www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating 2017: 5.03
TPI 2017; 6(9): 159-167

www.thepharmajournal.com
Received: 08-07-2017
Accepted: 09-08-2017

Arvind Kumar
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Manas Denre
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Ruplal Prasad
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Correspondence
Arvind Kumar
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Concentration of trace metals and potential health risk assessment via consumption of food crops in the South Chotanagpur of Jharkhand, India

Arvind Kumar, Manas Denre and Ruplal Prasad

Abstract
Metal contamination in agricultural soils is of increasing concern due to food safety issues and potential health risks. Accumulation of heavy/trace metals in plants occur by various sources but soil is considered the major one. Consumption of edible plant parts containing (heavy/trace) metals is one of the main ways in which these elements enter the human body. Once entered, heavy metals are deposited in human body, overlapping noble minerals and cause an array of diseases. The present study aimed to investigate the concentration of different metals in agricultural soil and also in plants grown on those soils for notice the possible health risks to human body through food chain transfer. Contamination levels in soils and plants with metals were measured and transfer factors (TF) from soil to plants and its health risk were calculated accordingly. Results showed that concentration of Zn, Cu, Fe, Mn, Pb, Ni, Co and Cd in soil is lower than the WHO/FAO value. The intake of metals (Zn, Cu, Fe, Mn, Pb, Ni, Co and Cd) in human body through plant is not high and was found within the permissible limit as recommended by WHO, Food and Nutritional Board and US EPA. The Health Risk Index (HRI), on the basis of metals (Zn, Cu, Fe, Mn, Pb, Ni and Co) concentration in all edible plant parts were found < 1.0 except mustard can be considered safe with no risk to human health, while in mustard HRI value of Mn (1.0593) was found slightly higher to 1.0 and this value for Pb and Ni were observed 2.5969 and 1.6720 indicates matter of concern and need comprehensive study on soil plant relationship in plateau areas of Jharkhand having a sheath of mines and industries. Considering the content of Mn, Pb and Ni in mustard, all the edible part of plants were good source of essential trace metals, they may provide the required amount of trace metals to human body with sufficient daily intake.

Keywords: daily intake; health risks index; trace elements concentration; soil and food crops; transfer factors

Introduction
Food safety is a major public concern worldwide. The increasing demand for food and food safety has drawn the attention of researchers to the risk associated with consumption of contaminated foodstuffs *i.e.*, pesticides, heavy metals and other toxic substances in vegetables [1, 2]. Plants are able to mobilize and accumulate nonessential trace elements because of chemical similarity to other essential elements or ions [3]. If excessive amounts of these trace elements are accumulated in a plant, a pathway is created for potentially hazardous trace elements to enter the food chain and impact on human health [4]. Mostly, the concentrations of heavy metal are higher in soil than vegetables grown on the same soils. This indicated that only a small portion of soil heavy metals is transferred to the vegetables and root acts as a barrier to the translocation of heavy metals within plant [5, 6]. Most of the heavy metals are the natural constituents of earth's crust and from there they are taken by plants and thus transferred to food chain. These metal concentrations vary from soil to soil. Metals concentration of vegetables mainly depends on the texture of soil or media on which they grow but this also depends on the type and nature of plant [7]. Heavy metal concentrations of plants is directly associated with their concentrations in soils, but their levels significantly differ with plant species, and even can also affected by genotypes within the same species [7]. Plants display a wide range of adaptations to soils with contrasting metal contents. Heavy metal uptake, translocation, and sequestration are key aspects of a plant's ability to accumulate and cope with high concentrations of heavy metals. Since plants originate from different growing areas, great differences in the uptake and concentrations of heavy metals in the plant tissue may be expected [8].
The uptake of heavy metals from soil to the edible parts of the plants is a significant path to

harm human health. It is therefore important to control and limit the accumulation of heavy metals in plants from soil. To accomplish this, we need to investigate the transfer characteristics of heavy metals from soil to plants. Further, the dietary intake of heavy metals through plants is very important for assessing their risk to human health. The knowledge of dietary intake of toxic elements in Jharkhand is limited. Therefore, this study evaluated the contamination level of (Fe, Co, Cu, Zn, Mn, Pb, Cd and Ni) heavy metals in common plants mostly consumed for health nutrition in Jharkhand and grown in farmer's fields of rural areas of Khunti district. Further, the plant transfer factor (PTF) and the daily intake of heavy metals were estimated to know the source of human exposure risk. Finally, the probabilistic risk assessment models were used to determine the health risks of heavy metals intake through plants of study area to specify the toxic level of heavy metals which cause health risks.

