Food Research International 125 (2019) 108518

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

The concentration of potentially toxic elements (PTEs) in the onion and tomato irrigated by wastewater: A systematic review; meta-analysis and health risk assessment

Ali Atamaleki[a], Ahmadreza Yazdanbakhsh[b,*], Yadolah Fakhri[c,*], Fayyaz Mahdipour[b], Soheila Khodakarim[d], Amin Mousavi Khaneghah[e]

[a] Student Research Committee, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[b] Workplace Health Promotion Reseach Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[c] School of Public Health, Hormozgan University of Medical Sciences, Bandar Abbas, Iran
[d] Department of Epidemiology, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[e] Department of Food Science, Faculty of Food Engineering, State University of Campinas (UNICAMP), 13083-862 Campinas, São Paulo, Brazil

ARTICLE INFO

Keywords:
Potentially toxic elements (PTEs)
Vegetable
Systematic review
Wastewater
Health risk

ABSTRACT

Nowadays, vegetable irrigation with wastewater in developing countries has become a serious issue. In this regard, the current investigation was performed to collect the related data regarding the concentration of potentially toxic elements (PTEs) including Fe, Zn, Cu, Cr, Pb, Ni, and Cd in onion and tomato samples irrigated with wastewater by the aid of a systematic review among the Scopus, Medline and Embase databases between 1/January/1983 to 31/January/2019. Also, the health risk assessment for consumers due to PTEs ingestion via the consumption of onion and tomato was estimated by using target hazard quotient (THQ). In this context, 35 articles with 64 studies out of 779 retrieved citations were included in the meta-analysis. The ranking of different parts of tomato based on Pb, Cd, and Cu concentration was shoot > root > leave > edible part; Fe, leave > shoot > root > edible part; Cr, root > leave > shoot > edible part; Zn, shoot > leave > root > edible part; and Ni, leave > edible part > root > shoot. Moreover, the ratio concentration of Pb, Cd, Cu, Fe, Cr, Zn and Ni in the edible part to leave of onion was 2.92, 6.01, 1.29, 4.17, 0.84, and 3.55, 10.10, respectively. According to findings, the rank order of PTEs in the onion was Fe (43.09 mg/kg-dry weight) > Zn (34.3 mg/ kg-dry weight) > Pb (18.54 mg/ kg-dry weight) > Cu (14.9 mg/ kg-dry weight) > Ni (11.92 mg/ kg-dry weight) > Cr (7.24 mg/ kg-dry weight) > Cd (0.23 mg/ kg-dry weight) and tomato; Fe (139.12 mg/ kg-dry weight) > Zn (29.81 mg/ kg-dry weight) > Cu (25.04 mg/ kg-dry weight) > Cr (14.28 mg/ kg-dry weight) > Pb (9.58 mg/ kg-dry weight) > Ni (9.23 mg/ kg-dry weight) > Cd (4.64 mg/kg-dry weight). However, the concentration of PTEs investigated in the edible part of onion was higher than leaves; their concentrations in the edible part of the tomato were lower than other parts. The health risk assessment indicated that consumers groups are at significant non-carcinogenic risk due to the ingestion of PTEs via consumption of the onion and tomato vegetable wastewater irrigated (THQ > 1). Therefore, the irrigation of vegetables with wastewater should be monitored and controlled by some prevention plans.

1. Introduction

There are several reports regarding water scarcity which attributed to the non-uniform distribution of water on earth and also, the increase in demand following by development of cities and urbanization (Becerra-Castro, Lopes, Vaz-Moreira, Silva, & Manaia, 2015; Lyu, Chen, Zhang, Fan, & Jiao, 2016). In this regard, it was forecasted that half of the world's population would suffer from water shortage in 2025 (Quist-Jensen, Macedonio, & Drioli, 2015). Moreover, since the early nineteenth century, the people facing water shortage has risen 16 times along with the 4-fold increase in world population. So, supplying a well-treated wastewater source is necessary to solve the problem (Kummu et al., 2016).

While annually, 80% of the urban population, generate 261 km^3 wastewater around the world (Mateo-Sagasta, Raschid-Sally, & Thebo, 2015), Wastewater reuse (WWR) is one of the high-priority ways to

* Corresponding authors.
E-mail addresses: Yazdanbakhsh@sbmu.ac.ir (A. Yazdanbakhsh), Ya.fakhri@gmail.com (Y. Fakhri).

https://doi.org/10.1016/j.foodres.2019.108518
Received 14 April 2019; Received in revised form 14 June 2019
Available online 24 June 2019

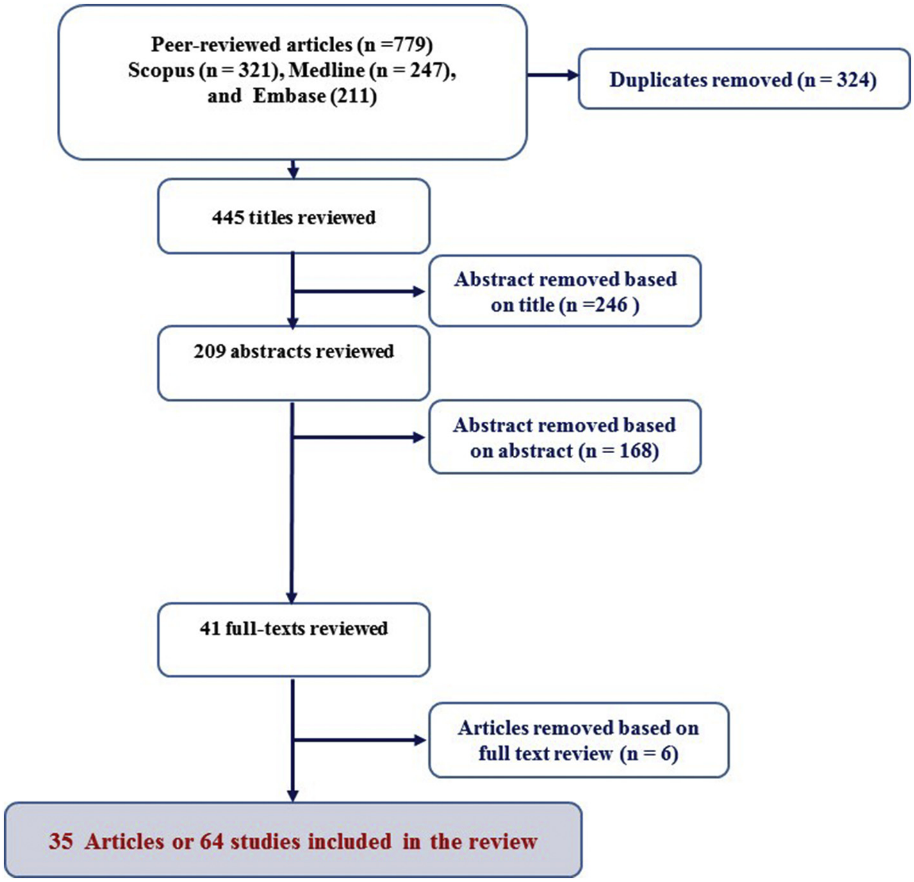

Fig. 1. Selection process studies conducted on concentration of potentially toxic elements (PTEs) in onion and tomato irrigated wastewater.

reduce the water stress and unavailability which attracted notable attention among some countries such as U. S, European Union, China, and Australia (Pintilie, Torres, Teodosiu, & Castells, 2016; Tarpani & Azapagic, 2018; Tran, Schwabe, & Jassby, 2016). Treated wastewater as an alternative source for fresh water can be used in agriculture, industry, aquifer recharge, power plants, and environmental uses (Bunani et al., 2015; Cao, Liang, & Liu, 2008). Irrigation of fields by wastewater have advantages such as supplying low-cost water and nutrients, reducing fertilizer consumption, soil modification; and increasing in crop production (Prazeres et al., 2016). In this regard, Najafi (Najafi, 2006) and Zavadil (Zavadil, 2009) demonstrated that wastewater significantly increased the yield of crops. Since the agricultural sector can be considered as one of the biggest consumers of water ($>$ 70%), reusing of treated wastewater in this sector plays an important role in sustainable agriculture (Tran et al., 2016; Zou & He, 2016). Nevertheless, even treated wastewater has remaining substances such as emerging and toxic pollutants that can lead to contamination of surface water, soil, and plants (Rizzo, Fiorentino, Grassi, Attanasio, & Guida, 2015; Turan et al., 2018).

