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Consumer health risk due to intake of some popular fruit vegetables cultivated in waste water irrigated farm soil

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ABSTRACT

Due to unique tendency of bio-accumulation of heavy metals are accumulated from soil in to the roots, tubers, stem, leaves and fruits of the vegetable plants and other crops; regular consumption of such farm produces for long as a dietary component may cause health hazards to mankind. This work presents the estimation of levels of accumulated Cd, Pb, Cr, Ni and Cu in commonly consumed ten fruit vegetables and thereby computation of daily intake of metals through vegetables consumption to assess the health consequences of metal contaminated vegetables, grown on urban waste water irrigated farm soil, in terms of the metal pollution index (MPI) and consumer health risk index (HRI). The order of accumulated metals in fruit vegetables under study was Pb> Cr > Ni > Cu > Cd. The MPI (mg/Kg) values for all studied vegetables were < 1 and the order was *Pointed gourd* (1.57) > *Lady finger* (1.36) > *Capsicum* (1.30) > *French bean* (1.29) > *Indian bean* (1.24) > *Bitter gourd* (1.24) > *Tomato* (1.21) > *Sponge gourd* (1.18) > *Cucumber* (1.13) > *Bottle gourd* (1.08). The order of consumer health risk index (HRI) based on the daily intake of metal (DIM) through consuming vegetables was assessed as: Cd (289-459) > Pb (151- 230) > Ni (18.90- 31.75) > Cu (9.35-18.27) > Cr (0.411-0.578).

***Key words**: Accumulation of heavy Metals, Vegetables, MPI, DIM, HRI*

Introduction

Advancements during 20th century have brought social and economic benefits to humanity but these have also caused a wide range of environmental problems at all levels (Kulshrestha *et al.*, 2012). Toxic metals have always been present in the ecosystem, but since the industrial revolution there has been a massive redistribution of metals on the surface of the earth (Kulshrestha *et al.*, 2012; Singh, 2005). The non-biodegradable characteristic makes heavy metals persistent in nature for long, consequently, on entering human body through contaminated food crops even at low level (Iked *et al.*, 2000) due to their bio-accumulating capability, may get deposited in various human sensitive internal organs. Large deposits may cause series of damage in the body and have become a major cause of illness, ageing and even genetic defects (Kulshrestha *et al.*, 2012). Mining- metallurgical operations -finishing of metal-products, application of fertilizers-pesticides; the cultivation of food crops and vegetables using urban waste water for long usually raises the levels of heavy metals in farm- soil. Their excessive accumulation in soils may result not only in soil contamination, but raises concern for food quality and human safety (Fernando *et al.*, 2012). Many of these metals via bio-concentration process may be stored selectively in the roots, tubers and above ground parts. The uptake of metals from the soil to plant depends on their soluble fraction in soil, soil pH, plant species, fertilizers and soil type (Dilek and Akosy, 2006).

In Indian sub-continent varieties of fresh fruits and vegetables are available round the year to fulfill our requirements of essential nutrients, anti-oxidants, carbohydrates, vitamins, dietary fiber and many more. Vegetables are vital for human balance diet and in particular provide the trace elements and useful heavy metals (Dilek and Akosy, 2006), yet regular consumption of vegetables grown on metal contaminated soil for long may result metabolic disorders and several adverse health problems (Sharma *et al*., 2006). Evaluation of the levels of accumulation of heavy metals in food crops cultivated by using waste water is important to assess their risk to human health (Khan *et al*., 2013). The heavy metals find entry in the food crops mainly through the quality of the farm-soil and water used for irrigation, as both treated and untreated waste water contain high concentration of heavy metals. The main route of community exposure to heavy metals is consumption of contaminated food crops as dietary intake (Ying Chen *et al*., 2014). Further, consumption of contaminated foodstuff for long may lead to the high deposition of toxic metals in the sensitive organs such as liver and kidney resulting in disturbance in several biochemical processes and health complications (Adeel and Malik, 2014). The evaluation of possible health risk due to consumption of farm products and vegetables now has become one of the focused and vibrant field of recent research globally (Arora *et al*., 2008; Khan *et al*., 2008; Singh *et al*., 2012; Ghosh *et al*., 2012, 2013; Chauhan and Chauhan, 2014).