Materials and methods

Study area

The study area Khunti district is located at South Chotanagpur Division (Sub zone IV of ACZ VII) of Jharkhand, India ($N22^0$48'52.4" to $N23^0$26'40.7" and $E85^0$00'08.9" to $E85^0$37'32.6" and 234-694 msl) (Fig. 1). It is a smaller district in the state and comprising only six blocks and also having thin population (5, 31, 885 people). Khunti has the highest concentration of tribal populations in the state and more than 90% of people live in rural areas. The total geographical area of the district is 7, 59, 250 hectors and only 2, 76, 091 hectors are net sown area. The forest cover is about 18% (>40% canopy) of the total geographical area having hilly and forested terrains. Economy and livelihood of the tribal farmers mainly depend upon rain fed agriculture and trading of forestry products. The average rainfall varies from 1050 mm to 1500 mm. Agriculture is characterized by mono cropping practices with only the net irrigated area is 36,620 hectors, which is 14% the net cultivated area. Paddy based primary cropping system mainly adopted by the farmers in the district, while vegetables, mustard and pulses also in practice as secondary crop as per availability of water resources.

Fig 1: Location map of Khunti district (South Chotanagpur of Jharkhand, India).

Soil and plant sampling

GPS (Global Positioning System) enable fifty nine edible plant parts of different crop species and side by side soil samples (0.0-15.0 cm) were collected randomly from all around the six blocks of the Khunti district during January-February 2016. Soil samples were air-dried in shadow, ground on wooden pestle and mortar. After that soil samples were passed through 2.0 mm sieve and stored in properly labeled plastic bags for analysis. Processed soil samples were analyzed for pH, electrical conductivity (EC) by employing the method (1:2.5: soil: water) as outline by Jackson, [9] organic carbon (potassium dichromate and sulfuric acid method) by Walkley and Black [10]. The DTPA-extractable Zn, Cu, Fe, Mn, Pb, Ni and Co were extracted with di-ethelene tri-amine penta-acetic acid (DTPA) solution [11]. Hot water soluble boron of soils was estimated as per method outlined by Gupta [12] using Azomethine-H through UV-spectrophotometer at 420 nm.

Fresh weight of edible plant parts were taken after properly washing and air drying. Kept the plant samples in sun light for sun death and after that plant parts were kept for 5 hours in oven at 70 °C and moisture percentage in plants were determined after cooling the samples. Grinding was made following the standard procedure. Ground plant part (0.5 g) was taken in a conical flask and 10 mL of tri-acid mixture (HNO_3: $HClO_4$: H_2SO_4 in 10: 4: 1) was added. It was heated on a hot plate till complete digestion [13] in digestion chamber. The residues dissolved in double-distilled water and after completion of filtration (Whatman filter paper No. 42), its final volume was made to 25 mL. The concentration of Zn, Cu, Fe, Mn, Pb, Ni and Co in soil and plant samples were determined with the help of atomic absorption spectrophotometer (ECIL-4139).

Translocation factor (TF)

The transfer capability of trace elements from soil to the edible part of plants was generally described using the translocation factor [14] of trace metals and that calculated as follows:

$$TF = \frac{\text{Trace element concentration in edible plant part}}{\text{Trace element concentration in soil from where the plant was grown}}$$

Estimate Daily Intake of Trace Metal (DITM)

The average daily edible plant part intake was calculated by conducting a survey (during delineation programme of AICRP-MSPE) with 100 people having average body weight of 60 kg and age group 18 years to 70 years in study areas of the district and found rice is the main food stuff of tribal farmers and also they include sufficient vegetables in their daily diet that grown on their own field. DITM was calculated on the basis of 250g edible plant part in his/her daily diet by adopting the following equation:

$DITM = C_{metal} \times D_{\text{food intake}} / B_{average\ weight}$

Where, C_{metal}, $D_{food\ intake}$ and $B_{average\ weight}$ represent the metal concentration in edible plant part, daily intake of edible plant part and average body weight respectively [15].