The most important concern regarding wastewater irrigation is related to the aggregation of PTEs in crops and further transfer to the food chain (Nair, Levitan, & Oyama, 2008; Reddy, Reddy, Narayana, Sarala, & Reddy, 2008). Vegetables as one of the major sources for human nutrition can absorb PTEs from polluted soils through their roots (Fathabad et al., 2018). The high absorption can even hurt to a different part of the plant and cause some issues in terms of growth and yield (Ahmad et al., 2017). Moreover, the consumption of heavy metal through contaminated vegetables by human also leads to serious issues in some organs (kidney and heart) and also, malfunctions of some systems like nervous, immunological, skeletal, and digestive (Anwar et al., 2016).

Among the PTEs, Hg enters the crops by methylation process and causes amalgam, allergy, proteinuria, and problems on some limbs (lung and kidney) (El-Kady & Abdel-Wahhab, 2018; Fathabad et al., 2018). Cd is known as a carcinogen agent, which can lead to breast and lung cancer. The itai-itai is also a famous disease caused by long-term Cd exposure (Peralta-Videa, Lopez, Narayan, & Saupe, 2009; Roh et al., 2015; WHO, 2002). Pb is another carcinogen and through brain damage, disturbs the children's learning systems. Other problems like encephalopathy, anemia, vomiting, and nausea are also attributed to Pb ingestion. Generally speaking, Pb combined with Hg, Cu, and Cd can damage the kidney (El-Kady & Abdel-Wahhab, 2018; Ghasemidehkordi et al., 2018; Koduru & Lee, 2014; Rai, Lee, Zhang, Tsang, & Kim, 2019). Another carcinogen is Cr which its hexavalent ion is much more toxic than trivalent, leads to health issues such as hemolysis, hemorrhage, and gastrointestinal. Cr in combination with Zn can also create some disorders for the respiratory system (Fakhri et al., 2018; Lingamdinne et al., 2017; Lingamdinne, Koduru, Choi, Chang, & Yang, 2016; Rai et al., 2019; Reddy, Kumar, Ramachandraiah, Thriveni, & Reddy, 2007; Sarma, Kumar, Reddy, Thriveni, & Reddy, 2006).

Among the literature, the PTEs aggregation in tomato irrigated by different dilutions of wastewater investigated by Al-Lahham, El Assi, and Fayyad (2007). The results indicate that an increment in Mn and Zn concentrations by increasing in the proportion of wastewater against fresh water was observed (Al-Lahham et al., 2007). Another study also found that irrigation of radish by untreated textile wastewater resulted in the higher accumulations of Ni and Pb in the plant while compared to treated wastewater (Rehman & Bhatti, 2008). According to another survey, the vegetables irrigated by wastewater showed higher accumulation of PTEs in comparison with those irrigated with groundwater. Based on the findings, the rank order of PTE concentrations in both irrigation water types, as well as the type of vegetables, was Mn $>$ Zn $>$

Cu > Pb > Cr > Cd (Cheshmazar, Arfaeinia, Karimyan, Sharafi, & Hashemi, 2018).

Although in the several studies concentration of PTEs in vegetables including onion (*Allium cepa L.*) and tomato *(Solanum Lycopersicon L.*) wastewater irrigated was detected, no systematic review and meta-analysis has been performed (Cherfi, Achour, Cherfi, Otmani, & Morsli, 2015; Dong, Cui, & Liu, 2001; Hossain, Strezov, & Nelson, 2015; Safi & Buerkert, 2011). Hence, the main objectives of the current study were to conduct a meta-analysis concentration of PTEs in onion and tomato vegetable wastewater irrigated based on countries subgroup. Also, Non-carcinogenic health is in the adults and children consumers was estimated.

2. Material and method

2.1. Search strategy

Searching was done according to Cochrane protocols (Fig. 1) (Higgins & Green, 2011; Khaneghah et al., 2019; Khaneghah et al., 2019; Liberati et al., 2009). The searching was accomplished to obtain articles aimed at the accumulation of PTEs in vegetables, including onion and tomato irrigated by the wastewater on a global scale. The searching was performed among some of the international databases such as Scopus, Medline, and Embase between 1/January/1983 to 31/January/2019.

The following terms were used: Scopus: ((ti/ab ("metals") OR ti/ab ("heavy metals") OR ti/ab ("trace metals"))) OR ti/ab ("metal(oid)s") AND ((ti/ab ("vegetables") ((ti/ab ("tomato") OR ((ti/ab ("spinach") OR ((ti/ab ("onion") OR ti/ab ("plants"); Medline: Search ((("Metals"[Mesh]) OR (((heavy metals [Ti/Ab]) OR metals [Ti/Ab]) OR metal(oid)s [Tit_Abs]))) AND (((((((Plant [Ti/Ab]) OR vegetables [Ti/Ab]) onion [Ti/Ab]) radish[Ti/Ab]) spinach [Ti/Ab]) tomato[Ti/Ab]); Embase: ('metals':abt OR 'heavy metals':abt OR' trace metal:abt OR' metal(oid)s:abt) AND 'vegetables':abt OR plants'. Also, the references lists of articles were assessed in order to retrieve additional citations.

2.2. Inclusion criteria and data extraction

Inclusion criteria in the current study were defined as a) reporting of PTEs concentration in the onion and tomato vegetables; b) published in English language; c) cross-sectional study; d) reporting of average and range concentration of PTEs; e) irrigated vegetables by wastewater. In this regard, clinical trial study, case reports, review articles, books, and experimental studies were excluded (Khaneghah, Fakhri, Raeisi, Armoon, & Sant'Ana, 2018; Khaneghah, Fakhri, & Sant'Ana, 2018). Also, studies with other types of irrigation systems such as those vegetables irrigated by river water contain wastewater excluded (Fakhri et al., 2019; Khaneghah, Fakhri, et al., 2019; Khaneghah, Kamani, et al., 2019).

The data regarding PTE concentrations in vegetables as a graph was extracted by the GetData Graph Digitizer software (ver.2.24 (http://getdata-graph-digitizer.com)). In this regard, articles that did not fit the quality of the graphs were excluded. Also, studies which reported wastewater and sludge for irrigation of plants simultaneously were excluded.

The extracted characteristics of each study consist of the year of study, country, WHO regions, type of vegetables, parts of vegetables, sample size, mean and range of PTEs concentration, the standard deviation of PTE concentrations. In order to harmonize the units, all unit of concentration of PTEs including μg/kg, ppb and ng/g were converted to mg/kg-dry-weight.

2.3. Meta-analysis and statistical analysis

The pooled concentration of PTEs was investigated via mean and standard error (SE) (Higgins, White, & Anzures-Cabrera, 2008; Quan & Zhang, 2003).

The SE of the concentration of PTEs was calculated via the following equation:

$$SE = \frac{SD}{\sqrt{n}} \tag{1}$$

while SD and n are a standard deviation and sample size, respectively.

