Contamination of vegetables with heavy metals across the globe: hampering food security goal

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Abstract Food Security is a multifaceted aspect covering nutrition, availability, sufficiency, accessibility and safety. Millennium Development Goals as framed by United Nations focused to attain food security for all. The biggest hindrance in attaining food security was less productivity due to lack of enough resources. In order to increase the availability and produce sufficient food, malpractices like growing food on contaminated land or using untreated wastewater for irrigation came into play. Such practices have led to the transfer of heavy metals, pathogens and other harmful toxins to food crops. Various studies across the world have documented high concentration of heavy metals in vegetable crops. Root tubers and succulent stems are hyperaccumulators of heavy metals and thus tend to pose health hazard to the consuming population. In many instances the content of toxic metals in vegetables is much beyond permissible limits. Hazard quotient assessment in various studies has shown that consumption of these vegetables can be toxic to both adults and children. So, the question arises are we really attaining the global food security? There is a need to find a solution to produce sufficient, safe and nutritious food for the civilization so as to meet the goal of “zero hunger”.

Keywords Food security · Heavy metals · Vegetables · Hyperaccumulators

Introduction

During FAO et al. (2015), 182 countries committed to eradicate hunger and reduce the undernourished population by 2015. The policy planning throughout the world is focused to fight the hunger stress and provide the major fundamental right to each individual alive. In 2000, members of the United Nations collectively formulated Millennium Development Goals which targeted the reduction of chronically hungry population to half (FAO et al. 2015). As we observe the history behind the development of concept of food security we realize that this concept originated in 1970s due to the social, economic and climatic circumstances. Occurrences of famine, lack of resources and economic and social disparity were identified as reasons for the macro-nutrient deficient population. Definition of food security has evolved from the concept of availability, accessibility and utility to stability, safety and nutritional quality. The multifaceted concept of food security is depicted in Fig. 1.

Food security is multi-faceted idea and is expected to be attained when “*everyone* (each individual beyond any racial or economic discrimination) *and always*” (throughout the year without being affected by the seasons and climatic factors) has *access* (no hindrance of transportation or distribution) to “*sufficient* (supplying all macro and micro nutrients required) and *safe*” (free from contaminants, pathogens and/or toxins) food to lead healthy and active life (FAO and WHO 2011; FAO et al. 2015). So, mere availability of food doesn’t fulfill the concept of food security. It is important to have a safe and balanced diet having all the nourishment. Vegetables are thus the important portion of platter because of various nutritional benefits. But, many reports published in past decade have depicted the health hazard associated with consumption of

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Fig. 1 Multifaceted concept of food security

vegetables in various parts of the world. The health hazard associated with vegetables is mainly due to high content of toxic metals present in these crops (Jolly et al. 2013; Sharma et al. 2016a).

Vegetables: nutrition or poison?

Consumption of vegetables in both raw and cooked forms is an essential part of diet throughout the world. Vegetables not only provide the micro-nutrients and trace elements but also act as buffering agents in the process of digestion (Jolly et al. 2013). Vegetables add colour to the plate and thus also trigger the salivating glands. It has been reported that the consumption of vegetables in cooked or raw form, significantly lower cancer instances especially, gastric cancers. According to WHO/FAO, consumption of 400 g of vegetables by an individual per day is essential to combat various cardiac problems, cancer and obesity (Kanungsukkasem et al. 2009; National Institute of Nutrition 2011). WHO (2003) claims that globally, 2.7 million lives can be saved annually by consuming sufficient vegetables. Various parts of plants including inflorescences, leaves, fruits, tubers are consumed as the vegetable. A closer view of literature suggests that the average consumption of vegetables per capita per day in India, Mali and Pakistan is mere 100 g or less, while in Australia, Europe and USA is 300 g (Kanungsukkasem et al. 2009). Low consumption of vegetables is attributed to less availability or less production causing the increase in price of food commodities.

Crop yield is reliant mainly upon natural resource availability and climatic conditions. Being micro scale conditions, climatic factors generally do not cause large scale impact on production. Thus, resource availability i.e. fertile land and sufficient water for irrigation becomes the major determinant for crop yield. If we consider the availability of these resources, it is to be noted that per capita availability of arable land in 1960 was 0.45 ha

(approx.) which was further reduced to 0.25 ha in 2009 (Bruinsma 2009). Also, decrease in availability of fresh water because of increasing needs, injudicious use and climatic changes has also drastically affected agricultural yield. But, despite lack of availability of resources United Nations admitted that the implementation of the Millennium Development Goals has resulted in 50% decrease in the undernourished population in the developing nations from 1990 to 2015 (United Nations 2015). The question arises; “how this was achieved?”—the use of improper agricultural practices, over use of agrochemicals, cultivation on contaminated land which is not suitable for food production and utilizing wastewater for irrigation were the steps that were adopted to increase the crop yield and availability. The present review summarizes effects of haphazard planning to increase food production in order to attain Millennium development goals.