Health Risk Index (HRI)

The health risk index was calculated as the ratio of estimated exposure of test edible plant part and oral reference dose [16]. Oral reference doses (RfDo) were depicted in Table 1. Estimated exposure is obtained by dividing daily intake of trace metals by their safe limits. An index more than 1.0 is considered as not safe for human health [17]. HRI was calculated by the following equation:

$HRI = DITM/RfDo$

Where, DITM and RfDo represent the daily Intake of Trace Metal and oral Reference Dose respectively.

Statistical Analysis

Concentrations of trace metals were calculated on a dry weight basis and fresh weight was converted by moisture content percentage. All analyses were replicated three times. To assess the concentration of trace metals, mean, minimum, maximum and standard deviation of samples. Analysis of variance (ANOVA) test for assessing the significance of differences in trace metal concentrations due to performed by using Microsoft Excel (Version 2007).

Results and discussion

Moisture content in edible parts of plant

Moisture content in edible part of plant were observed higher in radish (93.12%) followed by tomato (92.99%) and cauliflower (91.44%), while lower content of moisture 10.23% was observed in mustard seed followed by 16.99% in rice grain (Table 2).

Various elements content in edible part of plant

Fresh vegetables are important sources of nourishment and a vital ingredient in healthy and balance diets. Vegetable has nutritive significance due to enrichment of minerals and vitamins, which is essential for the maintenance of good health of human, particularly resource poor vegetarian tribal farmers they mostly include rice and vegetables in their daily diet. The overall concentrations of the each element in tested edible part of plant samples are shown in Table 3. The concentrations of Zn, Cu, Fe, Mn ranged from 1.82 (tomato) to 39.41 mg kg^{-1} (mustard), 0.13 (radish) to 1.32 mg kg^{-1} (rice), 4.57 (Radish) to 121.19 mg kg^{-1} (mustard), 1.81 (Radish) to 35.59 mg kg^{-1} (mustard), while range of B, S, Ca, Mg were observed 0.12 (ladies finger) to 3.48 (mustard), 1.38 (tomato) to 31.31 (mustard), 1.52 (tomato) to 66.03 (rice), 15.97 (potato) to 352.6 (mustard), in the other hand content of heavy metal *viz*., Pb, Ni and Co found in the range of 0.05 (radish) to 2.18 (mustard), 0.06 (cauliflower) to 8.03 (mustard) and 0.03 (carrot) to 2.76 (rice) mg kg^{-1} with their mean value 7.33 (Zn), 0.56 (Cu), 21.34 (Fe), 8.15(Mn), 0.78 (B), 7.25 (S), 11.48 (Ca), 82.56 (Mg), 0.47 (Pb), 0.88 (Ni), 0.52 (Co) mg kg^{-1}, respectively. Experimental result showed that among all the edible part of plants, edible part of mustard and rice content of elements were significantly higher than others. The concentration of elements in edible part of plants found in the order of Mg>Ca>Fe>Mn>Zn>S>B>Cu>Ni>Co>Pb, which agreed with the findings of Khan *et al*. [18] in the vegetables that grown at Dhaka, Bangladesh, they found the trend of metals content Fe>Mn>Zn>Cu >Co in vegetables. Moreover, Jena *et al*. [19] also reported that the concentration of heavy metals in vegetables was in order of Zn> Fe> Cu>Pb>Mn after study on vegetable grown in industrial area of Chhattisgarh. A decreasing order of Fe>Zn>Mn>Cu>Ni>Pb also reported by Mahakalkar *et al*. [20] in vegetables of Mahalgaon, Nagpur, Maharashtra, India. The average concentrations of trace metals in vegetable samples in decreasing order: Zn>Cu >Ni>Pb>Cd also reported by Islam and Hoque [21]. The mean concentrations of trace metals in various vegetable species collected from the study area were compared with the standards set for plants by FAO and WHO, [22] Awashthi [23] (Table 3). Since, Pb in some vegetables exceeded the EU, 2002 standards in food (Table 3), which agreed with the findings of Ghosh *et al*. [24] in the vegetables from Ranchi, Jharkhand, India, they were reported that the concentration of Pb content varies from 0.466 to 12.066 mg kg^{-1} that was exceeded the EU [25] (0.30 mg kg^{-1}) standards in plant.