The Chi-square (I^2) test was performed to detect heterogeneity. If I^2 was higher than 50%, heterogeneity is considerable (Higgins & Thompson, 2002). Due to the high percentage of I^2 achieved in this study (> 50%), the random effect model (REM) was applied (Kuroki et al., 2017). The meta-analysis statistical procedure was conducted by STATA ver.14.0 (2015; STATA 14.0 Statistical Software, College Station, TX, USA). $P < .05$ was considered as the level for statistically significant.

2.4. Non-carcinogenic risk assessment

The non-carcinogenic risk due to ingestion of PTEs via consumption of vegetable was calculated with the aid of the following equation (Nazaroff & Alvarez-Cohen, 2001; Shahrbabki et al., 2018):

$$EDI = \frac{Cm \times IR \times EF \times ED}{BW \times ATn} \tag{2}$$

where, EDI is estimated daily intake; Cm, concentration of metal (mg/kg-dry weight); IR, ingestion rate (g/n-d); EF, exposure frequency (350 day/year); ED, exposure duration (children = 6 years and adults = 30 years); BW, Body weight (children = 15 kg and adults = 70 kg); ATn (EF × ED), average time exposure (children = 2190 days and adults = 10,950 days) (EPA, 1989; EPA, 2011). The average world ingestion rate of onion and tomato is 30.68 and 55.89 g/n-d, respectively (Helgilibrary, 2011).

While the concentration of PTEs as mg/kg-dry weight, the unit was converted to mg/kg-wet weight by using the presented equation below:

$$ww = \frac{dw \times (100 - \%M)}{100} \tag{3}$$

In this equation, is concentration based on wet weight; dw, concentration based on dry weight and %M is content in onion and potato that is 70% and 90%, respectively (Canet, 1988).

Target hazard quotient (THQ) was estimated by the following equation (Nazaroff & Alvarez-Cohen, 2001):

$$THQ = \frac{EDI}{RfD} \tag{4}$$

where, THQ is target hazard quotient; EDI estimated daily intake; RfD, oral reference dose. RfD for Pb, Cd, Cu, Fe, Cr (Total), Zn and Ni is not available, 0.001, 0.04, 0.7, not available, 0.3 and 0.011 mg/kg-d (EPA, 1993, 2000, 2018).

3. Results and discussion

3.1. Retrieve studies process

It should be noted that some of the investigated metals in the current investigations such as Fe, Zn and Cu cannot be considered as heavy metals while others such as Cr, Pb, Ni, and Cd are heavy metals. In this regard, in order to uniform terminology, the term of "Potentially Toxic Elements" or "PTEs" was used.

By searching among the Scopus, Medline, and Embase international databases, 779 articles published between 1/January/1983 and 31/January/2019 were retrieved. In the first step, 324 articles were excluded via EndNote citation manager (vX7.4, Thomas Reuters, New York, USA) due to repetition. Based on the titles of retrieved articles, 445 articles were selected as potentially suitable. Afterward, due to the irrelevant title, 246 articles were excluded. Based on the abstract, 209 articles were reviewed, and then 168 articles were excluded. Full texts of the retrieved 41 articles were downloaded and reviewed, and finally, 35 articles with 64 studies (sample size of 1406) were included (Fig. 1 and Table 1AS).

3.2. Characteristics of studies

The ranking of countries based on number of study was India (19 studies) > Pakistan (17 studies) > Turkey (9 studies) > Ethiopia (3 studies) ~ Iran (3 studies) > China (2 studies) ~ Cyprus (2 studies) > Afghanistan (1 study) ~ Algeria (1 study) ~ Australia (1 study) ~ France (1 study) ~ Greece (1 study) ~ Iraq (1 study) ~ Italy (1 study) ~ Jordan (1 study) ~ Korea, Rep. (1 study) (Table 1As).

The rank order of studies based on the type of wastewater was industrial wastewater (23 studies) > unspecified wastewater (20 studies) > domestic wastewater (13 studies) > both industrial and domestic wastewater (8 studies) (Table 1As).

3.3. PTEs in vegetables

Generally, high concentrations of PTEs in the environment may result in higher levels of translocation to vegetables. In a literature review conducted by Rai et al. (Rai et al., 2019), its explained that irrigation by wastewater or sludge in developing countries is the main translocation way of pollutants to crops. They are also concluded that uptake of PTEs by plants is a complex process which involved several factors; such as plant properties, the characteristics of PTEs, as well as physicochemical characteristics of irrigating wastewater and soil characteristics (Gupta, Nayek, Saha, & Satpati, 2008; Khawla, Besma, Enrique, & Mohamed, 2019; Leblebici & Kar, 2018; Mitch, 2002).

3.3.1. Plant properties

Previous studies demonstrated that different parts of the plants mainly depend on plant species, have difference tendency to the uptake of PTEs (Al-Lahham et al., 2007; Berry, Wallace, & Lunt, 1980; Falahi-Ardakani, Corey, & Gouin, 1988; Fazeli, Sathyanarayan, Satish, Muthanna, & Sciences, 1991). Some plant parts, like fruit and seed due to their high content of phloem tissue, have lower ability to accumulate the PTEs while compared with others which can be associated with the poor mobility of PTEs among these tissues (Khawla et al., 2019). Alemu, Mekonnen, and Leta (2017a, 2017b) surveyed aggregation of Cr parts of tomato, onion, beet, and carrot, which were irrigated by tannery wastewater. The results showed that each of the vegetables had different absorption ability in terms of Cr (Alemu et al., 2017a). According to Gupta, Khan, and Santra (2008), the plants, with regards to differences in their physiological needs, can uptake high concentration of Fe, Cu, and Zn (Gupta, Nayek, et al., 2008). Therefore, each plant has a unique ability to uptake the PTEs.

In the current study, the rank order of different parts of tomato based on Pb, Cd, and Cu concentration was shoot > root > leave > edible part; Fe, leave > shoot > root > edible part; Cr, root > leave > shoot > edible part; Zn, shoot > leave > root > edible part; and Ni, leave > edible part > root > shoot (Table 1). Concentration of PTEs in the edible part was mainly lower than other parts of tomato (Table 1).

3.3.2. Type of PTEs

The ranking of PTEs concentration in onion was Fe > Zn > Pb > Cu > Ni > Cr > Cd (Table 2). The ratio concentration of Pb, Cd, Cu, Fe, Cr, Zn and Ni in the edible part to leave of onion was 2.92, 6.01, 1.29, 4.17, 0.84, and 3.55, 10.10, respectively (Table 2).

The ranking of PTEs concentration in tomato was Fe (139.12 mg/ kg-dry weight) > Zn (29.81 mg/ kg-dry weight) > Cu (25.04 mg/ kg-dry weight) > Cr (14.28 mg/ kg-dry weight) > Pb (9.58 mg/ kg-dry weight) > Ni (9.23 mg/ kg-dry weight) > Cd (4.64 mg/ kg-dry weight) (Table 2).

The bioavailability of PTEs in plants is variable, which can be correlated with the unique uptake mechanism of each of PTEs (Chaoua, Boussaa, El Gharmali, & Boumezzough, 2018). For instances, bioavailability and movement of Fe, Cd, and Cu from soil to aerial plant parts are high, while Pb is one of the low-mobility PTEs which can be accumulated in higher concentration among the root. According to Gupta, Khan, and Santra (2008), no particular pattern was noted for the transportation of PTEs inside of tomato parts (Gupta, Nayek, et al., 2008). According to our findings, unlike other PTEs, Cd, Zn, and Cu had the highest accumulation in the shoot. Translocation of PTEs along the path of root to shoot through xylem and their storage in leave vacuoles depends on phytochelatins and the concentration of organic acids (Nayek, Gupta, & Saha, 2010). The high uptake during chlorophyll synthesis and be abundance in earth crust can be the main causes of high concentration of Fe in vegetables (Leblebici & Kar, 2018). The interaction between PTEs is another reason for non-uniform distribution in plant parts (Nayek et al., 2010). In some studies, antagonism correlation between Zn and Cu was reported, which led to the high accumulation of Zn than Cu, under the effect of soil pH (Chaudhry, Sharif, Latif, & Qureshi, 1973; Jan et al., 2010; Njuguna et al., 2019).