Irrigation with wastewater

Water is considered as an elixir of life, the survival and sustenance of life is dependent upon water. Although, 70% of our planet is water, only 3% of that is fresh water and a major portion of this 3% is frozen in glaciers, leading to deprivation of water for 1.1 million people (WWF 2016). Thus, shortage of irrigation water is in many parts of the world, specifically in arid and semi-arid regions. Use of treated wastewater is projected to be an alternative for irrigation in these areas (Angelakis et al. 2005). Utilizing wastewater for irrigation is considered to be helpful in recycling nutrients and water to the soil as the presence of organic content in wastewater can increase the fertility of some kind of soils. However, higher content of organic matter can lead to decrease in soil porosity and clogging of irrigation equipment. Wastewater can also add moderate levels of salts and nutrients like N, P and K to soil (Mahmoud et al. 2003). Using wastewater generated from various sources for irrigation can prevent problems associated with discharge of wastewater on surface water bodies which lead to depletion of oxygen and eutrophication (World Bank 2010). Adding human waste or wastewater generated from household to the agricultural farms isn't a new process; this reuse strategy is documented to be about 4000 years old (Angelakis et al. 2005). During past few decades, the shortage of water resources and increase in food demand has led to a sharp increase in usage of wastewater as irrigation water source.

80–90% of water supplied to household, commercial and industrial places is not consumed but is added back to the environment as wastewater or sewage water (Asano et al. 2007). Van der Hoek (2004) identified that wastewater is mostly generated from urban activities which can be combination of domestic effluent (containing human feces,

kitchen and bathroom wastewater), industrial discharge (may contain hazardous chemicals), commercial, institutional and hospital discharge. In most of the developing and under-developed countries there is direct usage of wastewater for agriculture i.e. untreated and raw wastewater is used for irrigation (WHO 2006). Across the world about 20 million hectares of land producing 10% of crop is irrigated with untreated wastewater (Jiménez and Asano 2008). The untreated wastewater can contain disease causing microbes, certain toxins, drugs and toxic metals among other things. Thus, the risk associated with consumption of food growing in areas irrigated with wastewater is extremely high (Singh et al. 2009). The transfer of pathogens and diseases through vegetable consumption is noticed and documented (World Bank 2010). Also, a major issue of transfer of toxic chemicals and metals by consumption of wastewater irrigated food crops is widely reported (Singh et al. 2009; Boamponsem et al. 2012; Orisakwe et al. 2012b; Jolly et al. 2013).

Apart from water, the other resource required for agriculture is land. Since, there is a less availability of arable land; the cultivation of agricultural crops is carried out in areas not suitable for cultivation, as they are either contaminated or in the vicinity of industrial areas (Luo et al. 2011).

Cultivation on contaminated land

Increasing pace of urbanization and commercialization has led to a decrease in per capita availability of arable land across the world. The cultivation of food crops on contaminated land is being carried out throughout the world (Chove et al. 2006; Luo et al. 2011). Cultivation on contaminated sites like mining sites, landfill sites, sites near industries etc. led to accumulation of toxins in the plants which thus enter food chain (Harmanescu et al. 2011). Across the world, many studies are carried out to estimate the content of heavy metals in the soil samples of contaminated sites and their accumulation in the plants grown on those sites.

Heavy metals present in soil are considered to be the major cause of the genotoxic nature of soil. The soil of contaminated areas is known to be genotoxic for the plants and produces many stress responses in plants growing in those areas. As a result of this practice, the heavy metals are taken up and accumulated in food crops and are thus transferred to the food chain (Harmanescu et al. 2011).

Heavy metals in soil

Soil is an important medium for the sustenance of life. It acts as a sink for nutrients and provides a medium for the completion of various biogeochemical cycles. As discussed,

heavy metals are added to soil through natural weathering of rocks, discharge of polluted waste and wastewater on soil, deposition from atmosphere etc. The subtle danger related to presence of these metals in soil lies in their being genotoxic/mutagenic.

High content of heavy metals in agricultural soil in many parts of the world is reported (Zhuang et al. 2009). Irrigation of agricultural land of Central Punjab Province of Pakistan with wastewater was reported to increase the buildup of toxic metals such as nickel (Ni), copper (Cu), chromium (Cr), cadmium (Cd) and cobalt (Co) in the soil samples. In Dar es Salaam City, Tanzania, the concentration of lead in soil samples was reported to be 22.85 mg/kg, the maximum concentration of chromium in soil samples of the area was 502.33 mg/kg and that of copper was 21.073 mg/kg. Also, it was reported that the content of heavy metal was highest in the top layer and decreased downwards (Mwegoha and Kihampa 2010). Singh et al. (2009) estimated the effect of wastewater irrigation on the agricultural crops and reported increase in bioavailability of heavy metals. Also, they found that availability of metals to plants was negatively correlated to the pH of soil. The most abundant metal was manganese in wastewater irrigated sites followed by zinc (Zn), copper, lead and chromium (Singh et al. 2009). In a study carried out at Zimbabwe, effects of long term irrigation with wastewater were estimated on maize crop. The study showed that the concentration of copper, zinc, cadmium, nickel and chromium in soils was more than the permissible limits. In another study carried out in Bangalore city of India, it was found that the soil receiving the sewage water had maximum concentration of chromium followed by lead, nickel and cadmium. In a fly ash contaminated site near thermal power plant in Uttar Pradesh, India concentration of cadmium was found to be maximum followed by iron, nickel and lead (Singh et al. 2010). In Dongguan City, Guangdong, China the concentrations of copper (105.60 mg/kg), zinc (169.50 mg/kg), nickel (57.46 mg/kg), lead (137.20 mg/kg), cadmium (0.67 mg/kg) and mercury (Hg) (1.01 mg/kg) was reported to be much higher than background levels. In another study carried out across the Xiangjiang river, China concentration of Cd, Pb, Cu, Zn and Ni was found to be higher than the background levels (Wang et al. 2008). In Baoding City, China the sewage water irrigated soil had significantly higher concentration of Zn (153.77 mg/kg), Pb (38.35 mg/kg), Cu (35.06 mg/kg), Ni (29.81 mg/kg), and Cd (0.22 mg/kg) than the control soil (Xue et al. 2012). A study carried out in the industrial area of Dhaka, Bangladesh showed that the trend of heavy metal in soil ($\text{Fe} > \text{Zn} > \text{Ni} > \text{Cr} > \text{Pb} > \text{Cu} > \text{Cd}$) was almost similar to trend of heavy metals of sewage water ($\text{Fe} > \text{Cu} > \text{Zn} > \text{Cr} > \text{Pb} > \text{Ni} > \text{Cd}$) which was used for irrigation (Ahmad and Goni 2010). Significant heavy metal contamination (Ti, Pb, Cu, Zn, and Ni) of agricultural soil around a sulfuric acid