Trace elements content in soil

Trace elements content in soil (Table 4) that collected side by side from the standing crop of farmers field of Khunti district varied from 0.47 to 4.74, 0.38 to 2.10, 37.30 to 81.52 and 26.90 to 39.80 for Zn, Cu, Fe and Mn respectively, while B, Pb, Ni and Co content ranged from 0.25 to 2.31, 1.31 to 2.10, 0.62 to 2.79 and 0.09 to 3.79 for with their mean value 1.43 (Zn), 1.12 (Cu), 52.06 (Fe), 34.03 (Mn), 0.68 (B), 1.50 (Pb), 1.46 (Ni) and 1.37 (Co) mg kg^{-1}. Comparatively low content of Cu, Pb, Ni, Co and high content of Zn, Fe and Mn in soil of Khunti district were noticed that situated in sub zone IV of ACZ VII to earlier reported value of element content by Kumar *et al*. [26] in soil of adjoining area of Subarnarekha Multipurpose Command Project, East Singhbhum of Jharkhand, India that situated in sub zone VI of ACZ VII. The trend of the average content of heavy metal in soil of studied areas found in following order Fe > Mn > Pb > Ni > Zn > Co> Cu>Cd. Content in soil of all these element was found below the respective toxic limit as per reported permissible limit by World Health Organization (WHO) and Food and Agricultural Organization (FAO).

Transfer factor for trace elements

Transfer factor (TF) in edible parts of plant is one of the key components of human exposure to trace elements through the food chain. It determined to quantify the relative difference in bioavailability of trace elements to plants or to identify efficiency of plant species to accumulate a given trace elements. TF of trace elements for plants grown at Khunti district were computed and noticed in the range of 1.42 to 37.34 (Zn), 0.09 to 1.03 (Cu), 0.08 to 1.70 (Fe), 0.05 to 0.91 (Mn), 0.20 to 4.15 (B), 0.04 to 1.65 (Pb), 0.04 to 5.21 (Ni) and 0.05 to 19.56 (Co). Mean value of transfer factor for Zn, Cu, Fe and Mn were observed 6.15, 0.52, 0.36 and 0.24, while this value for B, Pb, Ni and Co were found 1.11, 0.33, 0.59 and 1.96 respectively (Table 5). Trend of the metal transfer factor from soil to edible parts of plant was found in the order Mn>Pb>Fe>Cu>Ni>B>Co>Zn. Moreover, Mahakalkar *et al*. [20] and Mahmood and Malik [27] also reported transfer factor in some vegetable species in order of Zn>Fe>Cu>Ni>Mn>Pb. The TF for Zn of all the edible plant parts were found >1.0 that indicated the plants are good accumulator of this element particularly in sedentary acidic soil. Among all the plant samples, TF for Fe, Mn, Cu, Pb, Ni and Co is <1.0 except B and Co in rice, Cu and B in Chilli, Co in cauliflower, B in dolicous bean and Fe, B, Pb, Ni and Co in mustard due to the indigenous crop species generally grown by the farmers.