This study was aimed to investigate the levels of Cd, Pb, Cr, Ni and Cu accumulated in the fruit vegetables, *Solanum lycopersicum* L. (Tomato), *Capsicum annuum* (Capsicum), *Abelmoschus esculentus* L. (Lady finger), *Phaseolus vulgaris* (French bean), *Lablab purpureus* (Indian bean, Sem), *Momordica charantia* (Bitter guard), *Cucumis sativus* (Cucumber), *Lagenaria siceraria* (Bottle gourd) and *Luffa cylindrical* (Sponge gourd) and *Trichosanthes dioica* (pointed gourd) and thereby the evaluation of community health risk due to dietary intake of metal contaminated vegetables in terms of metal pollution index (MPI) and daily intake of metal (DIM) based health risk Index (HRI).

Materials and Methods

Sample Collection

The selected fruit vegetables and their dietary importance are listed in the Table 1. Farmers of Doiwala, Premnagar, Biharigarh and Chutmalpur fulfill the vegetable requirements of Dehradun City. These places are sub-urban settlements devoid of proper sewage and waste water disposal facilities. Farmers of the area mostly use dug wells, hand pumps and domestic and other waste water to irrigate the vegetables crops. Brick kilns, stone crushers, rice mills, oil extraction plants, gur – khand units and metal finishing-welding units are main sources of heavy metals contamination of water and soil (Kulshrestha *et al.*, 2012). The freshly supplied samples of each fruit vegetables were collected from five different vegetable traders operating at different locations of Dehradun city, during September to December 2015.

Digestion of Vegetable Samples and Estimation of Metals under study

Samples were thoroughly cleaned with tap water and then with distilled water, cut into small pieces and spread over clean filter paper sheets and allowed to air dry for 3-4 days to make moisture free. The samples were then dried in electric oven at 60-65^{0}C for 4-5 hours and then grinded to homogenous powder and kept in labelled sample bottles. For estimation of the accumulated metals in vegetable samples, 1.0 g of the powdered samples were subjected to HNO_3 – $HClO_4$ (5:1, v/v) digestion at nearly 80^{0}C, following the standard methods (APHA, 2005) for several hours to get a transparent light colored liquid, which was then filtered on Whatman paper in a 100 ml volumetric flask and filled up to the mark with double distilled water. The accumulated concentration of Cd, Cr, Pb, Cu and Ni (mg/Kg, dw) in the vegetable samples were determined by using atomic absorption spectrometer (Perkin Elmer, *Analyst 200*), with air- acetylene flame, in accordance to Standard Methods (APHA, 2005; Jones J. Benton Jr, 2001).

Various A.A.S. standard stock solutions of metal ions used were from *Sigma Aldrich*, which were diluted to required concentrations to prepare working standards (Kulshrestha *et al.*, 2012). Other reagents, chemicals, and solvents used were of analytical grade. Doubly- distilled water was used for all purposes.

Table 1. Selected Vegetables and their Dietary Importance

Scientific Name, Family	Common Name	Dietary Importance
Solanum lycopersicum L., Solanaceae	Tomato	Good source of minerals, fiber, antioxidant-lycopene, ß-carotene, vitamin A, C, B, E, K, folate, reduces heart diseases and cancer.
Capsicum annuum, Solanaceae	Capsicum	Contains lycopene, ß- carotene, vitamin A, C, K, anti-oxidants, anticancer, good for Eyes, ulcer, heart, diabetes,
Abelmoschus esculentus L., Malvaceae	Lady Finger	It has high nutrition, immune booster, lowers cholesterol, controls sugar level, antioxidants, and has anti-tumor and anti-cancer properties. Good for eyes and digestion.
Phaseolus vulgaris, Fabaceae	French bean	It has fiber, vitamin C, iron, good for eyes, heart, regulates sugar level, boost immune system and energy.
Lablab purpureus Fabaceae	Indian bean (Sem)	It has K, Mo, Fe, vitamin A, C, K, B2, **antioxidants,** cures migraine, cataracts and sugar levels, strengthens heart.
Cucumis sativus, Cucurbitaceae	Cucumber	It has high nutrients, vitamins A, C, fibers, Antioxidants, raises hydration and lowers blood sugar, skin care.
Momordica charantia, Cucurbitaceae	Bitter guard	It has Fe, Mg, K, Ca and vitamins A, C, ß- carotene, antioxidants, lowers bad cholesterol, boost immune and skin health, anti-ageing, anti-diabetic, supports digestion.
Lagenaria siceraria, Cucurbitaceae	Bottle gourd	It has high Fe, K, vitamins B, C, antioxidants, anti-asthmatic, anti-allergic, cardio-protective, immune booster.
Luffa cylindrica Cucurbitaceae	Sponge gourd	It has dietary fiber, vitamin A, B5, B6, C, riboflavin, thiamine, ß- carotene, and blood purifier and supports liver.
Trichosanthes dioica Cucurbitaceae	Pointed guard (Parwal)	Has high antioxidants, vitamins A,B1,B2 , fiber, helpful in diabetes, cholesterol, hypertension, jaundice, blood purifier

Results and Discussion

The concentrations of accumulated Cd, Cr, Pb, Cu and Ni as mg/Kg, dry weight of edible parts of *Tomato, Capsicum, Lady finger, French bean, Indian bean (sem or* hyacinth), Cucumber*, Bitter gourd, Bottle gourd, Sponge guard* and *Pointed gourd* are presented in Table 2.

