemshahr (Malidareh et al. 2014), Golestan (Shokrzadeh et al. 2014a, b), and Shiraz (Naseri et al. 2015). The minimum and maximum amount of cadmium was found in imported rice. The mean cadmium concentration in imported rice in Shiraz was higher than allowable limit (0.4 mg kg^{-1}) sets by FAO/WHO (FAO/WHO 2011). Cadmium amount in about 75% of the domestic and imported rice samples was higher than maximum limit approved by ISIRI (0.06 mg kg^{-1}) (2010). Only, Cd amount in consumed Indian rice in Golestan and cultivated rice in Lorestan were lower than ISIRI maximum limit.

The mean Cd was recorded 0.041 (mg kg^{-1}) in China (Yuan et al. 2014), 0.05 (mg kg^{-1}) in Japan (Shimbo et al. 2000), 0.008 (mg kg^{-1}) in France (Arnich et al. 2012), and 0.021 (mg kg^{-1}) in South Korea (Myung Chae et al. 2005). The comparison of these results showed that mean cadmium in consuming rice samples was higher in Iran than the mentioned countries. The cadmium content in rice samples in Lorestan was observed as the lowest level compared with other studies.

This variation in Cd levels might be due to various determinants such as variation of Cd concentrations in soil, type and consumption level of fertilizers, water supply, or differences in Cd uptake between genotypes (Jahed Khaniki and Zozali 2005).

Rice consumption in Iran was reported by ISIRI approximately 110 g per capita per day and it has been used in all studies for EWI calculation (ISIRI 2010). The calculated EWI observed in domestic rice (5.3 μg kg BW^{-1} $week^{-1}$) and imported rice (5.76 and 5.63 μg kg BW^{-1} $week^{-1}$) in Shiraz (Naseri et al. 2015) was very close to PTWI (5.6–5.8 μg kg BW^{-1} $week^{-1}$) set by FAO/WHO (2011).

Cereal and legumes The Cd level in wheat that has been cultivated in Kermanshah was higher than the recommended maximum level by WHO/FAO (0.2 mg kg^{-1}) and ISIRI (0.03 mg kg^{-1}) (Pirsaheb et al. 2016). The mean cadmium content in legume samples observed was 0.14 mg kg^{-1}. It was higher than the maximum level by WHO/FAO and ISIRI (0.1 mg kg^{-1}). The mean Cd level of legumes reported 0.1 μg day^{-1} in South Korea (Kim and Wolt 2011), 0.0155 mg kg^{-1} in China (Yuan et al. 2014), 0.011 mg kg^{-1} in Cameroon (Gimou et al. 2013), and 53 μg kg^{-1} in Hong Kong (Chen et al. 2014). The mean Cd content in Iranian