Table 1 Summary of some recent literature showing content of cadmium (mg/kg) in vegetable samples from some parts of the world

S. no.	Country	Location	Spinach	Coriander	Lettuce	Turnip	Radish	Carrot	Brinjal	Cabbage	References
1.	Bangladesh	Ruppur area, Pabna Distt, Bangladesh	< 0.06	n.d	n.d	n.d	0.65	< 0.06	< 0.06	n.d	Jolly et al. (2013)
2.	Bangladesh	Industrial areas, Dhaka, Bangladesh	n.d	n.d	n.d	n.d	n.d	n.d	2.91	2.05	Ahmad and Goni (2010)
3.	Bangladesh	Central market Rajshahi City, Bangladesh	n.d	n.d	n.d	n.d	1.178	n.d	1.388	n.d	Saha and Zaman (2013)
4.	Brazil	Sao Paulo State, Brazil	0.13	0.16	0.08	n.d	n.d	0.03	0.04	0.04	Guerra et al. (2012)
5.	China	Wastewater Irrigated, Tongzhou Distt, Beijing, China	0.75	n.d	> 0.9	0.78	0.9	n.d	n.d	0.4	Khan et al. (2008)
6.	China	Near Dabaoshan mine in Guangdong, China	3.8	n.d	4	2.9	n.d	n.d	n.d	1.8	Zhuang et al. (2009)
7.	China	Zhongxin (ZX), Near Dabaoshan Mine, China	n.d	n.d	0.33	0.28	0.13	0.38	0.28	0.21	Zhuang et al. (2008)
8.	China	Vicinity of industrial zone in Jiangsu, China	0.042	n.d	0.099	n.d	n.d	n.d	0.014	0.025	Cao et al. (2010)
9.	China	Zhejiang province, China	0.03	n.d	n.d	n.d	n.d	n.d	0.015	0.01	Huang et al. (2014)
10.	China	Near e-waste processing site, China	n.d	n.d	0.38	n.d	0.05	0.18	n.d	n.d	Luo et al. (2011)
11.	China	Beijing	0.023	n.d	n.d	n.d	0.037		0.062	0.020	Song et al. (2009)
12.	China	Wastewater Irrigated Beijing and Tianjin city cluster, China	n.d	n.d	0.49	n.d	0.2	n.d	n.d	0.19	Wang et al. (2012)
13.	Ethiopia	Laelay Wukro	n.d	n.d	0.30	n.d	n.d	n.d	n.d	0.20	Gebrekidan et al. (2013)
14.	Ethiopia	Addis Ababa, Ethiopia	n.d	n.d	0.66	n.d	n.d	n.d	n.d	1.8	Weldegebriel et al. (2012)
15.	Ghana	Ghana Market	n.d	n.d	0.08	n.d	n.d	0.03	n.d	0.15	Bempah et al. (2011)
16.	Greece	Industrial Area, North	0.67	n.d	0.67	n.d	n.d	0.5	n.d	0.4	Fytianos et al. (2001)
17.	India	Around sewage treatment plant, Varanasi	4	n.d	n.d	n.d	2.3	n.d	3.9	9.5	Singh et al. (2010)
18.	India	Soil waste disposal site, By Pass, Kolkata	0.37	n.d	n.d	n.d	n.d	n.d	0.51	0.073	Banerjee et al. (2010)
19.	India	Raichak, Parganas,	0.12	n.d	n.d	n.d	n.d	n.d	7.32	0.85	Banerjee et al. (2010)
20.	India	Ghatakpur, Kolkata	BDL	n.d	n.d	n.d	n.d	n.d	BDL	BDL	Banerjee et al. (2010)
21.	India	Wastewater Irrigated area, Titagarh, West bengal	14.58	14.05	13.38	n.d	17.79	n.d	n.d	n.d	Gupta et al. (2012)
22.	India	Vegetable market of Anand, Gujarat	n.d	18	n.d	n.d	n.d	6	8	n.d	Kumar et al. (2010)
23.	India	Wastewater irrigated site, Varanasi, India	0.39	n.d	n.d	n.d	0.38	n.d	n.d	0.56	Mishra and Tripathi (2008)