Statistical analysis:

Pearson Correlation analysis (r) was computed to find out the closeness of relationship between the heavy metals: Cd, Pb, Cr, Ni and Cu, the results are presented in Table 3. To evaluate significant differences among the accumulated metals in edible parts of fruit vegetables under study, *one-way* ANOVA was also computed at $p<0.05$ level. The *ANOVA* outputs for cadmium, lead, chromium, nickel and copper levels in vegetables were found significant at $p<0.05$.

Bio-accumulation of Tested Metals in Fruit Vegetables

The ability of bio-accumulation of heavy metals by a plant is related to its bio-availability in soil near the plant roots, characteristics of farm soil and plant age (Singh, 2012). The bio- accumulation potential of plant root system for metals differs widely due to their diverse morphology (FAO/ WHO 2014) and may be significantly selective for one or more metals. Permissible limit for cadmium in fruits vegetables is 0.05 mg/kg, while for leafy and tuberous vegetables permissible limit is 0.1 mg/kg (FAO/ WHO 2014). Cadmium is carcinogenic (Iqbal *et al*, 2020) and its elevated levels can damage human liver and kidney. The level of accumulated Cadmium (Table 2) was lowest in *Indian bean* (0.68± 0.02) and maximum in pointed gourd (1.08± 0.041) and the order was: *Pointed gourd* (1.08± 0.04) > *Capsicum* (0.92± 0.023) >*Bitter gourd* (0.88± 0.023) > *Cucumber* (0.85± 0.023) > *Lady finger* (0.82± 0.023) > *Tomato* (0.78± 0.034) > *French bean* (0.76± 0.025, mg/Kg, d.w.) >*Sponge gourd* (0.76± 0.025) > *Bottle gourd* (0.72± 0.018) > *Indian bean* (0.68± 0.02). However, in all fruit vegetables the accumulated level of Cd, which is a non-essential metal, was below the recommended safe limit (WHO, 2007). Lead exerts toxic effect on kidney, brain and central nervous system and may be fatal to human. The lead levels in all the vegetables under study were below permissible limit, and the overall levels of lead in vegetables were; *Pointed gourd* (2.28± 0.046) > *Lady finger* (2.14± 041) > *French bean* (2.07± 0.037) > *Indian bean* (1.76± 0.025) > *Sponge gourd* (1.74± 0.032) > *Bottle gourd* (1.71± 0.028) > *Bitter gourd* (1.62± 0.028) > *Cucumber* (1.56± 0.032) > *Capsicum* (1.46± 0.032) *Tomato* (1.42± 0.034 mg/Kg, d.w.). Chromium is an important micro element needed for plant growth, was found below the recommended safe limit (Awasthi, 2000; WHO, 2007**)**, in all the vegetables under study. The overall order of accumulated Chromium was: *Tomato* (2.04± 0.043) > *Capsicum* (1.88± 0.036) > *French bean* (1.81± 0.032) > *Lady finger* (1.76± 0.038) > *Indian bean* (1.73± 0.033) > *Sponge gourd* (1.68± 0.028) >Pointed *gourd* (1.54± 0.051) > *Cucumber* (1.49± 0.028> Bitter *gourd* (1.46± 0.027) > Bottle *gourd* (1.45± 0.023 mg/Kg, d.w.). The order of accumulated nickel in vegetables was: *Pointed gourd* (1.46± 0.052) > *Tomato* (1.32± 0.27) > *French bean* (1.23± 0.026) > *Capsicum* (1.19± 0.023) > *Bitter gourd* (1.17± 0.029) > *Lady finger* (1.08± 0.032) > *Cucumber* (1.05± 0.025) > *Sponge gourd* (0.97± 0.018) > *Indian bean* (0.92± 0.023) > *Bottle gourd* (0.89± 0.025). However, the order of accumulated Cu in vegetables was: *Pointed gourd* (1.72± 0.042) > *Lady finger* (1.42± 0.032) > *Bitter gourd* (1.22± 0.023) > *Capsicum* (1.22± 0.023) > *Sponge gourd* (1.04± 0.023) > *French bean* (1.02± 0.023) > Indian *bean* (0.98± 0.028) > *Bottle gourd* (0.95± 0.023) > Cucumber (0.89± 0.023) >*Tomato* (0.88± 0.023 mg/Kg, d. w.). In all the fruit vegetable samples the accumulation of copper was much below the recommended safe limit (Awasthi, 2000).