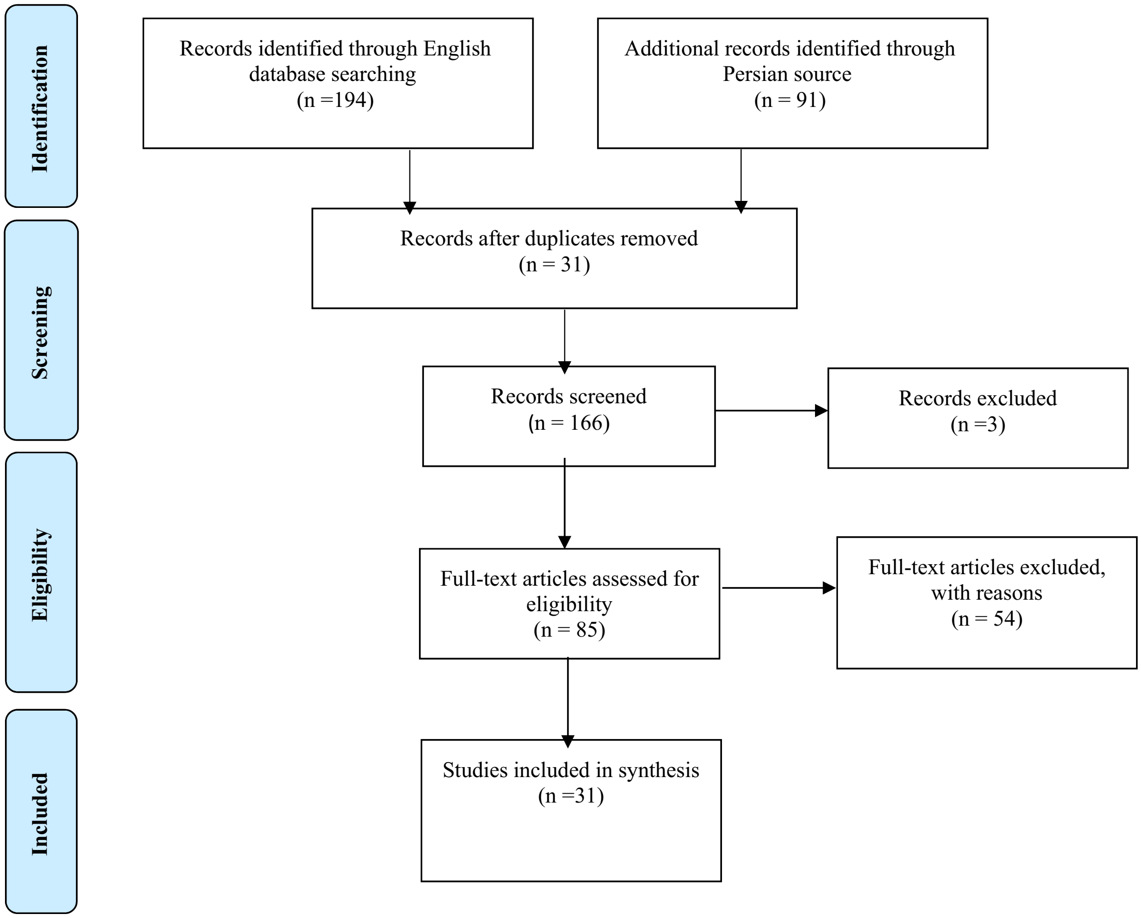

Fig. 1 Flow diagram of the search and selection of papers

legumes was higher than that in other studies. In searching stage, we found one study about cadmium level in cereal in Iran and more studies need to be done in this issue.

Tea The different results were observed of studies conducted on most consumed black tea brands in Iran (domestic and imported) (Zazouli et al. 2010; Falahi and Hedaiati 2013; Aghelan and Sobhan Ardakan 2016). The minimum and maximum concentration of Cd was found in domestic black tea. ISIRI does not set a maximum allowable and safe concentration of Cd in tea yet. According to high consumption of tea in Iran, it is very necessary.

Canned tuna fish The highest of Cd concentration was observed in canned fish samples that were taken of south of Iran (Malakootian et al. 2013). The concentration of cadmium in canned tuna fish (0.0046 to 0.0720 with an average value of 0.0223 μg g^{-1}) from the Persian Gulf area (Emami Khansari et al. 2005) was similar to that in samples from the Mediterranean coast (Voegborlo et al. 1999). The differences in levels of toxic elements in shellfish are related to age, sex, season, and place. ISIRI was set 0.05 mg kg^{-1} as maximum allowable of cadmium in fish. The results were shown the Cd level in purchased samples at Tehran's market (Hosseini et al. 2015) and samples were taken of south of Iran (Malakootian et al. 2013) above the maximum level.

In addition, the Cd level in muscle tissues and skin of white Indian prawn in Shiraz was higher than ISIRI limit (Cheraghi et al. 2014a, b). There is little available information in this regard and it needs to conduct further studies.

Vegetables The mean Cd level of consumed cucumbers in Gorgan and Gonbad and tomato in Gorgan (Zafarzadeh and Rahimzadeh 2015) was higher than the safe amount of cadmium (0.05 mg kg^{-1}) that was set by ISIRI and FAO/WHO. Cadmium content in Hamadan's greenhouse tomato recorded higher than the safe level. It is expected to take more control in production, usage of fertilizer, and pesticide in greenhouse crops. The amount of Cd reported in tomato samples was 0.33 mg kg^{-1} in India (Parveen et al. 2003) and 0.0188 mg kg^{-1} in Greece (Karavoltsos et al. 2002). The Cd concentration in Iranian's tomato samples was higher than that in Greece and lower than that in India.