Table 1 continued

S. no.	Country	Location	Spinach	Coriander	Lettuce	Turnip	Radish	Carrot	Brinjal	Cabbage	References
24.	India	Industrial effluent irrigated Vadodara	4	3	n.d	n.d	25	n.d	5	n.d	Tiwari et al. (2011)
25.	Iran	Wastewater Irrigated, Shah-Re Iran	0.20	0.13	n.d	n.d	0.59	n.d	0.17	n.d	Bigdeli and Seilsepour (2008)
26.	Libya	Market Sites Misurata Area, Libya	0.27	n.d		n.d	n.d	0.12	n.d	n.d	Elbagermi et al. (2012)
27.	Morocco	Market, Morocco	0.0045	n.d	0.0079	n.d	n.d	0.0045	n.d	n.d	Bakkali et al. (2012)
28.	Pakistan	Effluent treated, Faislabad, Pakistan	0.061	0.062	0.049	n.d	0.051	n.d	n.d	0.073	Farooq et al. (2008)
29.	Pakistan	Gilgit, northern Pakistan	2.10	n.d	0.84	n.d	n.d	n.d	n.d	n.d	Khan et al. (2010)
30.	Pakistan	Wastewater irrigating zone, Lahore, Pakistan	0.14	0.37	n.d	n.d	n.d	0.09	n.d	n.d	Mahmood and Malik (2014)
31.	Pakistan	Wastewater Irrigated site, Peshawar, Pakistan	n.d	16.24	15.24	n.d	49.9	n.d	n.d	3.9	Perveen et al. (2012)
32.	Romania	Near Mining Areas, Romania	n.d	n.d	0.09	n.d	n.d	0.02	n.d	0.12	Gergen and Harmanescu (2012)
33.	Saudi Arabia	Urban areas, Dammam City	4.02	n.d	n.d	1.34	n.d	1.20	n.d	0.97	Ali and Al-Qahtani (2012)
34.	Saudi Arabia	Urban areas, Riyadh City, Saudi Arabia	4.13	n.d	n.d	1.29	n.d	1.43	n.d	1.34	Ali and Al-Qahtani (2012)
35.	Saudi Arabia	Urban areas, Tabouk City, Saudi Arabia	3.89	n.d	n.d	1.24	n.d	1.21	n.d	1.10	Ali and Al-Qahtani (2012)
36.	Saudi Arabia	Urban areas, Jazan City, Saudi Arabia	3.95	n.d	n.d	1.29	n.d	1.25	n.d	1.09	Ali and Al-Qahtani (2012)
37.	Spain	Market, Spain	0.0051	n.d	0.0019	n.d	n.d	0.0036	n.d	n.d	Bakkali et al. (2012)
38.	Spain	Southern Spain,	0.00511	n.d	0.0019	n.d	n.d	0.0018	n.d	n.d	Bakkali et al. (2012)
		Central Spain,	0.0081		–			0.0105			
		Northern Spain	0.0029		–			0.0016			
39.	Tehran	Wastewater Irrigated, South of Tehran	1.3	n.d	2.8	1.1	1.4	n.d	n.d	n.d	Harati et al. (2011)
40.	Turkey	Manisa, Turkey	0.024	n.d	0.005	n.d	n.d	n.d	n.d	n.d	Bagdatlioglu et al. (2010)

Permissible Limit: For Leafy Vegetables: 0.2 mg/kg; Fruits/Tubers: 0.1 mg/kg

n.d. not done, *BDL* below detection limits

factory was reported in Western Guangdong Province, China (Liu et al. 2012). In a study in Swat District, Pakistan contents of metals like, Cr, Cu, Mn, Ni and Zn in the soils were found to be correlated with the content of these metals in vegetables growing in those areas (Khan et al. 2013). In another study carried out in Beijing–Tianjin city cluster,

China, the concentrations of heavy metal in wastewater irrigated agricultural soil were found to be within permissible range (Wang et al. 2012). Among 149 samples studied from Shandong Province, China 22 samples were found to be contaminated with higher concentration of Cd, Ni, Cu, or Hg (Liu et al. 2011). More than 100% increase in metals like

Table 2 Summary of some recent literature showing content of lead (mg/kg) in vegetable samples from some parts of the world