The overall order of accumulated metals in *Tomato* was : Cr (2.04± 0.043)> Pb (1.42± 0.034) > Ni (1.32± 0.27) > Cu (0.88± 0.023) > Cd (0.78± 0.034); in *Capsicum*: Cr(1.88± 0.036) > Pb (1.46± 0.032) > Cu (1.22± 0.023) > Ni (1.19± 0.023) >Cd (0.92± 0.023); in *Lady finger;* Pb (2.14± 041) > Cr (1.76± 0.038) > Cu (1.42± 0.032) > Ni (1.08± 0.032) >Cd (0.82± 0.023); in *French bean:* Pb (2.07± 0.037) > Cr (1.81± 0.032) > Cu (1.42± 0.032) > Ni (1.23± 0.026) >Cd (0.82± 0.023); in *Indian bean*: Pb (1.76± 0.025) > Cr (1.73± 0.033) > Cu (0.98± 0.028) > Ni (0.92± 0.023) >Cd (0.68± 0.02); in *Cucumber* : Pb (1.56± 0.032) > Cr (1.49± 0.028) > Ni (1.05± 0.025) > Ni (0.92± 0.023) > Cu (0.89± 0.023) >Cd (0.85± 0.023); in *Bitter gourd* : Pb (1.62± 0.028) > Cr (1.46± 0.027) > Cu (1.22± 0.023) > Ni (1.17± 0.029) >Cd (0. 88± 0.023); in *Bottle gourd*: Pb (1.71± 0.028) > Cr (1.45± 0.023) > Cu (0.95± 0.023) > Ni (0.89± 0.025) >Cd (0. 72± 0.018); in *Sponge gourd* : Pb (1.74± 0.032) > Cr (1.68 ± 0.028) > Cu (1.04± 0.023) > Ni (0.97± 0.018) >Cd (0. 76± 0.018); in *Pointed gourd:* Pb (2.28±

Table 2. Metal Concentrations, mg/ Kg, dry weight of Edible Parts of Vegetables.

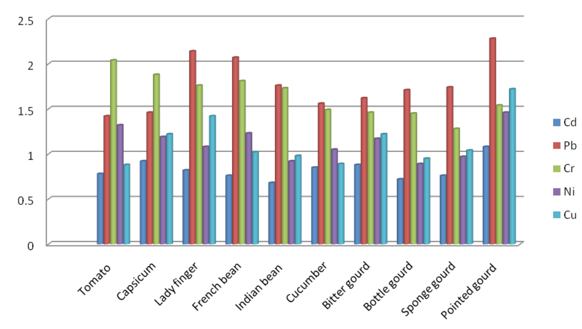
Vegetables/Metals	Cadmium	Lead	Chromium	Nickel	Copper
Tomato, (n = 5)	0.78± 0.034	1.42± 0.034	2.04± 0.043	1.32± 0.27	0.88± 0.023
Capsicum, (n = 5)	0.92± 0.023	1.46± 0.032	1.88± 0.036	1.19± 0.023	1.22± 0.023
Lady finger, (n = 5)	0.82± 0.023	2.14± 041	1.76± 0.038	1.08± 0.032	1.42± 0.032
French bean, (n = 5)	0.76± 0.025	2.07± 0.037	1.81± 0.032	1.23± 0.026	1.02± 0.023
Indian bean, (n = 5)	0.68± 0.02	1.76± 0.025	1.73± 0.033	0.92± 0.023	0.98± 0.028
Cucumber, (n = 5)	0.85± 0.023	1.56± 0.032	1.49± 0.028	1.05± 0.025	0.89± 0.023
Bitter gourd, (n = 5)	0.88± 0.023	1.62± 0.028	1.46± 0.027	1.17± 0.029	1.22± 0.023
Bottle gourd, (n = 5)	0.72± 0.018	1.71± 0.028	1.45± 0.023	0.89± 0.025	0.95± 0.023
Sponge gourd,(n =5)	0.76± 0.018	1.74± 0.032	1.68± 0.028	0.97± 0.018	1.04± 0.023
Pointed gourd, (n=5)	1.08± 0.041	2.28± 0.046	1.54± 0.051	1.46± 0.052	1.72± 0.042
Safe limits (Awasthi, 2000; WHO, 2007)	(1.5)	(2.5)	(5.0)	(1.5)	(30)

Table 3. Pearson Correlations (r) among the Heavy Metals in Edible parts of Vegetables

Metals	Cadmium	Lead	Chromium	Nickel	Copper
Cd	1				
Pb	0.2984684	1			
Cr	-0.2026162	-0.20047	1		
Ni	0.7484966	0.264586	0.292113	1	
Cu	0.7959413	0.688239	0.688239	0.547494	1

0.046) > Cu (1.72± 0.042) > Cr (1.54 ± 0.051) >Ni (1.46 ± 0.052) >Cd (1.08± 0.041 mg/Kg, d.w.). Thus all the vegetables under study differ greatly in their metal bio- accumulating potential to accumulate the studied metals, Cd, Pb, Cr, Ni and Cu.