In studies on plants, selected plants were not the same but all of them were from the leafy vegetable group. Based on the results of studies, the mean of cadmium in plants of Yazd was

Table 1 General characteristic of included articles

First author	Year	Location	Type of sample			Study design and sample size	Key finding (Cd concentration)
			Food type	Blood	Urine		
Ostadrahimi et al.	2016	Tabriz		Whole blo-od		111 control, 90 persons were non-smoking, and 21 persons were smoking	Mean ± SD (μg L^{-1}) in control group 2.1 ± 1.83
Amiri Qandashtani and Mohamadi	2016	Torbat Heidarieh	Imported rice			200 from 10 imported brands in market	Range (μg g^{-1}): 0.085–0.385 Mean ± SD (μg g^{-1} dry weight) Indian: 0.242 ± 0.039, 0.221 ± 0.010, and 0.385 ± 0.021 Pakistan: 0.171 ± 0.02, 0.195 ± 0.014, 0.131 ± 0.011, 0.098 ± 0.008, 0.112 ± 0.010, 0.085 ± 0.009, and 0.0295 ± 0.31
Pirsaheb et al.	2016	Kermanshah	Cereal			150 packed from different brand in market	(μg g^{-1}) Range—wheat: 0.038–1.99, corn:0.05–1.048, peas: 0.033–0.4, lentil: 0.045–0.127, lean: 0.065–0.186, split peas: 0.107–0.205 Mean—wheat: 0.41, corn: 0.29, peas: 0.09, lentil: 0.07, bean:0.13 and split peas: 0.15
Ghasemkhani et al.	2016	Hamedan	Commercial fruit juices			16 samples from 4 brands	(mg L^{-1}) Range: 0.1–0.4 Mean ± SD: 0.18 ± 0.07
Miri et al.	2016	Yazd	4 plants: (leek, parsley, lettuce and coriander)			40 samples	Mean ± SD (μg g^{-1} dry weight) Leek: 27.5 ± 2.12, parsely: 23 ± 2.82 Lettuce: 34.5 ± 0.707 Coriander: 34.5 ± 0.707 Total: 27.125 ± 5.313
Aghelan and Sobhan Ardakan	2016	Hamadan	Black and green tea			12 samples	Mean ± SD (μg g^{-1}) of black tea Domestic: 0.035 ± 0.021 Imported: 0.036 ± 0.02 Mean ± SD (μg g^{-1}) of green tea Domestic: 0.037 ± 0.015 Imported: 0.027 ± 0.023
Moradi et al.	2016	Shiraz		Serum		25 patients, 50 healthy people from Isfahan and Shiraz as control	Mean of serum blood in healthy people (μg L^{-1}) Isfahan: 0.02 Shiraz: 0.01
Farahani et al.	2015	Markazi	Albumen of hen eggs			32 samples from industrial poultry farms	(μg g^{-1}) Range: 0.025–6.388 Mean ± SD: 0.248 ± 1.12
Naseri et al.	2015	Shiraz	Rice			210 packed rice samples from varies of imported and domestic	Mean ± SD (μg g^{-1} dry weight) Domestic: 0.34 ± 0.02 Imported: 0.41 ± 0.03
Hosseini et al.	2015	Tehran	Canned tuna fish			120 samples of four different commercial types	Range (μg g^{-1}): 0.00–0.27
Zafarzadeh and Rahimzadeh	2015	Gorgan and Gonbad	Cucumber and tomato			96 samples (48 samples from each vegetable	(μg g^{-1} wet weight) Cucumber Range: 0.008–0.4 Gorgan Mean ± SD: 0.12 ± 0.017 Range: 0.005–0.515 Gobad Mean ± SD: 0.092 ± 0.013 Tomato Range: 0–0.395

Table 1 (continued)