S. no.	Country	Location	Spinach	Coriander	Lettuce	Turnip	Radish	Carrot	Brinjal	Cabbage	References
1.	Bangladesh	Ruppur area, Pabna Distt,	0.98	n.d	n.d	n.d	0.51	0.72	0.83	n.d	Jolly et al. (2013)
2.	Bangladesh	Industrial areas, Dhaka	n.d	n.d	n.d	n.d	n.d	n.d	11.97	22.09	Ahmad and Goni, (2010)
3.	Bangladesh	Central market Rajshahi City,	n.d	n.d	n.d	n.d	10.430	n.d	1.887	n.d	Saha and Zaman (2013)
4.	Brazil	Sao Paulo State	1.05	1.24	0.48	n.d	n.d	0.38	0.44	0.60	Guerra et al. (2012)
5.	China	Wastewater Irrigated, Tongzhou Distt, Beijing,	4.5	n.d	5.8	5.2	2.2	n.d	n.d	4	Khan et al. (2008)
6.	China	Near Dabaoshan mine in Guandong,	1.9	n.d	2.1	1.9	n.d	n.d	n.d	1.9	Zhuang et al. (2009)
7.	China	Zhongxin (ZX), Near Dabaoshan Mine	n.d	n.d	0.13	0.20	0.12	0.09	0.18	0.12	Zhuang et al. (2008)
8.	China	Vicinity of industrial zone in Jiangsu,	0.184	n.d	0.192	n.d	n.d	n.d	0.017	0.16	Cao et al. (2010)
9.	China	Jiangsu Province,	0.093	n.d	0.053	n.d	n.d	n.d	0.126	n.d	Hao et al. (2009)
10.	China	Zhejiang province,	0.06	n.d	n.d	n.d	n.d	n.d	0.02	0.02	Huang et al. (2014)
11.	China	Near e-waste processing site,	n.d	n.d	0.77	n.d	0.11	0.48	n.d	n.d	Luo et al. (2011)
12.	China	Beijing	0.061	n.d	n.d	n.d	0.440	n.d	0.367	0.286	Song et al. (2009)
13.	China	Wastewater Irrigated Beijing and Tianjin city cluster	n.d	n.d	0.9	n.d	0.2	n.d	n.d	0.59	Wang et al. (2012)
14.	Ghana	Mining Site	n.d	n.d	< 0.005	n.d	n.d	< 0.005	n.d	< 0.005	Boamponsem et al. (2012)
15.	Ghana	Ghana Market	n.d	n.d	0.56	n.d	n.d	0.16	n.d	0.43	Bempah et al. (2011)
16.	Greece	Industrial Area,	> 7	n.d	> 4	n.d	n.d	> 1	n.d	> 2	Fytianos et al. (2001)
17.	India	Across Musi River, Hyderabad	3.6	3.4	n.d	n.d	n.d	n.d	3.4	n.d	Chary et al. (2008)
18.	India	Urban area, Bangalore	149.5	75.5	n.d	n.d	n.d	n.d	n.d	n.d	Ramesh and Yogananda Murthy (2012)
19.	India	Durgapur Industrial Belt	n.d	58	n.d	n.d	n.d	n.d	25	n.d	Kisku et al. (2011)
20.	India	Around sewage treatment plant, Varanasi	15	n.d	n.d	n.d	12.5	n.d	15.5	10	Singh et al. (2010)
21.	India	Solid waste disposal site, By Pass Kolkata	16.57	n.d	n.d	n.d	n.d	n.d	14	5.14	Banerjee et al. (2010)
22.	India	Raichak, Parganas, Kolkata	14.72	n.d	n.d	n.d	n.d	n.d	7.32	13.19	Banerjee et al. (2010)

Table 2 continued

S. no.	Country	Location	Spinach	Coriander	Lettuce	Turnip	Radish	Carrot	Brinjal	Cabbage	References
23.	India	Ghatakpur, West Bengal	3.567	n.d	n.d	n.d	n.d	n.d	0.685	4.48	Banerjee et al. (2010)
24.	India	Wastewater Irrigated area, Titagarh, West Bengal	49.59	31.13	34.94	n.d	57.63	n.d	n.d	n.d	Gupta et al. (2012)
25.	India	Vegetable market of Anand town, Gujarat	n.d	152	n.d	n.d	n.d	78	111	n.d	Kumar et al. (2010)
26.	India	Wastewater irrigated site, Varanasi,	2.64	n.d	n.d	n.d	2.85	n.d	n.d	3.56	Mishra and Tripathi (2008)
27.	India	Industrial effluent irrigated Vadodara,	16	24	n.d	n.d	10	n.d	8	n.d	Tiwari et al. (2011)
28.	Iran	Wastewater Irrigated, Shah-Re Iran	2.57	1.35	n.d	n.d	0.75		1.43		Bigdeli and Seilsepour (2008)
29.	Libya	Market Sites in the Misurata Area,	0.32	n.d	n.d	n.d	n.d	0.21	n.d	n.d	Elbagermi et al. (2012)
30.	Morocco	Market, Morocco	0.0107	n.d	0.0598	n.d	n.d	0.0341	n.d	n.d	Bakkali et al. (2012)
31.	Nigeria	Sokoto	2.07	n.d	1.59	n.d	n.d	n.d	n.d	n.d	Sani et al. (2011)
32.	Nigeria	Maiduguri	4.67	n.d	5.88	n.d	n.d	n.d	n.d	n.d	Uwah et al. (2011)
33.	Pakistan	Effluent irrigated, Faislabad,	2.25	2.65	2.4	n.d	2.25	n.d	n.d	1.92	Farooq et al. (2008)
34.	Pakistan	Wastewater Irrigated, Distt Mardan	n.d	n.d	n.d	n.d	n.d	n.d	14.15	n.d	Amin et al. (2013)
35.	Pakistan	Tube-well Irrigated, Mardan Distt,	n.d	n.d	n.d	n.d	n.d	n.d	4.35	n.d	Amin et al. (2013)
36.	Pakistan	Gilgit, northern Pakistan	18	n.d	15	n.d	n.d	n.d	n.d	n.d	Khan et al. (2010)
37.	Pakistan	Wastewater irrigating zone, Lahore,	0.38	0.38	n.d	n.d	n.d	0.26	n.d	n.d	Mahmood and Malik (2014)
38.	Pakistan	Wastewater Irrigated site, Peshawar	n.d	36.1	2.20	n.d	86.3	n.d	n.d	43	Perveen et al. (2012)
39.	Romania	Ruschita, Mining area	n.d	n.d	0.62	n.d	n.d	2.1	n.d	0.9	Harmanescu et al. (2011)
40.	Romania	Mol Dova Noua, Mining Area, Banat County,	n.d	n.d	0.21	n.d	n.d	0.09	n.d	0.25	Harmanescu et al. (2011)
41.	Romania	Near Mining Areas,	n.d	n.d	0.62	n.d	n.d	2.11	n.d	0.90	Gergen and Harmanescu (2012)
42.	Saudi Arabia	Urban areas, Dammam City,	2.88	n.d	n.d	2.04	n.d	1.42	n.d	5.31	Ali and Al-Qahtani (2012)
43.	Saudi Arabia	Urban areas, Riyadh City, Saudi Arabia	1.26	n.d	n.d	1.27	n.d	1.13	n.d	3.80	Ali and Al-Qahtani (2012)
44.	Saudi Arabia	Urban areas, Tabouk City,	4.14	n.d	n.d	4.37	n.d	1.64	n.d	3.49	Ali and Al-Qahtani (2012)