Potential human Health risk posed by the consumption of edible part of plant

The value estimated daily intake of trace metals by human being from the consumption of the plants grown around Khunti district are presented in Table 6. In view of the dietary pattern on the Khunti district where edible plant part is taken as part of daily diet average (vegetables + rice) of 250 g fresh weight per day and an average human body weight of 60 kg. The daily intake of Zn, Cu, Fe, Mn, Pb, Ni and Co from edible plant parts 0.0305, 0.0023, 0.0889, 0.0340, 0.0019, 0.0037, 0.0022 mg, respectively. From this data, it can be observed that mustard is relative high accumulator of trace metals as compared to other edible part of plants (Fig. 2). The sequence of mean values of DITM in general for the elements were found in decreasing order Fe>Mn>Zn>Ni>Cu>Co>Pb. Calculated health risk index (HRI) for all the trace metals were found <1.0 (Table 7) in all edible part except mustard (Fig. 3) and can be advocated safe with no risk to human health. The HRI value for Zn, Cu, Fe, Mn, Pb, Ni and Co for mixed edible parts of plant was observed 0.1018, 0.0581, 0.1270, 0.2426, 0.5590, 0.1834 and 0.0502, respectively and followed a sequence of increasing order is Co<Cu<Zn<Fe<Ni<Mn<Pb <1.0 therefore, if farmers of study areas intake 250g fresh mixed edible parts of plant in their diet per day there his/her no risk for health.

Kumar *et al*. [26] observed wide variation and higher accumulation of Fe, Zn, Cu and Mn in plant species collected from rural areas of Jharkhand. Our results also highlighted that (Table 8) on the basis of analyzed trace metal content in edible part of plant that were grown in farmers' field, if farmers use 250g fresh edible part of plant per day in their diet, even then it does not fulfill the recommended nutrition. A wider gap in recommended and supplement amount of Zn, Cu, Mn and Fe was found in dietary allowance per day (Table 8) for people living in rural areas in Khunti district. Singh [28] also reported that if micronutrient availability in soil is adequate for crop production, then the soil may not necessarily produce fodder and concentrates rich in micronutrient from the point of view of animal health.

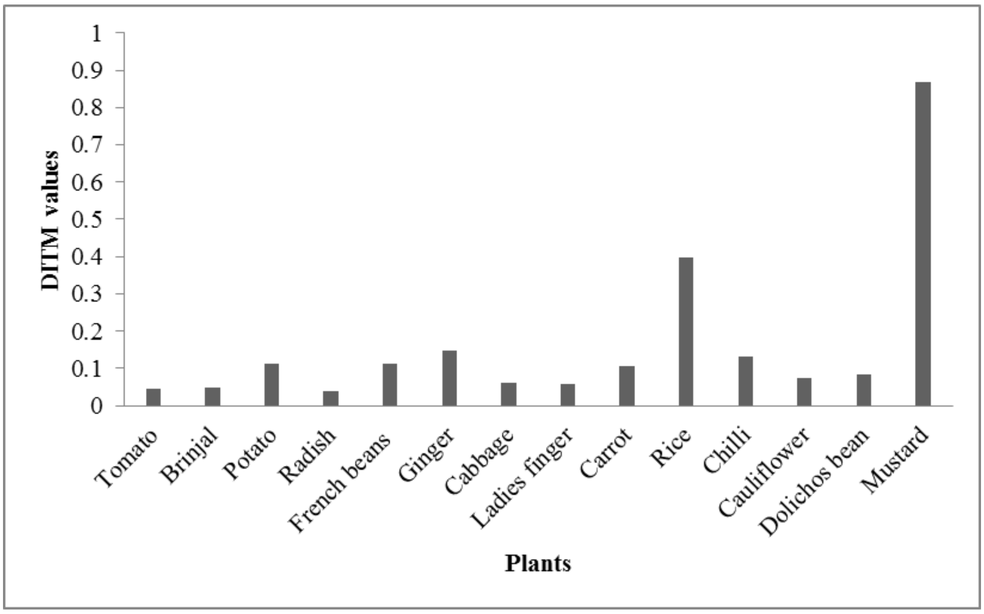


Fig 2: The DITM value of edible plant parts for seven metals: Zn, Cu, Fe, Mn, Pb, Ni and Co.