3.3.3. Soil characteristics

Besides the type of plants and PTEs, physicochemical characteristics of soil also can affect the PTEs uptake by plant parts. Considering to findings of a previously conducted investigation, the low bioavailability (element or compound that is accessible to an organism) of soil is a main inhibiting factor to uptake PTEs by vegetables(Mitch, 2002; Semple et al., 2004). Generally speaking, PTEs can be stabilized by some factors such as the concentration of phosphate, organic matter, and pH, of soil. In this regard, forming of carbonates and hydroxides as result of increase in pH significantly reduces the PTEs mobility (Amin, Hussain, Alamzeb, & Begum, 2013; Chaoua et al., 2018; Khan et al., 2011). Moreover, irrigation by wastewater and cultivation of different plants can also change the soil pH, which may be due to absorption and nitrification of ammonia, leaching of cations, and increasing in organic matter. Additionally, organic matter with clay in the soil can boost the binding PTEs to the soil (Khawla et al., 2019). Increasing in organic matter in the soil by irrigating wastewater, can be resulted in the formation of low weight organic molecules, that serve as PTEs carriers (Chaoua et al., 2018).

3.3.4. Irrigating wastewater characteristics

Several investigations have accentuated the role of wastewater characteristic in the aggregation of PTEs in irrigated soil and subsequently in vegetables is the most considerable factor. As the PTEs content of wastewater increases, their accumulation in the plants also can be increased. Gupta, Khan, and Santra (2012) investigated the accumulation of some PTEs in cauliflower, spinach, coriander, parsley, radish, and pudina vegetables cultivated in India, which irrigated by both the wastewater and clean water. All vegetables irrigated by wastewater, compared to the clean water, had a significant concentration of PTEs (Gupta et al., 2012). Another study in China also proved that using wastewater for irrigation while compared with groundwater has led to the significant aggregation of some PTEs into the soil as well as crops (Xue, Liu, Liu, & Yan, 2012). According to findings of a previously published report, the concentrations of Pb, Cr, Ni, and Cd in the edible part of onion irrigated by tube well water, were 0.0187, 0.0017, 0.039, and 0.001 mg/kg, respectively. While the corresponded values for same PTEs for tomato were measured as0.0197, 0.004, 0.0253, and 0.0017 mg/kg, respectively. The concentrations of Pb, Cr, Ni, and Cd in the edible parts of onion which irrigated by river water were 0.0227, 0.004, 0.0477, and 0.001 mg/kg. While in terms of tomato, the corresponded values for same PTEs were mentioned as 0.0310, 0.004, 0.0363, and 0.0013 mg/kg, respectively (Leblebici & Kar, 2018). In

Table 1
Meta-analysis of potentially toxic element (PTE) concentrations of tomato samples irrigated wastewater based on vegetable part.

(PTEs)	Vegetable part	Number of studies	ES (mg/Kg-dry weight)	(95% CI)	Weight	Heterogeneity			
						Statistic	df	*P* value	I^2 (%)
Pb	Edible	20	5.560	5.18–5.94	77.27	2.8e+05	19	0.000	100
	Root	2	39.029	0–91.85	4.79	1052.77	1	0.000	99.9
	Shoot	2	42.713	38.22–47.2	4.4	4.61	1	0.032	78.3
	Leave	4	31.8	18.57–45.04	8.96	827.93	3	0.000	99.6
	ND	1	2.520	1.83–3.2	4.57	0.00	0	–	–
	Overall	29	9.583	9.24–9.92	100	2.9e+05	28	0.000	100
Cd	Edible	22	0.453	0.37–0.52	84.09	15,154.90	21	0.000	99.9
	Root	2	57.195	40.76–73.62	2.26	121.22	1	0.000	99.2
	Shoot	2	57.626	46.76–68.48	2.27	55.53	1	0.000	98.2
	Leave	4	20.217	1.03–39.39	7.78	6727.51	3	0.000	100
	ND	1	0.020	0–0.51	3.59	0.00	0	–	–
	Overall	31	4.641	4.51–4.77	100	82,452.53	30	0.000	100
Cu	Edible	22	13.865	11.8–15.92	63.12	2.4e+05	21	0.000	100
	Root	3	44.890	25.3–64.47	8.49	554.34	2	0.000	99.6
	Shoot	3	69.398	27.9–110.89	8.58	3023.15	2	0.000	99.9
	Leave	6	38.248	18.26–58.23	16.90	5179.01	5	0.000	99.9
	ND	1	3.360	2.19–4.52	2.92	0.00	0	–	–
	Overall	35	25.049	23.26–26.82	100	2.8e+05	34	0.000	100
Fe	Edible	11	59.959	22.21–97.7	44.12	4981.72	10	0.000	99.8
	Root	4	102.80	5.55–200.06	15.96	81.69	3	0.000	96.3
	Shoot	4	165.33	0–337.46	15.96	259.14	3	0.000	98.8
	Leave	6	291.91	112.28–471.54	23.95	821.20	5	0.000	99.4
	ND	–	–	–	–	–	–	–	–
	Overall	25	139.12	82.52–195.72	100	53,958.10	24	0.000	100
Cr	Edible	20	4.540	4.24–4.83	87.51	5.6e+05	19	0.000	100
	Root	4	126.34	36.38–216.31	3.10	7655.33	3	0.000	100
	Shoot	4	69.681	10.53–128.82	4.14	4837.35	3	0.000	99.9
	Leave	5	105.30	0–224.87	3.24	21,499.70	4	0.000	100
	ND	1	2.360	0.49–4.22	2	0.00	0	–	–
	Overall	34	14.285	13.99–14.57	100	6.5e+05	33	0.000	100
Zn	Edible	21	20.858	17.7–24.01	57.17	54,426.13	20	0.000	100
	Root	4	30.973	5.27–56.66	10.95	433.88	3	0.000	99.3
	Shoot	4	48.198	10.73–85.65	10.92	871.70	3	0.000	99.7
	Leave	7	45.915	23.95–67.87	18.11	1689.04	6	0.000	99.6
	ND	1	33.080	29.91–36.24	2.85	0.00	0	–	–
	Overall	37	29.814	27.15–32.47	100	70,051.47	36	0.000	99.9
Ni	Edible	14	9.579	7.17–11.98	69.80	4874.01	13	0.000	99.7
	Root	1	5.700	3.99–7.4	5.09	0.00	0	–	–
	Shoot	1	4.400	2.69–6.1	5.09	0.00	0	–	–
	Leave	4	10.845	2.17–19.51	20.03	453.55	3	0.000	99.3
	ND	–	–	–	–	–	–	–	–
	Overall	20	9.235	7.7–10.76	100	5619.44	19	0.000	99.7

comparing with our results, it is obvious that irrigated crops with tube well and river water showed the lower PTEs concentration. In another study, the concentration of Zn, Cu, Cd, Ni, Pb, and Cr in tomato irrigated with freshwater was reported as 27.5 mg/kg, 10, 0.072, 0.26 mg/kg, 0.16, and 0.42 mg/kg, respectively(Demir & Sahin, 2017).