Fig. 1. Accumulated levels of Metals in Fruit Vegetables



Although tested metals in all the vegetables found within the recommended safe limits (WHO, 2007), yet the metal pollution index (MPI) for all the vegetables were found in moderate category (< 2 mg/Kg). Regular and repeated application of waste water to irrigate farm-soil for long usually registers the elevated levels of heavy metals beyond their permitted limits. On comparing the results with earlier investigation, the accumulated values of Cd, Pb, Cr, Ni and Cu in fruit vegetables under study were lower than most of the earlier investigations. Thus, accumulated Cd, Pb, Cr, Ni and Cu in *Tomato*, reported from Varanasi (Singh *et al.*, 2010), Ni and Cu reported from Anand, Gujrat were comparable (Kumar *et al.*, 2007); while, Cd, Pb and Ni from Satana, MP (Tarmakar and Richhariya, 2012), Pb, Cr, Cu from Vellore (Ray *et al.*, 2014); Cd, Pb, Ni and Cu, from Naini, Allahabad (Yadav *et al.*, 2013), Pb, Ni and Cu in Kayseri, Turkey were higher (Dilek and Aksoy, 2006) than this work. Lead and nickel reported in *Capsicum* from Satna, MP (Tarmakar and Richhariya, 2012) were higher. In *Lady finger*, Cd, Pb, Ni and Cu reported from Banglades (Proshada *et al.*, 2018), Copper reported from Varanasi, India (Singh *et al.*, 2010), Pb and Cu reported from ICAR, Delhi (Singh, 2012), Cd, Pb and Ni reported from Satna, MP (Tarmakar and Richhariya, 2012) all were higher, while the level of Cd was comparable, Pb was lesser and Cu reported from Amritsar (Sharma *et al.*, 2016) was much higher than this finding. In *French been* the concentrations of Cd, Pb, Cr, Ni and Cu were lower than earlier investigations, reported from Bangladesh (Proshada *et al.*, 2018), Pb, Cr and Cu reported from Central Portugal (Paula *et al.*, 2016), Pb, Ni and Cu reported from Kayseri, Turkey (Dilek and Aksoy, 2006), Cr and Ni reported from Vellore, Tamil Nadu, India (Ray *et al.*, 2014). In *Cucumber* Cd, Pb and Cu reported from *Kayseri*, Turkey were much higher (Dilek and Aksoy, 2006), Cd, Pb, Cr, Ni and Cu reported from Banglades (Proshada *et al.*, 2018) were higher, while Pb, Cr and Ni reported from São Paulo, Brazil (Fernando *et al.*, 2012) were lower than this finding. The metals under study in *Bitter gourd* reported from Varanashi, India (Anita *et al.*, 2010) were lower except, Cadmium than this finding. In *Bottle gourd* Cd, Pb, Cr, Ni and Cu reported from Banglades (Proshada *et al.*, 2018) were higher; while, Ni and Cu reported from Anand, Gujrat (Kumarji *et al.*, 2007) were lower than this finding. However, Cd and Pb were lower and Cu was higher in *Bottle gourd* reported from Amritsar (Sharma *et al.*, 2016) and Pb, Ni and Cu reported from Varanashi, India (Singh *et al.*, 2010) was lower and Cd was higher than this finding. In *Sponge gourd* Cr, Ni and Cu reported from Bangladesh (Proshada *et al.*, 2018) were higher. Results reported from Jamalpur, Bangaladesh (Akter *et al.*, 2019), Cr and Ni were comparable while, Pb and Cu were much higher while, Cd reported from Varanasi (Singh *et al.*, 2010) was higher, but Pb, Cr, Ni and Cu were lower than this finding. In *Pointed gourd* all the metals registered higher values than reported from Varanasi, India (Anita *et al.*, 2010).