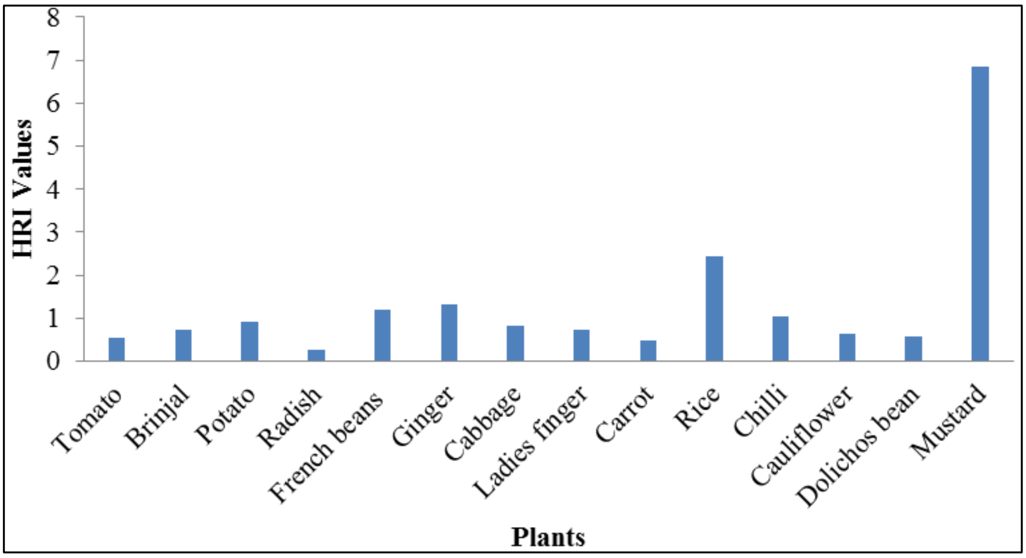


Fig 3: The HRI value of edible plant parts for seven metals: Zn, Cu, Fe, Mn, Pb, Ni and Co.

Table 1. Oral Reference Doses (RfDo).

Trace metal	RfDo (mg/kg/day)	Reference
Zn	3.0×10^{-1}	USEPA [31-33]
Cu	4.0×10^{-2}	
Fe	7.0×10^{-1}	
Mn	1.4×10^{-1}	
Ni	2.0×10^{-2}	
Pb	3.5×10^{-3}	WHO [34]
Co	4.3×10^{-2}	Food and Nutrition Board [35]

Table 2. Moisture content (MC) of edible parts of plant collected from different sites of Khunti district in Jharkhand.

Name of Crop	Edible part of vegetable	Family	Botanical name	No. of sample	MC (%)
Tomato	Fruit	Solanaceae	*Solanum lycopersicum*	11	92.99
Brinjal	Fruit	Solanaceae	*Solanum melongena*	7	90.11
Potato	Modified stem	Solanaceae	*Solanum tuberosum*	9	78.29
Radish	Modified root	Brassicaceae	*Raphanus sativus*	6	93.12
French beans	Fruit	Zingiberaceae	*Phaseolus vulgaris*	3	86.55
Ginger	Rhizome	Amaranthaceae	*Zingiber officinale*	2	89.33
Cabbage	Leaf	Brassicaceae	*Brassica oleracea* var. capitata	2	91.21
Ladies finger	Fruit	Malvaceae	*Abelmoschus esculentus*	2	90.01
Carrot	Modified root	Apiaceae	*Daucus carota* subsp. sativus	2	86.11
Rice	Grain	Poaceae	*Oryza sativa*	3	16.09
Chilli	Fruit	Solanaceae	*Capsicum annuum*	3	82.66
Cauliflower	Modified flower	Brassicaceae	*Brassica oleracea* var. botrytis	2	91.44
Dolichos bean	Fruit	Fabaceae	*Lablab purpureus* L.	5	87.42
Mustard	Seed	Brassicaceae	*Brassica rapa* L.	2	10.23

Table 3: Different elements content [Fresh weight basis (mg/kg)] in edible plant part.