As the electrical conductivity of wastewater increases, PTEs solubility increased and subsequently, their transfer (bioavailability) to plants could be enhanced (Chaoua et al., 2018). The high concentration of PTEs in the tomato and onion in the current study can be associated with a high concentration of the PTEs in wastewater that used for irrigation. Therefore, wastewater composition, or in other words, its characteristics can directly affect the transfer and further accumulation of PTEs in crops. The wastewater characteristics can be varied depending on source type (domestic, industrial or both) and treatment process used (Ahmad et al., 2018; Khanum et al., 2017; Khawla et al., 2019; Leblebici & Kar, 2018; Nikaido et al., 2010). Generally, industrial wastewater has a higher load of PTEs than municipal wastewater that relatively they can distribute them to the environment in a larger amount. The type and efficiency of applied technology in wastewater treatment are also important. Clearly, higher levels of PTEs removal can be achieved using modern and high-efficiency treatment units (Inyinbor, Bello, Oluyori, Inyinbor, & Fadiji, 2019; Rai et al., 2019; Verma, Agrawal, & Sagar, 2015). The findings of an investigation underlined that Pb, Ni, and Cd concentration in three vegetables (turnip, radish, and brassica) were increased by using untreated textile industry effluents (Rehman & Bhatti, 2008). Moreover, due to the higher resistance of PTEs (low chemical reactivity), frequency and duration of irrigation can pose incremental effects on the concentration of PTEs in irrigated crops (Mahmood & Malik, 2014). Based on the results of Solís et al. (2005) longer irrigation with wastewater can be resulted in higher levels Organic total content and consequently increasing in PTEs bioavailability (Solís et al., 2005).

3.4. Risk assessment

The measured non-carcinogenic risk due to ingestion of PTEs via consumption of onion and tomato irrigated wastewater in various countries was presented in Table 2s and 3s. The THQ values for both consumer groups in all investigated countries were calculated as higher than 1 representing a considerable health risk for them (EPA, 1989; EPA, 2011). Similar to previously conducted a health risk assessment (Fakhri et al., 2018; Ghasemidehkordi et al., 2018; Shahrbabki et al., 2018; Yousefi et al., 2018), THQ in the children due to lower BW was 4.78 times higher than adults. Therefore, children are at higher health risk (Nazaroff & Alvarez-Cohen, 2001; Razzaghi et al., 2018; Tajdaroranj et al., 2018). The dietary pattern of vegetables (onion and tomato) consumption, per capita consumption of vegetables and concentration of PTEs in soil and wastewater used to in the irrigation of vegetables are

Table 2
Meta-analysis of potentially toxic element (PTE) concentrations of onion samples irrigated wastewater based on vegetable part.

(PTEs)	Vegetable part	Number of studies	ES (mg/Kg-dry weight)[a]	(95% CI)	Weight	Heterogeneity			
						Statistic	df	*P* value	I^2 (%)
Pb	Edible	13	19.2	16.96–21.44	81.25	1.10E+05	12	0	100
	ND	1	34.26	32.81–35.7	6.18	0	0	–	–
	Leave	2	6.465	3.79–16.72	12.57	213.22	1	0	99.5
	Overall	16	18.54	16.49–20.57	100	1.10E+05	15	0	100
Cd	Edible	8	0.18	0.12–0.23	98.7	226.4	7	0	96.9
	ND	1	11.49	9.99–12.98	0.25	0	0	–	–
	Leave	1	0.034	0.69–0.75	1.05	0	0	–	–
	Overall	10	0.238	0.16–0.31	100	450.14	9	0	98
Cu	Edible	10	15.21	11.1–19.3	76.32	4829.2	9	0	99.8
	ND	1	17.57	17.36–17.77	7.94	0	0	–	–
	Leave	2	11.98	10.41–34.36	15.74	350.85	1	0	99.7
	Overall	13	14.9	9.86–19.94	100	25,306.15	12	0	100
Fe	Edible	7	44.17	41.14–47.19	98.14	8.36	6	0.213	28.2
	ND	–	–	–	–	–	–	–	–
	Leave	3	10.07	19.36–39.51	1.86	0.51	2	0.776	0
	Overall	10	43.09	39.04–47.12	100	14.16	9	0.117	36.4
Cr	Edible	7	1.218	0.17–2.26	73.68	9.30E+05	6	0	100
	ND	1	46.41	45.41–47.4	13.27	0	0	–	–
	Leave	2	1.438	0.78–3.65	13.05	1.35	1	0.245	25.9
	Overall	10	7.245	6.34–8.14	100	9.40E+05	9	0	100
Zn	Edible	11	32.51	27.45–37.55	73.32	15,186.09	10	0	99.9
	ND	1	125	121.9–128	6.85	0	0	–	–
	Leave	3	9.202	8.15–26.56	19.83	79.15	2	0	97.5
	Overall	15	34.3	29.22–39.36	100	21,406.26	14	0	99.9
Ni	Edible	8	10.34	3.11–17.55	72.91	4686.37	7	0	99.9
	ND	1	47.39	43.68–51.09	8.88	0	0	–	–
	Leave	2	0.991	0.83–2.81	18.21	2.27	1	0.132	56
	Overall	11	11.92	5.67–18.16	100	5265.82	10	0	99.8

[a] Effect size (ES).

among most important factors in exposed health risk due to ingestion of PTEs via consumption of onion and tomato (Fakhri, Khaneghah, et al., 2018; Ghasemidehkordi et al., 2018; Yousefi et al., 2018). However, the high value of THQ in the current investigation can be associated with a high concentration of PTEs in onion and tomato due to irrigation with (Cherfi et al., 2015; Safi & Buerkert, 2011; Zhao, Jin, Shen, & Guo, 2011b).

4. Conclusions

In the current study, the concentration of PTEs in the onion and tomato vegetables irrigated by wastewater was meta-analyzed, and non-carcinogenic health risk in the adults and children was assessed. Some factors such as plant properties, the characteristics of PTEs, as well as physicochemical characteristics of irrigating wastewater and soil characteristics play important roles in the uptake of PTEs by plants, particularly onion and tomato. According to findings, the minimum and maximum concentrations of PTEs in the onion and tomato was related to Cd and Fe, respectively, also the concentration of PTEs in the edible part of onion was higher than leaves. Dislike onion, the aggregation of PTEs in the edible part of tomato was lower than other parts. The health risk assessment shows that consumers of all ages are at considerable non-carcinogenic risk due to the existence of PTEs in the onion and tomato vegetable irrigated by wastewater (THQ > 1). The results of our study proved that irrigation of vegetable by wastewater could be converted vegetables from nutrient food to a hazardous food. Therefore, further control among the wastewater treatment and during irrigation of vegetable wastewater regarding the concentration of PTEs is highly recommended. Furthermore, preventive approaches in order to limit of untreated wastewater usages in irrigation of vegetables such as onion and tomato should be considered by governments as well as farmers.

Acknowledgment

The authors would like to thank the student research committee at Shahid Beheshti University of Medical Sciences for the financial grants of this study (1397/68632).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2019.108518.