Quantification of Consumer Health Risk

Heavy metal contamination now has become a serious problem globally that adversely affecting the entire ecosystem including plants, animals and local population. The non-biodegradable characteristic makes heavy metals persistent in ecosystem for long and their bio-accumulating capability facilitates their passage to human body through contaminated food crops even at low level (Iked *et al.*, 2000) these get deposited in our sensitive internal organs, due to their bio-accumulating capability. Dietary intake of metal-contaminated fruits and vegetables poses a serious health risk to the consumers (National Center for Environmental Assessment, 1997). The quantification of consumer health risk can be estimated in various ways such as the metal pollution index (MPI) and consumer health risk index (HRI) or health Quotient (HQ).

Metal Pollution Index (MPI)

The assessment of overall load of metals in each vegetable was made by computing metal pollution index (MPI) (Usero *et al*., 1997). The MPI is a reliable and precise method for monitoring metal pollution in vegetables (Usero *et al*., 1997). The metal pollution index due to bio- accumulation of metals in edible parts of a vegetable under study was computed by calculating the geometrical mean of concentrations of all the metals in that vegetable, using following equation (Usero *et al.*, 1997).

MPI- (mg/kg) = $(Cf_1 \times Cf_2 \times Cf_3 .... \times Cf_n)$ 1/n .. (1),

Where, Cn = *Concentration of metal* **n** in the edible part of food or vegetable sample**.** The MPI values are classified (Sharma *et al*., 2016; Rashed, 2010; Wu *et al*., 2015; Rai *et al*., 2019] in several contamination classes or scales, thus MPI value <1, no contamination; >1 and up to 2, moderate contamination; >2 and up to 3, moderate to strong contamination; >3 and up to 5, Very strong contamination.

The contribution of heavy metals accumulated in vegetables under study, to the metal pollution index (MPI) were obtained by putting the observed concentrations of Cd, Pb, Cr, Ni and Cu in the edible parts of vegetables in above equation (1). The results are compiled in Table 4.

Table 4 shows that the recorded MPI of all the ten fruit vegetables under study are >1 and up to 2, that may be placed in moderate category. The level of metal pollution index was lowest in *Bottle gourd* (1.08), while that of *Pointed guard* (1.57) was the highest and the overall order of MPI was: *Pointed guard* (1.57) >*Lady finger* (1.36) > *Capsicum* (1.30) > *French bean* (1.29) > *Indian bean* (1.24) >*Bitter gourd* (1.24) > *Tomato* (1.21)> *Sponge gourd* (1.18) > *Cucumber* (1.13) >*Bottle gourd* (1.08). Such elevated levels of metals in the concerned fruit vegetables are bound to aggravate the community health risk, in future on regular consumption of metal contaminated vegetables (Ghosh *et al.*, 2012; Paula *et al.*, 2016).

Assessment of Consumers Health Risk

The prolonged intake of heavy metals through dietary intake of vegetables, even at low concentrations has a consequence on human health, and after

Fig. 2. MPI Values of Fruit Vegetables

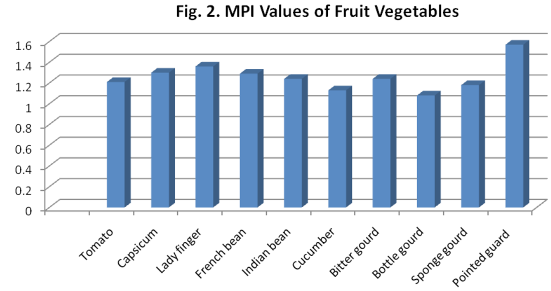


Table 4. Computed Values of Metal Pollution Index (MPI) for Fruit Vegetables

S. N.	Vegetables	MPI (mg/Kg)	S. N.	Vegetables	MPI(mg/Kg)
1.	Tomato	1.21	6.	Cucumber	1.13
2.	Capsicum	1.30	6.	Bitter gourd	1.24
3.	Lady finger	1.36	8.	Bottle gourd	1.08
4.	French bean	1.29	9.	Sponge gourd	1.18
5.	Indian bean	1.24	10	Pointed guard	1.57

Table 5. Daily Intake of Metals (DIM, mg/Kg/day/person) on taking Vegetables in Diet