Name of Crop	Zn	Cu	Fe	Mn	B	S	Ca	Mg	Pb	Ni	Co
Tomato	1.82	0.45	6.18	1.99	0.21	1.38	1.52	17.28	0.28	0.14	0.19
Brinjal	2.04	0.64	5.61	2.39	0.38	2.58	2.86	34.44	0.41	0.12	0.27
Potato	5.19	0.97	16.36	3.72	0.79	4.21	1.86	15.97	0.35	0.45	0.10
Radish	2.56	0.13	4.57	1.81	0.22	2.89	3.80	28.70	0.05	0.23	0.19
French beans	5.29	0.60	11.50	8.16	0.68	5.53	6.02	55.91	0.56	0.19	0.34
Ginger	6.23	0.40	16.27	11.64	0.25	3.82	8.14	37.45	0.58	0.08	0.38
Cabbage	2.37	0.14	4.58	7.02	0.29	3.19	13.63	42.43	0.42	0.12	0.21
Ladies finger	2.57	0.35	7.54	3.14	0.12	2.00	4.06	40.00	0.40	0.11	0.17
Carrot	5.57	0.13	15.32	3.90	0.65	5.91	5.60	33.63	0.11	0.22	0.03
Rice	17.55	1.32	55.31	16.70	2.57	27.67	66.03	314.71	0.54	1.57	2.76
Chilli	4.28	1.10	19.30	4.91	0.60	4.57	7.31	91.44	0.33	0.83	0.45
Cauliflower	3.39	0.32	5.54	7.94	0.16	2.28	3.51	37.98	0.22	0.06	0.10
Dolichos bean	4.29	0.60	9.51	5.19	0.54	4.20	6.10	53.29	0.15	0.18	0.28
Mustard	39.41	0.63	121.2	35.59	3.48	31.31	30.21	352.6	2.18	8.03	1.76
Range	1.82-39.41	0.13-1.32	4.57-121.2	1.81-35.59	0.12-3.48	1.38-31.31	1.52-66.03	15.97-352.6	0.05-2.18	0.06-8.03	0.03-2.76
Mean	7.33	0.56	21.34	8.15	0.78	7.25	11.48	82.56	0.47	0.88	0.52
CD ($p \leq 0.05$)	0.87	0.27	1.44	0.82	0.28	0.90	1.03	3.27	0.18	0.16	0.16
Guideline for safe limits											
Indian Standard[23]	50.00	30.00	-	-					2.50	-	-
WHO/FAO[22]	60.00	40.00	450.0	500.0	-	-	-		5.00	-	-
European Union Standards[25]	60.00	40.00	-	-	-	-	-		0.30	-	-
World Health Organization (WHO), Food and Agricultural Organization (FAO) and Ewers U, Standard Guidelines in Europe[34]	100.0	73.00	425.0	500.0	-	-	-		0.30	67.00	50.00

Table 4: Trace element concentration in soil from where the plant was grown.

Name of Crop	Zn	Cu	Fe	Mn	B	Pb	Ni	Co
Tomato	0.98	1.33	50.27	28.89	0.42	1.32	1.33	1.78
Brinjal	1.02	1.14	47.59	34.74	0.67	1.31	0.87	2.13
Potato	1.64	1.15	51.32	35.09	0.96	1.52	2.79	1.82
Radish	1.80	1.41	56.88	33.93	1.08	1.42	2.36	2.04
French beans	0.82	1.45	81.52	28.93	0.32	1.63	0.72	3.79
Ginger	1.30	0.77	37.30	26.90	0.37	1.33	1.74	1.93
Cabbage	1.30	0.77	37.30	26.90	0.37	1.33	1.74	1.93
Ladies finger	1.54	0.38	46.60	38.20	0.60	1.64	0.62	0.48
Carrot	1.54	0.38	46.60	38.20	0.60	1.64	0.62	0.48
Rice	0.47	2.09	66.67	34.93	0.62	2.10	1.91	0.58
Chilli	0.97	1.07	46.48	34.93	0.49	1.61	1.26	0.57
Cauliflower	0.58	0.74	37.60	39.80	0.25	1.34	1.38	0.10
Dolichos bean	1.28	0.89	51.36	35.80	0.51	1.54	1.52	1.41
Mustard	4.74	2.10	71.40	39.20	2.31	1.32	1.54	0.09
Range	0.47-4.74	0.38-2.10	37.30-81.52	26.90-39.80	0.25-2.31	1.31-2.10	0.62-2.79	0.09-3.79
Mean	1.43	1.12	52.06	34.03	0.68	1.50	1.46	1.37

Table 5: Translocation factor (TF) of trace metals from soil to edible plant part.