References

Ahmad, K., Ashfaq, A., Khan, Z. I., Bashir, H., Sohail, M., Mehmood, N., & Dogan, Y. (2018). Metal accumulation in Raphanus sativus and Brassica rapa: An assessment of potential health risk for inhabitants in Punjab, Pakistan. *Environmental Science and Pollution Research, 25*, 16676–16685.
Ahmad, K., Khan, Z. I., Ashfaq, A., Ashraf, M., Akram, N. A., Sher, M., ... Cazzato, E. (2017). Uptake of hazardous elements by spring onion (Allium fistulosum L.) from soil irrigated with different types of water and possible health risk. *Environmental Earth Sciences, 76*, 322.
Alemu, T., Mekonnen, A., & Leta, S. (2017a). Integrated tannery wastewater treatment for effluent reuse for irrigation: Encouraging water efficiency and sustainable development in developing countries. *Journal of Water Process Engineering, 5*, 1–20.
Alemu, T., Mekonnen, A., & Leta, S. (2017b). Integrated tannery wastewater treatment for effluent reuse for irrigation: Encouraging water efficiency and sustainable development in developing countries. *Journal of Water Process Engineering, 30*, 100514.
Al-Lahham, O., El Assi, N. M., & Fayyad, M. (2007). Translocation of heavy metals to tomato (Solanum lycopersicom L.) fruit irrigated with treated wastewater. *Scientia Horticulturae, 113*, 250–254.
Amin, N. U., Hussain, A., Alamzeb, S., & Begum, S. (2013). Accumulation of heavy metals in edible parts of vegetables irrigated with waste water and their daily intake to adults and children, district Mardan, Pakistan. *Food Chemistry, 136*, 1515–1523.
Anwar, S., Nawaz, M. F., Gul, S., Rizwan, M., Ali, S., & Kareem, A. (2016). Uptake and distribution of minerals and heavy metals in commonly grown leafy vegetable species irrigated with sewage water. *Environmental Monitoring and Assessment, 188*, 541.
Becerra-Castro, C., Lopes, A. R., Vaz-Moreira, I., Silva, E. F., Manaia, C. M., & Nunes, O. C. (2015). Wastewater reuse in irrigation: A microbiological perspective on implications in soil fertility and human and environmental health. *Environment International, 75*, 117–135.
Berry, W., Wallace, A., & Lunt, O. J. H. (1980). Utilization of municipal wastewater for