Vegetables/Metals	Cadmium	Lead	Chromium	Nickel	Copper	Total
Tomato	0.331	0.603	0.867	0.561	0.374	2.736
Capsicum	0.391	0.620	0.799	0.501	0.518	2.829
Lady finger	0.348	0.909	0.748	0.459	0.604	3.068
French bean	0.323	0.880	0.769	0.523	0.433	2.928
Indian bean	0.289	0.748	0.735	0.391	0.416	2.579
Cucumber	0.361	0.663	0.633	0.446	0.378	2.481
Bitter gourd	0.374	0.688	0.621	0.497	0.518	2.698
Bottle gourd	0.306	0.727	0.616	0.378	0.404	2.431
Sponge gourd	0.323	0.739	0.714	0.412	0.442	2.632
Pointed guard	0.459	0.919	0.654	0.621	0.731	3.384

several years of exposure the detrimental effect becomes apparent (Liu *et al.*, 2005; Huang *et al.*, 2008). To assess the human health risk of heavy metals, it is necessary to calculate the level of human exposure to that metal by tracing the route of exposure of pollutant to human body (Adeel and Malik, 2014). As per US UPA reports (National Center for Environmental Assessment, 1997, US-EPA, IRIS, 2006), the human health risks are based on the heavy metal concentrations in edible parts of the food crops compared with the reference dose, consumer's vegetable intake and body weight. The estimation of consumer health risk due to toxicity of heavy metal contaminated vegetables depends upon daily intake of metals (DIM) through vegetables (Singh *et al.*, 2010), which is obtained as a function of consumer's body weight and vegetables consumed.

Daily intake of metals (DIM)

The daily intake of metals (**DIM**) through vegetables consumption was calculated using the following relation (Chary *et al.*, 2008).

DIM = **C***metal* x **C***factor* x **D***food intake* / **B***average weight* .. (2)

The significance of **C***metal*, **C***factor*, **D***food intake* and **B***average* weight are -

(a) **C***metal* represents the heavy metal concentrations in plants (mg /kg),

(b) The **C***factor* of 0.085 as conversion factor is used to convert fresh vegetable weight to dry weight. (Rattan *et al.*, 2005; USDA, 2007).

(c) **D***food intake* is the daily intake of vegetables (US-EPA, 1989d, 2010e). The WHO guidelines suggested the average daily intake of vegetables (Kacholi and Sahu, 2018) in human adult diet is from 300 to 350 g / person (Kacholi and Sahu, 2018, FAO/ WHO Tech Report, 1989). In the present study the minimum of the average daily intake value is taken as 300g/ adult consumer.

(d) **B***average* weight is the average body weight of consumer. The average body weight of 60 kg was taken for their daily intake of vegetable (Wang *et al.*, 2005; Sajjad Khan *et al.,* 2009; US-EPA, 1989d, 2010e).

The **DIM** values are presented in Table- 5. The range of daily metal intake of Cd, Pb, Cr, Ni and Cu varied for Cd from 0.289 to 0.459; for Pb from 0.603 to 0.919; for Cr from 0.616 to 0.867; for Ni from 0.378 to 0.621 and for Cu from 0.374 to 0.731 mg/Kg / day/person (Ramteke *et al.,* 2016). The order of total daily intake of tested five metals (mg/Kg/day/person) due to ingestion of ten fruit vegetables was : *Pointed gourd* (3.384) > *Lady finger* (3.068) > *French bean* (2.928) > Capsicum (2.829) > *Tomato* (2.736) > *Bitter gourd* (2.698) > *Sponge gourd* (2.632) > Indian bean (2.579) > Cucumber (2.481) > Bottle gourd (2.431).

Consumer health risk index (HRI)

The consumer health risk index (HRI) on consuming Cd, Pb, Cr, Ni and Cu contaminated fruit vegetables was evaluated using following relation (Jan *et al.*, 2010).

Health risk index, **HRI** = **DIM** / **R***fd* .. (3).

In the above relation, DIM is the daily intake of metals as above and the term R*fd* represents the reference oral dose (US-EPA IRIS, 2006).

The oral reference dose of the metal (US EPA, 2010, US EPA, 2013) is an approximation of daily tolerable exposure (Kacholi and Sahu, 2018) to which a person is expected to have without any significant risk of harmful effects during a life span.

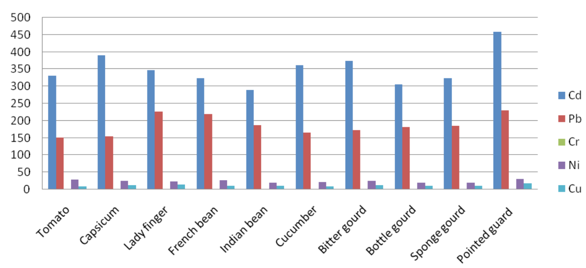
Table 6. Health Risk Index (HRI) values due to Accumulated Metals in Fruit Vegetables