Table 2 continued

S. no.	Country	Location	Spinach	Coriander	Lettuce	Turnip	Radish	Carrot	Brinjal	Cabbage	References
45.	Saudi Arabia	Urban areas, Jazan City,	2.85	n.d	n.d	2.94	n.d	1.52	n.d	2.75	Ali and Al-Qahtani (2012)
46.	Spain	Market, Spain	0.0133	n.d	0.0051	n.d	n.d	0.0071	n.d	n.d	Bakkali et al. (2012)
47.	Spain	Southern Spain,	0.0107	n.d	0.0041	n.d	n.d	0.0071	n.d	n.d	Bakkali et al. (2012)
		Central Spain,	0.033		0.0064			0.0141			
		Northern Spain	0.0083		0.021			0.004			
48.	Tanzania	Across Industrial Area	n.d	n.d	n.d	n.d	n.d	n.d	n.d	31	Chove et al. (2006)
49.	Tehran	Wastewater irrigated, South of Tehran	8.4	n.d	9.9	8.9	10.6	n.d	n.d	n.d	Harati et al. (2011)
50.	Turkey	Manisa,	0.139	n.d	0.163	n.d	n.d	n.d	n.d	n.d	Bagdatlioglu et al. (2010)

Permissible Limit: For Leafy Vegetables: 0.3 mg/kg; Fruits/Tubers: 0.1 mg/kg

n.d. not done

Cd, Cu, Pb, Ni and Cr was reported in wastewater irrigated agricultural sites of dry tropical area of India (Singh et al. 2010). The content of copper in agricultural soil near Narora Atomic Power Station (NAPS), Narora, India was 27.95 mg/kg (Singh and Prasad 2014). In agricultural soils around Durgapur Industrial belt, India the concentration of Zn, Cu and Pb was found to be 205–255, 101–130, 118–177 µg/g respectively (Kisku et al. 2011). In industrial wastewater irrigated agricultural fields in Vadodra, Gujrat, India contents of heavy metals were found to be significantly higher concentration than of those irrigated with tubewell water and the trend of heavy metals in this soil was Fe > Mn > Zn > Cd > Cu > Pb > Cr > As (Tiwari et al. 2011). Concentration of Cd, Cu and Zn was reported to be more than the permissible limits in the agricultural soil in Gilgit, North Pakistan (Khan et al. 2010).

Heavy metals in vegetables

Food security was conceptualized wrongly as mere availability of food. Thus, increase in production to feed the macro-nutrient deficient population was the sole aim. Though, the target to reduce chronically hungry population was met but another most important dimension of food security, i.e., safety was ignored. Cultivation of vegetable crops on the contaminated sites or using the wastewater water for irrigation has led to an increase in the concentration of metals in the vegetable samples. The content of toxic metals in vegetable sample was reported high in many parts of the world (Singh et al. 2009;

Harmanescu et al. 2011; Jolly et al. 2013; Sharma et al. 2016a, b; Orisakwe et al. 2012a).

Cadmium, considered as a potential carcinogen by USEPA has been reported at concentration beyond acceptable limits in vegetable samples from many parts of the world. Table 1 shows the summary of literature depicting content of cadmium in vegetable samples from some parts of the world. Lead is also identified as potential carcinogen. Vegetable crops growing in many parts of the world have high concentrations of lead. Table 2 shows the concentration of lead in vegetables samples across the world. Copper is an essential element for normal physiological functions of living organisms but the high concentration of copper is known to cause toxic effects to both plants and animals. Table 3 summarizes some studies on content of copper in some vegetable samples from some parts of the world.

Concentration of other metals in vegetable samples was also reported to be high in many parts of world. Vegetables grown near Ginfel river near Sheba Tannery, Tigray, Northern Ethiopia, accumulated many heavy metals and the uptake pattern of different heavy metals in vegetables were in order: Fe > Pb > Cd > Mn > Cu > Zn > Ni > Zn > Cr = Co (Gebrekidan et al. 2013). A study was carried out to compare the concentration of metals in vegetables irrigated with wastewater and tube well water in Keshopur, Delhi, India. It was reported that concentration of metals in vegetables irrigated with wastewater was much higher than those irrigated with tube well water. Concentration of iron in spinach was reported to be 711 mg/kg, in

Table 3 Summary of some recent literature showing content of copper (mg/kg) in vegetable samples from some parts of the world