the culture of horticultural crops. *HortScience, 15*, 169–171.
Bunani, S., Yörükoğlu, E., Yüksel, Ü., Kabay, N., Yüksel, M., & Sert, G. (2015). Application of reverse osmosis for reuse of secondary treated urban wastewater in agricultural irrigation. *Desalination, 364*, 68–74.
Canet, W. (1988). Determination of the moisture content of some fruits and vegetables by microwave heating. *Journal of Microwave Power and Electromagnetic Energy, 23*, 231–235.
Cao, J., Liang, P., & Liu, R. (2008). Determination of trace lead in water samples by continuous flow microextraction combined with graphite furnace atomic absorption spectrometry. *Journal of Hazardous Materials, 152*, 910–914.
Chaoua, S., Boussaa, S., El Gharmali, A., & Boumezzough, A. (2018). 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*. https://doi.org/10.1016/j.jssas.2018.02.003.
Chaudhry, F., Sharif, M., Latif, A., & Qureshi, R. J. P. (1973). Zinc-copper antagonism in the nutrition of rice (Oryza sativa L.). *Plant and Soil, 38*, 573–580.
Cherfi, A., Achour, M., Cherfi, M., Otmani, S., & Morsli, A. (2015). Health risk assessment of heavy metals through consumption of vegetables irrigated with reclaimed urban wastewater in Algeria. *Process Safety and Environmental Protection, 98*, 245–252.
Cheshmazar, E., Arfaeinia, H., Karimyan, K., Sharafi, H., & Hashemi, S. E. (2018). Dataset for effect comparison of irrigation by wastewater and ground water on amount of heavy metals in soil and vegetables: Accumulation, transfer factor and health risk assessment. *Data in Brief, 18*, 1702–1710.
Demir, A. D., & Sahin, U. (2017). Effects of different irrigation practices using treated wastewater on tomato yields, quality, water productivity, and soil and fruit mineral contents. *Environmental Science and Pollution Research, 24*, 24856–24879.
Dong, W. Q. Y., Cui, Y., & Liu, X. (2001). Instances of soil and crop heavy metal contamination in China. *Soil and Sediment Contamination, 10*, 497–510.
El-Kady, A. A., & Abdel-Wahhab, M. A. (2018). Occurrence of trace metals in foodstuffs and their health impact. *Trends in Food Science & Technology, 75*, 36–45.
EPA (1993). Reference Dose (RfD): Description and Use in Health Risk Assessments. https://www.epa.gov/iris/reference-dose-rfd-description-and-use-health-risk-assessments.
EPA (2000). *Risk-based concentration table.* Philadelphia PA: United States Environmental Protection Agency, Washington DC.
EPA (2011). *Exposure factors handbook* (2011 ed.). (EPA/600/R-09).
EPA (2018). IRIS Advanced Search. https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=pretilachlor.
EPA, A. (1989). Risk assessment guidance for superfund. *Human Health Evaluation Manual. Volume I* ((part a). EPA/540/1-89/002).
Fakhri, Y., Ghorbani, R., Taghavi, M., Keramati, H., Amanidaz, N., Moradi, B., ... Khaneghah, A. M. (2019). Concentration and prevalence of aflatoxin M1 in human breast Milk in Iran: Systematic review, meta-analysis, and carcinogenic risk assessment: A review. *Journal of Food Protection, 82*, 785–795.
Fakhri, Y., Khaneghah, A. M., Conti, G. O., Ferrante, M., Khezri, A., Darvishi, A., ... Keramati, H. (2018). Probabilistic risk assessment (Monte Carlo simulation method) of Pb and cd in the onion bulb (Allium cepa) and soil of Iran. *Environmental Science and Pollution Research, 25*, 30894–30906.
Fakhri, Y., Saha, N., Ghanbari, S., Rasouli, M., Miri, A., Avazpour, M., ... Mousavi Khaneghah, A. (2018). Carcinogenic and non-carcinogenic health risks of metal(oid)s in tap water from Ilam city, Iran. *Food and Chemical Toxicology, 118*, 204–211.
Falahi-Ardakani, A., Corey, K., & Gouin, F. J. H. (1988). Influence of pH on cadmium and zinc concentrations of cucumber grown in sewage sludge. *HortScience, 23*, 1015–1017.
Fathabad, A. E., Shariatifar, N., Moazzen, M., Nazmara, S., Fakhri, Y., Alimohammadi, M., ... Mousavi Khaneghah, A. (2018). Determination of heavy metal content of processed fruit products from Tehran's market using ICP- OES: A risk assessment study. *Food and Chemical Toxicology, 115*, 436–446.
Fazeli, M. S., Sathyanarayan, S., Satish, P., Muthanna, L. J. E. G., & Sciences, W. (1991). Effect of paper mill effluents on accumulation of heavy metals in coconut trees near Nanjangud, Mysore District, Karnataka, India. *Environmental Geology and Water Sciences, 17*, 47–50.
Ghasemidehkordi, B., Malekirad, A. A., Nazem, H., Fazilati, M., Salavati, H., Shariatifar, N., ... Mousavi Khaneghah, A. (2018). Concentration of lead and mercury in collected vegetables and herbs from Markazi province, Iran: A non-carcinogenic risk assessment. *Food and Chemical Toxicology, 113*, 204–210.
Gupta, N., Khan, D., & Santra, S. C. (2012). Heavy metal accumulation in vegetables grown in a long-term wastewater-irrigated agricultural land of tropical India. *Environmental Monitoring and Assessment, 184*, 6673–6682.
Gupta, N., Khan, D. K., & Santra, S. C. (2008). An assessment of heavy metal contamination in vegetables grown in wastewater-irrigated areas of Titagarh, West Bengal, India. *Bulletin of Environmental Contamination and Toxicology, 80*, 115–118.
Gupta, S., Nayek, S., Saha, R. N., & Satpati, S. (2008). Assessment of heavy metal accumulation in macrophyte, agricultural soil, and crop plants adjacent to discharge zone of sponge iron factory. *Environmental Geology, 55*, 731–739.
Helgilibrary (2011). *Onion and tomato ingestion rate.* https://www.helgilibrary.com/indicators/onion-consumption-per-capita/india/1–3.
Higgins, J., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine, 21*, 1539–1558.
Higgins, J., White, I. R., & Anzures-Cabrera, J. (2008). Meta-analysis of skewed data: Combining results reported on log-transformed or raw scales. *Statistics in Medicine, 27*, 6072–6092.
Higgins, J. P., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions.* John Wiley & Sons.
Hossain, M. K., Strezov, V., & Nelson, P. F. (2015). Comparative assessment of the effect of wastewater sludge biochar on growth, yield and metal bioaccumulation of cherry tomato. *Pedosphere, 25*, 680–685.
Inyinbor, A. A., Bello, O. S., Oluyori, A. P., Inyinbor, H. E., & Fadiji, A. E. (2019). Wastewater conservation and reuse in quality vegetable cultivation: Overview, challenges and future prospects. *Food Control, 98*, 489–500.
Jan, F. A., Ishaq, M., Khan, S., Ihsanullah, I., Ahmad, I., & Shakirullah, M. (2010). A comparative study of human health risks via consumption of food crops grown on wastewater irrigated soil (Peshawar) and relatively clean water irrigated soil (lower Dir). *Journal of Hazardous Materials, 179*, 612–621.
Khan, M. J., Jan, M. T., Farhatullah Khan, N. U., Arif, M., Perveen, S., Alam, S., & Jan, A. U. (2011). The effect of using waste water for tomato. *Pakistan Journal of Botany, 43*, 1033–1044.
Khaneghah, A. M., Fakhri, Y., Abdi, L., Coppa, C. F. S. C., Franco, L. T., & de Oliveira, C. A. F. (2019). The concentration and prevalence of ochratoxin A in coffee and coffee-based products: A global systematic review, meta-analysis and meta-regression. *Fungal Biology*. https://doi.org/10.1016/j.funbio.2019.05.012.
Khaneghah, A. M., Fakhri, Y., Raeisi, S., Armoon, B., & Sant'Ana, A. S. (2018). Prevalence and concentration of ochratoxin A, zearalenone, deoxynivalenol and total aflatoxin in cereal-based products: A systematic review and meta-analysis. *Food Chemical and Toxicology, 118*, 830–848.
Khaneghah, A. M., Fakhri, Y., & Sant'Ana, A. S. (2018). Impact of unit operations during processing of cereal-based products on the levels of deoxynivalenol, total aflatoxin, ochratoxin a, and zearalenone: A systematic review and meta-analysis. *Food Chemistry, 268*, 611–624.
Khaneghah, A. M., Kamani, M. H., Fakhri, Y., Coppa, C. F. S. C., de Oliveira, C. A. F., & Sant'Ana, A. S. (2019). Changes in masked forms of deoxynivalenol and their co-occurrence with culmorin in cereal-based products: A systematic review and meta-analysis. *Food Chemistry, 294*, 587–596.
Khanum, K., Baqar, M., Qadir, A., Mumtaz, M., Tahir, A., Jamil, N., & Mahmood, A. (2017). Heavy metal toxicity and human health risk surveillances of wastewater irrigated vegetables in Lahore District, Pakistan. *Carpathian Journal of Earth and Environmental Sciences, 12*, 403–412.
Khawla, K., Besma, K., Enrique, M., & Mohamed, H. (2019). Accumulation of trace elements by corn (Zea mays) under irrigation with treated wastewater using different irrigation methods. *Ecotoxicology Environmental Safety, 170*, 530–537.
Koduru, J. R., & Lee, K. D. (2014). Evaluation of thiosemicarbazone derivative as chelating agent for the simultaneous removal and trace determination of Cd (II) and Pb (II) in food and water samples. *Food Chemistry, 150*, 1–8.
Kummu, M., Guillaume, J. H. A., de Moel, H., Eisner, S., Flörke, M., Porkka, M., ... Ward, P. J. (2016). The world's road to water scarcity: Shortage and stress in the 20th century and pathways towards sustainability. *Scientific Reports, 6*, 38495.
Kuroki, T., Watanabe, Y., Teranishi, H., Izumiyama, S., Amemura-Maekawa, J., & Kura, F. (2017). Legionella prevalence and risk of legionellosis in Japanese households. *Epidemiology and Infection, 145*, 1398–1408.
Leblebici, Z., & Kar, M. (2018). Heavy metals accumulation in vegetables irrigated with different water sources and their human daily intake in Nevsehir. *Journal of Agricultural Science Technology, 20*, 401–415.
Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., ... Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLoS Medicine, 6*, e1000100.
Lingamdinne, L., Kim, I.-S., Ha, J.-H., Chang, Y.-Y., Koduru, J., & Yang, J.-K. (2017). Enhanced adsorption removal of Pb (II) and Cr (III) by using nickel ferrite-reduced graphene oxide nanocomposite. *Metals, 7*, 225.
Lingamdinne, L. P., Koduru, J. R., Choi, Y.-L., Chang, Y.-Y., & Yang, J.-K. (2016). Studies on removal of Pb (II) and Cr (III) using graphene oxide based inverse spinel nickel ferrite nano-composite as sorbent. *Hydrometallurgy, 165*, 64–72.
Lyu, S., Chen, W., Zhang, W., Fan, Y., & Jiao, W. (2016). Wastewater reclamation and reuse in China: Opportunities and challenges. *Journal of Environmental Sciences, 39*, 86–96.
Mahmood, A., & Malik, R. N. (2014). Human health risk assessment of heavy metals via consumption of contaminated vegetables collected from different irrigation sources in Lahore, Pakistan. *Arabian Journal of Chemistry, 7*, 91–99.
Mateo-Sagasta, J., Raschid-Sally, L., & Thebo, A. (2015). Global wastewater and sludge production, treatment and use. In P. Drechsel, M. Qadir, & D. Wichelns (Eds.). *Wastewater: Economic asset in an urbanizing world* (pp. 15–38). Dordrecht: Springer Netherlands.
Mitch, M. L. (2002). Phytoextraction of toxic metals: A review of biological mechanism. *Journal of Environmental Quality, 31*, 109–120.
Nair, J., Levitan, J., & Oyama, N. (2008). Zinc and copper uptake by silver beet grown in secondary treated effluent. *Bioresource Technology, 99*, 2537–2543.
Najafi, P. (2006). Effects of using subsurface drip irrigation and treated municipal waste water in irrigation of tomato. *Pakistan Journal of Biological Sciences, 9*, 2672–2676.
Nayek, S., Gupta, S., & Saha, R. N. (2010). Metal accumulation and its effects in relation to biochemical response of vegetables irrigated with metal contaminated water and wastewater. *Journal of Hazardous Materials, 178*, 588–595.
Nazaroff, W., & Alvarez-Cohen, L. (2001). *Environmental engineering science.* New York: John Wiley and Sons Inc1–20.
Nikaido, M., Tonani, K. A. A., Julião, F. C., Trevilato, T. M. B., Takayanagui, A. M. M., Sanches, S. M., ... Segura-Muñoz, S. I. (2010). Analysis of Bacteria, parasites, and heavy metals in lettuce (Lactuca sativa) and rocket salad (Eruca sativa L.) irrigated with treated effluent from a biological wastewater treatment plant. *Biological Trace Element Research, 134*, 342–351.
Njuguna, S. M., Makokha, V. A., Yan, X., Gituru, R. W., Wang, Q., & Wang, J. (2019). Health risk assessment by consumption of vegetables irrigated with reclaimed waste water: A case study in Thika (Kenya). *Journal of Environmental Management, 231*, 576–581.

Peralta-Videa, J. R., Lopez, M. L., Narayan, M., Saupe, G., & Gardea-Torresdey, J. (2009). The biochemistry of environmental heavy metal uptake by plants: Implications for the food chain. *The International Journal of Biochemistry & Cell Biology, 41*, 1665–1677.