Vegetables/Metals	Cadmium	Lead	Chromium	Nickel	Copper
Tomato	331	151	0.578	28.05	9.35
Capsicum	391	155	0.533	24.45	12.95
Lady finger	348	227	0.499	22.95	15.10
French bean	323	220	0.513	26.15	10.82
Indian bean	289	187	0.490	19.55	10.40
Cucumber	361	166	0.422	22.30	9.45
Bitter gourd	374	172	0.414	24.85	12.95
Bottle gourd	306	182	0.411	18.90	10.10
Sponge gourd	323	185	0.476	20.60	11.05
Pointed guard	459	230	0.436	31.05	18.27

The reported values of R*fd* as mg/kg/day for cadmium, chromium, copper, iron, lead, manganese and zinc are 0.001, 1.5, 0.04, 15, 0.004, 0.04, 0.14, 0.30 (US-EPA,1997, US-EPA IRIS, 2006), while that of nickel is 0.02, mg/Kg/day (US EPA, 2010).

Thus obtained **HRI** values for metals in studied vegetables are presented in Table-6. Among the fruit vegetables, HRI due to Cd was highest (>289) and the lowest HRI was due to Cr (<0.578),

Fig. 3 Health Risk Index due to Accumulated Metals in Vegetables



The overall order varied as : Cd (from 289 to 459) > Pb (from 151 to 230) > Ni (from 18.90 to 31.05) > Cu (from 9.35 to 18.27) >Cr (from 0.411 to 0.578). In all the vegetables, the order of HRI values due to accumulated metals was: Cd > Pb > Ni > Cu > Cr.

The order of HRI values due to Cd in vegetables was: *Pointed gourd* > *Capsicum* > *Bitter gourd* > *Cucumber* > *Lady finger* > *Tomato* > *French bean* > *Sponge gourd* > *Bottle gourd* > *Indian bean*. The order of HRI values in vegetables due to Pb was: *Pointed gourd* > *Lady finger* > *French bean* > *Indian bean* > *Sponge gourd* > *Bottle gourd* > *Bitter gourd* > *Cucumber* > *Capsicum* > *Tomato*; and due to Cr was: *Tomato* > *Capsicum* > *French bean* > *Lady finger* > *Indian bean* > *Sponge gourd* > *Pointed guard* > *Cucumber*> *Bitter gourd* > *Bottle gourd*. However, the order of HRI values due to Ni was: *Pointed gourd* > *Tomato* > *French bean* > *Bitter gourd* > *Capsicum* > *Lady finger* > *Cucumber* > *Sponge gourd* > *Indian bean* > *Bottle* gourd and due to Cu was: *Pointed guard* > *Lady finger* > *Capsicum* > *Bitter gourd.*> *Sponge gourd* > *French bean* > *Indian bean* > *Bottle gourd* > *Cucumber* > *Tomato.*

Conclusion

All the fruit vegetables under study differ in their potential to accumulate studied heavy metals, Cd, Pb, Cr, Ni and Cu. The order of accumulated metals in fruit vegetables under study was Pb > Cr > Ni > Cu > Cd. The MPI (mg/Kg) values for all studied vegetables were < 1 and the order was *Pointed gourd* (1.57) > *Lady finger* (1.36) > *Capsicum* (1.30) > *French bean* (1.29) > *Indian bean* (1.24) > *Bitter gourd* (1.24) > *Tomato* (1.21) > *Sponge gourd* (1.18) > *Cucumber* (1.13) > *Bottle gourd* (1.08). The order of consumer health risk index (HRI) based on the daily intake of metal (DIM) through consuming vegetables was found as: Cd (289-459) > Pb (151- 230) > Ni (18.90- 31.75) > Cu (9.35- 18.27) > Cr (0.411-0.578). Although, the observed results of this study indicated that accumulated levels of Cd, Pb, Cr, Ni and Cu in fruit vegetables under study were within the recommended safe limits established by regulatory authorities for human consumption, yet their regular intake bound to exert hazardous health risk.

The repeated use of treated or untreated sewage or waste water to irrigate crops for long is bound to contaminate the farm soil due to dissolved toxic chemicals and heavy metals that may result in the elevated level of accumulated metals in farm soil. Vegetables and other food crops grown on such soil may also bio-accumulate heavy metals in their roots, tubers, fruits, leaves and other above ground parts. Dietary intake of metal contaminated vegetables and other crop may in turn initiate heavy metal deposition in delicate, sensitive and physiologically important human organs impacting several health related risk that may take several years to become apparent and visible. Such risk is usually multiplied with a quantifiable exposure i.e. dose, time, etc. Regular monitoring of heavy metals in farm soil and water used to irrigate the crops will be a beneficial step to save the humanity by avoiding the risk and quantified hazards associated with the recurring accumulation of toxic metals in tissues and sensitive organs through food chain and sufferings from their un-repairable hazards.

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