S. no.	Country	Location	Spinach	Coriander	Lettuce	Turnip	Radish	Carrot	Brinjal	Cabbage	References
1.	Bangladesh	Ruppur area, Pabna Distt, Bangladesh	5.59	n.d	n.d	n.d	4.45	5.35	6.69	n.d	Jolly et al. (2013)
2.	Bangladesh	Directly Polluted area, Bangladesh	18.3	n.d	n.d	n.d	n.d	n.d	n.d	n.d	Naser et al. (2012)
3.	Bangladesh	Industrial areas, Dhaka, Bangladesh	n.d	n.d	n.d	n.d	n.d	n.d	8.63	14.25	Ahmad and Goni(2010)
4.	China	Wastewater Irrigated, Tongzhou Distt, Beijing, China	15	n.d	14.8	15	9.8	n.d	n.d	13	Khan et al. (2008)
5.	China	Near Dabaoshan mine in Guangdong, China	14	n.d	14	9.8	n.d	n.d	n.d	14	Zhuang et al. (2009)
6.	China	Zhongxin (ZX), Near Dabaoshan Mine, China	n.d	n.d	0.74	1.27	0.45	1.33	1.58	1.11	Zhuang et al. (2008)
7.	China	Vicinity of industrial zone in Jiangsu, China	2.35	n.d	1.31	n.d	n.d	n.d	0.99	0.62	Cao et al. (2010)
8.	China	Jiangsu Province, China	1.41	n.d	0.62	n.d	n.d	n.d	1.68	n.d	Hao et al. (2009)
9.	China	Near e-waste processing site, China	n.d	n.d	2.09	n.d	0.59	0.99	n.d	n.d	Luo et al. (2011)
10.	China	Beijing	1.05	n.d	n.d	n.d	1.20	n.d	2.71	1.0	Song et al. (2009)
11.	China	Wastewater Irrigated Beijing and Tianjin city cluster, China	n.d	n.d	11	n.d	4	n.d	n.d	9	Wang et al. (2012)
12.	Ghana	Mining Site, Ghana	n.d	n.d	0.172	n.d	n.d	0.221	n.d	0.040	Boamponsem et al. (2012)
13.	Ghana	Ghana Market		n.d	1.92	n.d	n.d	1.77	n.d	2.32	Bempah et al. (2011)
14.	Greece	Industrial Area, Northern Greece	> 8	n.d	> 5	n.d	n.d	> 4	n.d	> 1	Fytianos et al. (2001)
15.	India	Wastewater Irrigated, Rajasthan, India	16.5	12.1	n.d	16.1	6	12	10.2	n.d	Arora et al. (2008)
16.	India	Across Musi River, Hyderabad, India	1.1	1.6	n.d	n.d	n.d	n.d	0.9	n.d	Chary et al. (2008)
17.	India	Urban areas, Bangalore, India	34.7	60.7	n.d	n.d	n.d	n.d	n.d	n.d	Ramesh and Yogananda Murthy (2012)
18.	India	Durgapur Industrial Belt, India	n.d	51	n.d	n.d	n.d	n.d	55	n.d	Kisku et al. (2011)
19.	India	Around sewage treatment plant, Varanasi	15	n.d	n.d	n.d	14.8	n.d	14.8	6	Singh et al. (2010)
20.	India	Soil waste disposal site, By Pass, Kolkata	16.13	n.d	n.d	n.d	n.d	n.d	11.75	0.45	Banerjee et al. (2010)
21.	India	Raichak, Parganas,	5.91	n.d	n.d	n.d	n.d	n.d	12.12	6.43	Banerjee et al. (2010)
22.	India	Ghatakpur, Kolkata	8.97	n.d	n.d	n.d	n.d	n.d	13.25	9.87	Banerjee et al. (2010)
23.	India	Wastewater Irrigated area, Titagarh, West Bengal	34.49	25.10	24.93	n.d	28.08	n.d	n.d	n.d	Gupta et al. (2012)

Table 3 continued

S. no.	Country	Location	Spinach	Coriander	Lettuce	Turnip	Radish	Carrot	Brinjal	Cabbage	References
24.	India	Wastewater irrigated site, Varanasi, India	16.38	n.d	n.d	n.d	7.28	n.d	n.d	12.25	Mishra and Tripathi (2008)
25.	India	Sewage irrigated site, Delhi, India	20.6	n.d	n.d	n.d	10.4	n.d	n.d	n.d	Rattan et al. (2005)
26.	India	Industrial effluent irrigated Vadodara, India	18	30	n.d	n.d	19	n.d	29	n.d	Tiwari et al. (2011)
27.	Iran	Wastewater Irrigated, Shah-Re Iran	22.74	26.92	n.d	n.d	12.52	n.d	27.53	n.d	Bigdeli and Seilsepour (2008)
28.	Libya	Market Sites in the Misurata Area, Libya	5.32	n.d	n.d	n.d	n.d	5	n.d	n.d	Elbagermi et al. (2012)
29.	Morocco	Market, Morocco	0.0635	n.d	0.353	n.d	n.d	0.0508	n.d	n.d	Bakkali et al. (2012)
30.	Nigeria	Sokoto, Nigeria	1.1	n.d	0.8	n.d	n.d	n.d	n.d	n.d	Sani et al. (2011)
31.	Nigeria	Maiduguri, Nigeria	n.d	n.d	1.66	n.d	n.d	n.d	n.d	n.d	Uwah et al. (2011)
32.	Pakistan	Effluent treated, Faisalabad, Pakistan	0.923	0.653	0.851	n.d	0.462	n.d	n.d	0.252	Farooq et al. (2008)
33.	Pakistan	Wastewater Irrigated, Distt Mardan Pakistan	n.d	n.d	n.d	n.d	n.d	n.d	10.85	n.d	Amin et al. (2013)
34.	Pakistan	Tube-well Irrigated, Mardan Distt, Pakistan	n.d	n.d	n.d	n.d	n.d	n.d	6.85	n.d	Amin et al. (2013)
35.	Pakistan	Gilgit, northern Pakistan	11	n.d	24	n.d	n.d	n.d	n.d	n.d	Khan et al. (2010)
36.	Pakistan	Wastewater irrigating zone, Lahore, Pakistan	0.44	1.65	n.d	n.d	n.d	0.87	n.d	n.d	Mahmood and Malik (2014)
37.	Poznan	Markets, Poznań	n.d	n.d	4.6	n.d	n.d	4.2	n.d	2.1	Bosiacki and Tyksiński (2009)
38.	Romania	Ruschita, Mining area, Banat County, Romania	n.d	n.d	1.86	n.d	n.d	1.54	n.d	1.36	Harmanescu et al. (2011)
39.	Romania	Mol Dova Noua, Mining, area, Banat County, Romania	n.d	n.d	2.22	n.d	n.d	1.77	n.d	2.77	Harmanescu et al. (2011)
40.	Romania	Near Mining Areas, Romania	n.d	n.d	2.22	n.d	n.d	1.77	n.d	2.77	Gergen and Harmanescu (2012)
41.	Saudi Arabia	Urban areas, Dammam City, Saudi Arabia	11.38	n.d	n.d	6.21	n.d	3.60	n.d	4.24	Ali and Al-Qahtani (2012)
42.	Saudi Arabia	Urban areas, Riyadh City, Saudi Arabia	14.07	n.d	n.d	14.27	n.d	4.49	n.d	6.85	Ali and Al-Qahtani (2012)
43.	Saudi Arabia	Urban areas, Tabouk City, Saudi Arabia	7.82	n.d	n.d	n.d	11.80	4.44	n.d	2.76	Ali and Al-Qahtani (2012)
44.	Saudi Arabia	Urban areas, Jazan City, Saudi Arabia	10	n.d	n.d	7.45		7.82	n.d	3.88	Ali and Al-Qahtani (2012)
45.	Spain	Market, Spain	0.0518	n.d	18.9	n.d	n.d	0.0514	n.d	n.d	Bakkali et al. (2012)