Pintilie, L., Torres, C. M., Teodosiu, C., & Castells, F. (2016). Urban wastewater reclamation for industrial reuse: An LCA case study. *Journal of Cleaner Production, 139*, 1–14.

Prazeres, A. R., Rivas, J., Almeida, M. A., Patanita, M., Dôres, J., & Carvalho, F. (2016). Agricultural reuse of cheese whey wastewater treated by NaOH precipitation for tomato production under several saline conditions and sludge management. *Agricultural Water Management, 167*, 62–74.

Quan, H., & Zhang, J. (2003). Estimate of standard deviation for a log-transformed variable using arithmetic means and standard deviations. *Statistics in Medicine, 22*, 2723–2736.

Quist-Jensen, C. A., Macedonio, F., & Drioli, E. (2015). Membrane technology for water production in agriculture: Desalination and wastewater reuse. *Desalination, 364*, 17–32.

Rai, P. K., Lee, S. S., Zhang, M., Tsang, Y. F., & Kim, K.-H. (2019). Heavy metals in food crops: Health risks, fate, mechanisms, and management. *Environment International, 125*, 365–385.

Razzaghi, N., Ziarati, P., Rastegar, H., Shoeibi, S., Amirahmadi, M., Conti, G. O., ... Khaneghah, A. M. (2018). The concentration and probabilistic health risk assessment of pesticide residues in commercially available olive oils in Iran. *Food and Chemical Toxicology, 120*, 32–40.

Reddy, K. J., Kumar, J. R., Ramachandraiah, C., Thriveni, T., & Reddy, A. V. (2007). Spectrophotometric determination of zinc in foods using N-ethyl-3-carbazole-carboxaldehyde-3-thiosemicarbazone: Evaluation of a new analytical reagent. *Food Chemistry, 101*, 585–591.

Reddy, S. A., Reddy, K. J., Narayana, S. L., Sarala, Y., & Reddy, A. V. (2008). Synthesis of new reagent 2, 6-Diacetylpyridine Bis-4-Phenyl-3-Thiosemicarbazone (2, 6-DAPBPTSC): Selective, sensitive and extractive spectrophotometric determination of Co (II) in vegetable, soil, pharmaceutical and alloy samples. *Journal of the Chinese Chemical Society, 55*, 326–334.

Rehman, A., Bhatti, H. N., & Athar, H. (2008). Textile effluents affected seed germination and early growth of some winter vegetable crops: A case study. *Water, Air, and Soil Pollution, 198*, 155.

Rizzo, L., Fiorentino, A., Grassi, M., Attanasio, D., & Guida, M. (2015). Advanced treatment of urban wastewater by sand filtration and graphene adsorption for wastewater reuse: Effect on a mixture of pharmaceuticals and toxicity. *Journal of Environmental Chemical Engineering, 3*, 122–128.

Roh, H., Yu, M.-R., Yakkala, K., Koduru, J. R., Yang, J.-K., & Chang, Y.-Y. (2015). Removal studies of cd (II) and explosive compounds using buffalo weed biochar-alginate beads. *Journal of Industrial and Engineering Chemistry, 26*, 226–233.

Safi, Z., & Buerkert, A. (2011). *Heavy Metal and Microbial Loads in Sewage Irrigated Vegetables of Kabul, Afghanistan. 112*, 29–36.

Safi, Z., & Buerkert, A. (2011). Heavy metal and microbial loads in sewage irrigated vegetables of Kabul, Afghanistan. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 112*, 29–36.

Sarma, L. S., Kumar, J. R., Reddy, K. J., Thriveni, T., & Reddy, A. V. (2006). Studies of zinc (II) in pharmaceutical and biological samples by extractive spectrophotometry: Using pyridoxal-4-phenyl-3-thiosemicarbazone as chelating reagent. *Journal of the Brazilian Chemical Society, 17*, 463–472.

Semple, K. T., Doick, K. J., Jones, K. C., Burauel, P., Craven, A., & Harms, H. (2004). *Peer reviewed: Defining bioavailability and bioaccessibility of contaminated soil and sediment is complicated.* ACS Publications.

Shahrbabki, P. E., Hajimohammadi, B., Shoeibi, S., Elmi, M., Yousefzadeh, A., Conti, G. O., ... Khaneghah, A. M. (2018). Probabilistic non-carcinogenic and carcinogenic risk assessments (Monte Carlo simulation method) of the measured acrylamide content in Tah-dig using QuEChERS extraction and UHPLC-MS/MS. *Food and Chemical Toxicology, 118*, 361–370.

Solís, C., Andrade, E., Mireles, A., Reyes-Solís, I. E., García-Calderón, N., Lagunas-Solar, M. C., ... Flocchini, R. G. (2005). Distribution of heavy metals in plants cultivated with wastewater irrigated soils during different periods of time. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 241*, 351–355.

Tajdar-oranj, B., Shariatifar, N., Alimohammadi, M., Peivasteh-roudsari, L., Khaniki, G. J., Fakhri, Y., & Khaneghah, A. M. (2018). The concentration of heavy metals in noodle samples from Iran's market: Probabilistic health risk assessment. *Environmental Science and Pollution Research, 25*, 30928–30937.

Tarpani, R. R. Z., & Azapagic, A. (2018). Life cycle costs of advanced treatment techniques for wastewater reuse and resource recovery from sewage sludge. *Journal of Cleaner Production, 204*, 832–847.

Tran, Q. K., Schwabe, K. A., & Jassby, D. (2016). Wastewater reuse for agriculture: Development of a regional water reuse decision-support model (RWRM) for cost-effective irrigation sources. *Environmental Science & Technology, 50*, 9390–9399.

Turan, V., Khan, S. A., Mahmood ur, R., Iqbal, M., Ramzani, P. M. A., & Fatima, M. (2018). Promoting the productivity and quality of brinjal aligned with heavy metals immobilization in a wastewater irrigated heavy metal polluted soil with biochar and chitosan. *Ecotoxicology and Environmental Safety, 161*, 409–419.

Verma, P., Agrawal, M., & Sagar, R. (2015). Assessment of potential health risks due to heavy metals through vegetable consumption in a tropical area irrigated by treated wastewater. *Environment Systems Decisions, 35*, 375–388.

WHO (2002). *Safety evaluation of certain food additives and contaminants.* www.inchem.org/documents/jecfa/jecmono/v64je01.pdf*2*, World Health Organization1–20.

Xue, Z.-J., Liu, S.-Q., Liu, Y.-L., & Yan, Y.-L. (2012). Health risk assessment of heavy metals for edible parts of vegetables grown in sewage-irrigated soils in suburbs of Baoding City, China. *Environmental Monitoring and Assessment, 184*, 3503–3513.

Yousefi, M., Shemshadi, G., Khorshidian, N., Ghasemzadeh-Mohammadi, V., Fakhri, Y., Hosseini, H., & Mousavi Khaneghah, A. (2018). Polycyclic aromatic hydrocarbons (PAHs) content of edible vegetable oils in Iran: A risk assessment study. *Food and Chemical Toxicology, 118*, 480–489.

Zavadil, J. (2009). The effect of municipal wastewater irrigation on the yield and quality of vegetables and crops. *Soil and Water Research, 4*, 91–103.

Zhao, J. Y., Jin, X. L., Shen, Z. L., & Guo, H. M. (2011b). *Accumulation and risk assessment of heavy metals in vegetables in wastewater irrigation areas, Advanced Materials Research.* Trans Tech Publ527–531.

Zou, S., & He, Z. (2016). Enhancing wastewater reuse by forward osmosis with self-diluted commercial fertilizers as draw solutes. *Water Research, 99*, 235–243.