First author	Year	Location	Type of sample			Study design and sample size	Key finding (Cd concentration)
			Food type	Blood	Urine		
							Gorgan Mean ± SD: 0.08 ± 0.01 Range: 0–0.08 Gonbad Mean ± SD: 0.027 ± 0.004
Abbasi Kia et al.	2015	Tehran	Chicken egg			29 samples	Mean ± SD (μg g^{-1}): 0.01 ± 0.008
Eftekhari et al.	2014	Shiraz	Salt			38 pre-packed salt sample (22 samples refined with recrystallization and 16 with washing method)	(μg g^{-1}) Recrystallized salts Range: 0.026–0.078 Mean ± SD: 0.02 ± 0.02 Washed salts Range: 0.005–0.093 Mean ± SD: 0.017 ± 0.021
Cheraghi et al.	2014b	Hamadan	Greenhouse tomato			72 samples	(μg g^{-1}) Range: 0.08–5.25 Mean ± SD: 0.71 ± 1.42
Cheraghi et al	2014a	Shiraz	White Indian prawn			120 samples	Mean ± SD (μg g^{-1}) Muscle tissue: 1.08 ± 0.45 Skin: 1.28 ± 0.38
Malidareh et al.	2014	Ghaemshahr	Polished white rice			20 polished white samples at harvesting of rice	(μg g^{-1} dry weight) Range: 0.025–0.113 Mean: 0.0817
Shokrzadeh et al.	2014a	Arak		Blood		47 persons (teacher) as control group	Mean ± SD (μg L^{-1}) 1.61 ± 1.21
Shokrzadeh et al.	2014b	Golestan	Rice			30 samples (10 from imported and 20 samples from Tarom rice)	Mean ± SD (μg g^{-1}) Imported: 0.04 ± 0.02 Tarom: 0.17 ± 0.05
Kelishadi et al.	2013	National study		Blood		160 persons were in control group	Mean ± SD (μg L^{-1}) 10.09 ± 2.21
Falahi and Hedaiati	2013	Lorestan	Black tea			20 samples of most frequently consumed	(μg g^{-1}) Range: 0.01–0.05 Mean ± SD: 0.21 ± 0.01
Jaberi et al.	2013	Isfahan and Golpaye-gan	UF-cheese and yoghurt			24 samples (12 samples from each city)	(ppb) UF Cheese Golpayegan Mean ± SD: 37.67 ± 22.58 Isfahan Mean ± SD: 53.79 ± 19.29 Yoghurt Isfahan Mean ± SD: 19.03 ± 1.23 Golpayegan Mean ± SD: 16.84 ± 8.08
Malakootian et al.	2013	South of Iran	Canned fish			192 experiments	Mean ± SD (μg g^{-1}): 0.032 ± 0.019
Golbabaei et al.	2012	Broujen			Urine	25 subjects were selected from administrative department as control group	(μg g $creatinine^{-1}$) Mean ± SD: 0.04 ± 0.07 Range: 0.00–0.28
Abedi et al.	2011	Tehran	Sausage			30 sample (five brands of six types of beef sausages)	(μg g^{-1} wet weight) Range: 0.0022–0.0135 Mean: 0.0057
Falahi et al.	2010	Lorestan	Rice			99 rice samples were collected at 3 areas	Mean ± SD (μg g^{-1}): 0.000045
Zazouli et al.	2010		Black tea and tea liquor				Mean ± SD (μg g^{-1}) Iranian: 0.67 ± 0.51

Table 1 (continued)

First author	Year	Location	Type of sample			Study design and sample size	Key finding (Cd concentration)
			Food type	Blood	Urine		
						30 tea samples from 10 mostly consumed and 10 infusion	Non-Iranian: 0.52 ± 0.3 Cd was non-detectable in tea liquor for all samples at 15 min infusion time but there were a little amount in tea liquor at 30 min infusion time
Rahimi and Rabani	2010	Tehran	4 plants: (spinach, parsley, dill, and mint)				(μg g^{-1} dry weight) Spinach: 1.56, parsley: 1.24, dill: 26 and, mint: 0.96)
Khoshgoftarmanesh et al.	2009	Qom	Greenhouse cucumber and bell pepper			30 samples	(μg g^{-1}) Cucumber = ND Bell paper Range: ND-0.05 Mean: 0.04
Farzin et al.	2008	Tehran		Whole blo-od		101 persons (61 male and 40 female)	Mean ± SD (μg L^{-1}) Males: 1.88 ± 0.73 Females: 1.72 ± 0.78 Total: 1.82 ± 0.67
Maleki and Zarasvand	2008	Sanandaj	5 plants: (leek, sweet basil, parsley, garden cress and tarragon)			100 samples	Mean ± SD (μg g^{-1} dry weight) Leek: ND, sweet basil: 0.32 ± 0.05, parsley: 0.2 ± 0.006, garden cress: 0.65 ± 0.02, tarragon: 0.4 ± 0.05 Total: 0.31 ± 0.17
Emami Khansari et al.	2005	Tehran	Canned tuna fish			21 samples of commercial vessels from the Persian gulf	(μg g^{-1} wet weight) Range: 0.0046–0.072 Mean ± SD Range: 0.0223 ± 0.0193

much higher than that of Sanandaj (Maleki and Zarasvand 2008) and Tehran (Rahimi and Rabani 2010). The maximum level of Cd in leafy vegetables was set by ISIRI (0.1 mg kg^{-1}) and FAO/WHO (0.2 mg kg^{-1}). With the exception leek samples of Sanandaj, all of plants samples were more than the recommended limit by ISIRI. The highest level of Cd was found in lettuce and coriander in Yazd. Cadmium concentration was detected in lettuce samples in Egypt about 0.01 ± 0.0 mg kg^{-1}(Radwan & Salama 2006). This amount is negligible compared to the amount that was reported in Yazd (Miri et al. 2016).