Table 3 continued

S. no.	Country	Location	Spinach	Coriander	Lettuce	Turnip	Radish	Carrot	Brinjal	Cabbage	References
46.	Spain	Southern Spain,	0.0518	n.d	0.0189	n.d	n.d	0.0514	n.d	n.d	Bakkali et al. (2012)
		Central Spain,	0.0782		0.0126			0.0252			
		Northern Spain	0.0453		0.0235			0.0164			
47.	Tanzania	Across Industrial Area, Tanzania	n.d	n.d	n.d	n.d	n.d	n.d	n.d	140	Chove et al. (2006)
48.	Turkey	Manisa, Turkey	1.30	n.d	0.48	n.d	n.d	n.d	n.d	n.d	Bagdatlioglu et al. (2010)

n.d. not done

radish tuber was 166 mg/kg and in cauliflower was 328 mg/kg (Rattan et al. 2005). A study around wastewater irrigated site in Varanasi revealed that the continuous use of wastewater for irrigation caused a buildup of higher concentration of Cd, Cr, Ni and Pb as compared of ground water irrigated site. The relative efficiency of uptake of copper by different vegetables in sewage irrigated site of Baoding City, China was *S. oleracea* > *B. pekinensis* L. > *B. oleracea* > *A. fistulosum* (Xue et al. 2012). In sewage water irrigated fields in Vadodara, India, 5 out of 10 vegetable species (spinach, radish, tomato, chilli and cabbage) studied showed high accumulation of toxic metals like As, Cd, Cr, Pb and Ni (Tiwari et al. 2011). Concentration of Pb and Zn in sewage irrigated soil of Kabul city ranged from 1–5 and 33–160 mg/kg, which was much above the threshold levels i.e., 0.3 mg/kg for Pb and 50 mg/kg for Zn (Safi and Buerkert 2011).

Buildup of heavy metals is higher in vegetables as compared to grains owing to the fleshy tissues. Throughout the world, many studies have shown high concentration of heavy metals in vegetables growing at contaminated sites and/or those irrigated with wastewater. At many places, concentration of these metals in vegetables is found to be beyond permissible levels (Chove et al. 2006). The hazard associated with consumption of heavy metals with food crops is measured by assessing Metal Pollution Index (MPI) and Hazard Quotient (HQ) (Song et al. 2009; Huang et al. 2014; Sharma et al. 2016a, b). Levels of heavy metals in vegetables are reported to be beyond acceptable limits in many parts of the world thus representing potential health risk, these food crops can cause to the entire population (Jolly et al. 2013; Sharma et al. 2016a).

Need for a constructive solution

To attain food security it is important is also consider the safety aspect in production of food. There is need that scientific community, policy makers and society

understand the multifaceted aspect of food security and make the legible efforts to produce sufficient as well as safe food. There is a need to identify various remediation strategies and improve the irrigation mechanisms Soil remediation requirements may vary from region to region, so the alternatives should be suggested keeping in the mind the conditions of particular region. Irrigation with wastewater in developed nations might be a solution where the economic conditions permit to treat wastewater till tertiary levels. In developing or underdeveloped nations there is need to find a strategy that can enhance the quality of food in terms of safety and nutritious value. Strategies like organic soil amendments, drip irrigation, remediation technologies, low cost wastewater treatment techniques can be an answer to solve the issue. Internationally, efforts are required to make a paradigm shift of culture from just attaining sufficiency to safety.

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