The Cd level in mint samples from Tehran (Rahimi and Rabani 2010) was about 10 times than that in India (0.1 mg kg^{-1}). The Cd content in spinach samples in Tehran was reported about 14 times than that in Egypt (0.11 ± 0.04 mg kg^{-1}) (Radwan & Salama 2006 2006) and 30 times than that in Greece (0.0527 mg kg^{-1}) (Karavoltsos et al. 2002). Sharma et al. (2007) presented the variation of metals in vegetables that are affected by physical and chemical nature of the soil, the absorption capacity for each metal by each plant, and environmental and human factors. Using of wastewater for irrigation, too much consumption of fertilizers, and lack of surveillances can be reasons for high concentration of Cd in Iranian vegetables.

Fruit juice and dairy products FAO/WHO and ISIRI have not set a maximum level for cadmium in fruit juice and dairy products. A guideline value for cadmium in drinking water (0.003 mg/L) was set by WHO. The authors compared Cd level in fruit juice with this value. The reported Cd level in orange juice of Hamedan (0.15 mg L^{-1}) (Ghasemkhani et al. 2016) was the same as that of Poland (Krejpcio et al. 2005). Cadmium amount was in both studies higher than the guideline value.

Cadmium contamination found in UF cheese and yoghurt samples of Esfahan and Golpayegan (Jaberi et al. 2013). But Cd level in yoghurt from this study compared to an Egyptian study (0.059 mg kg^{-1}) showed a lower amount (Enb et al. 2009). Also, amount of Cd in cheeses in Saudi Arabia (0.14 mg kg^{-1}) Aly et al. (2010) has been reported more than Iran. Cadmium concentration in Iranian cheese samples was similar to a study in Turkey (Ayar et al. 2009). The variation of Cd level in dairy products might be due to reasons including proximity of farming to industrial areas and melting factories, consumption of polluted food and water by livestock, and production and packing processes.

Egg Included studies reported various amounts of cadmium. These values were from 0.01 mg kg^{-1} in Tehran (Abbasi Kia et al. 2015) to 0.2 ± 1.12 mg kg^{-1} in Markazi province (Farahani et al. 2015). The Cd amount in eggs from Markazi was higher than that of studies in Nigeria (0.07 mg kg^{-1}) (Fakayode and Olu-Owolabi 2003), Pakistan (0.075 mg kg^{-1}) (Khan and Naeem 2006), India (0.008 mg kg^{-1}) (Basha et al. 2013), Palestin (0.03 mg kg^{-1}) (Abdulkhaliq et al. 2012), and Egypt (0.007 mg kg^{-1}) (Hashish et al. 2012). Also, this value in Iranian studies was observed lower than Uluozlu et al. study (2009) in Turkey (2.33 mg kg^{-1}).

The estimated daily intake of Cd was determined in 0.27 mg kg $BW^{-1}day^{-1}$ in Markazi (Farahani et al. 2015) and 0.6 μg kg BW^{-1} day^{-1} in Tehran (Abbasi Kia et al. 2015). Iranian egg consumption is approximately 24 g per capita per day based on ISIRI but authors applied various amount of consumption, 60 and 22 g per capita per day in their studies. So, we could not compare the results.

Salt and sausage According to Codex legislation and ISIRI, the maximum permitted level of cadmium in salt is 0.5 mg kg^{-1} (ISIRI 2010; FAO/WHO 2011). Cadmium content of salt samples in Iran was less than this limit. Cadmium amount in salt samples in Shiraz (Eftekhari et al. 2014) was approximately similar to that in Brazil (0.01–0.03 mg kg^{-1}) (Amorim and Ferreira 2005), Turkey, Egypt, and Greece (0.014–0.030 mg kg^{-1}) (Soylak et al. (2008).

ISIRI and FAO/WHO do not set a maximum level of Cd in sausages. The mean Cd in Iranian study (0.0057 mg kg^{-1}) (Abedi et al. 2011) was approximate to that in Chile (Munoz et al. 2005), Tenerife (Spain) (Gonzalez-Weller et al. 2006), and Turkey (Oymak et al. 2009). Only a study was done about Cd amount in sausage in Iran and more studies are needed for more discussion.

Biomonitoring of cadmium in general population

Biomonitoring of cadmium can be assessed by urine and blood samples. The urinary cadmium reflects body burden and long-term exposure. In contrast, blood cadmium has been recognized to primarily reflect recent exposure but may also include a contribution from long-term body burden (Adams and Newcomb 2014). The different studies were investigated of Cd amount in biological samples. In reviewing of included studies in this system, Cd level was investigated in general population and healthy people in the control group of case-control study.

The minimum and maximum bCd amount of included studies reported 0.01 μg L^{-1} (Moradi et al. 2016) and 10.09 μg L^{-1} (Kelishadi et al. 2013). The mean blood cadmium in general population was reported 1.79 μg L^{-1} for men and 1.84 μg L^{-1} for women in Japan (Watanabe et al. 1993), 1.76 μg L^{-1} for women in Japan (Shimbo et al. 2000), 0.52 μg L^{-1} in Shanghai China (He et al. 2013), 2.02 μg L^{-1} in southern Sweden (Olsson et al. 2002), and 0.77 μg L^{-1} in New York City (McKelvey et al. 2007). The comparison of results in different countries showed that lowest (Moradi et al. 2016) and highest (Kelishadi et al. 2013) of bCd was found in Iran. The bCd amount in residents of Tehran recorded 1.88 ± 0.73 for male and 1.72 ± 0.78 for female (Farzin, Amiri et al. 2008). These results were similar to two studies that have been conducted in Japan (Watanabe et al. 1993; Shimbo et al. 2000).

Only one study has been done on concentration of urinary cadmium in Iran. The urinary cadmium of male in the control group was determined 0.04 ± 0.07 μg g^{-1} (Golbabaei et al. 2012). The mean uCd reported of the general population in different studies as follows: Shanghai China (1.88 ± 1.47 μg L^{-1}) (He et al. 2013), Mainland of China (2.30 μg g^{-1} creatinine), Japan (2.62 μg g^{-1} creatinine), Korea (2.19 μg g^{-1} creatinine), and women in south-east Asia (1.42 μg g^{-1} creatinine) (Ikeda et al. 2000), Japanese women (3.94 ± 2.11 μg g^{-1}creatinine) (Shimbo et al. 2000). The uCd concentration of the Swiss population was presented with median and as microgram per gram creatinine in male, female, and total, respectively, 0.14, 0.21, and 0.16 (Jenny-Burri et al. 2015).

The difference in urine and blood Cd level might depend on various intake amount, possible environmental pollution, individual characteristic and life habits, continuous monitoring and controlling policy in communities.

Limitations and strengths

A few numbers of articles were based on cadmium exposure in general population by biological samples through urine and blood and population under these studies was very heterogeneous. Also, cadmium amount was investigated in different food groups. Therefore, because of this heterogeneity, we could not involve data in a meta-analysis.

This study was conducted as the first systematic review on cadmium amount in foods and biological samples (blood and urine) in general population of Iran. So, it can make people aware on exposure to cadmium.

Conclusion

Cadmium contamination was found in Iranian food groups such as rice, cereal and legumes, canned tuna fish, vegetables, fruit juice, and egg. The study showed that Cd amount in 75% of consumed rice samples (domestic and imported) was higher than the maximum limits approved by ISIRI (0.06 mg kg^{-1}). Lettuce samples in Yazd recorded the highest concentration of cadmium compared to other studies.

A few studies were done about bCd and uCd of the general population in Iran. The comparison of results in different countries showed that highest of bCd was found in Iran. It needs to conduct more studies in these fields.

Regarding to cadmium contamination in foods and blood samples in Iran, policies must be adopted to reduce exposure to cadmium through different matrices as much as possible.

Funding information This study was conducted as partly of Ph.D. thesis of first author with code number 9221150004 at Tehran University of Medical Sciences, Iran. It was supported by the Institute for Environmental Research (IER), Tehran University of Medical Sciences and Ministry of Health and Medical Education under grants numbers, respectively 96-02-46-34989 and 494.

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