Crops	Zn	Cu	Fe	Mn	B	Pb	Ni	Co
Tomato	1.86	0.34	0.12	0.07	0.50	0.21	0.11	0.11
Brinjal	2.00	0.56	0.12	0.07	0.57	0.31	0.14	0.13
Potato	3.16	0.84	0.32	0.11	0.82	0.23	0.16	0.05
Radish	1.42	0.09	0.08	0.05	0.20	0.04	0.10	0.09
French beans	6.45	0.41	0.14	0.28	2.13	0.34	0.26	0.09
Ginger	4.79	0.52	0.44	0.43	0.68	0.44	0.05	0.20
Cabbage	1.82	0.18	0.12	0.26	0.78	0.32	0.07	0.11
Ladies finger	1.67	0.92	0.16	0.08	0.20	0.24	0.18	0.35
Carrot	3.62	0.34	0.33	0.10	1.08	0.07	0.35	0.06
Rice	37.34	0.63	0.83	0.48	4.15	0.26	0.82	4.76
Chilli	4.41	1.03	0.42	0.14	1.22	0.20	0.66	0.79
Cauliflower	5.84	0.43	0.15	0.20	0.64	0.16	0.04	1.00
Dolichos bean	3.35	0.67	0.19	0.14	1.06	0.10	0.12	0.20
Mustard	8.31	0.30	1.70	0.91	1.51	1.65	5.21	19.56
Range	1.42-37.34	0.09-1.03	0.08-1.70	0.05-0.91	0.20-4.15	0.04-1.65	0.04-5.21	0.05-19.56
Mean±SD	6.15±9.21	0.52±0.28	0.36±0.43	0.24±0.24	1.11±1.01	0.33±0.40	0.59±1.35	1.96±5.21

Table 6: Daily intake of trace metal (mg/person/day) from edible part of plant growing in Khunti district of Jharkhand.

Name of Crop	Zn	Cu	Fe	Mn	Pb	Ni	Co
Tomato	0.0076	0.0019	0.0257	0.0083	0.0012	0.0006	0.0008
Brinjal	0.0085	0.0027	0.0234	0.0099	0.0017	0.0005	0.0011
Potato	0.0216	0.0040	0.0682	0.0155	0.0014	0.0019	0.0004
Radish	0.0107	0.0006	0.0190	0.0075	0.0002	0.0010	0.0008
French beans	0.0221	0.0025	0.0479	0.0340	0.0023	0.0008	0.0014
Ginger	0.0260	0.0017	0.0678	0.0485	0.0024	0.0003	0.0016
Cabbage	0.0099	0.0006	0.0191	0.0293	0.0017	0.0005	0.0009
Ladies finger	0.0107	0.0015	0.0314	0.0131	0.0016	0.0004	0.0007
Carrot	0.0232	0.0005	0.0638	0.0163	0.0005	0.0009	0.0001
Rice	0.0731	0.0055	0.2305	0.0696	0.0022	0.0065	0.0115
Chilli	0.0179	0.0046	0.0804	0.0205	0.0014	0.0035	0.0019
Cauliflower	0.0141	0.0013	0.0231	0.0331	0.0009	0.0002	0.0004
Dolichos bean	0.0179	0.0025	0.0396	0.0216	0.0006	0.0008	0.0012
Mustard	0.1642	0.0026	0.5050	0.1483	0.0091	0.0334	0.0073
Mean	0.0305	0.0023	0.0889	0.0340	0.0019	0.0037	0.0022

Table 7: Health Risk Index (HRI).

Name of Crop	Zn	Cu	Fe	Mn	Pb	Ni	Co
Tomato	0.0253	0.0473	0.0368	0.0592	0.3288	0.0296	0.0185
Brinjal	0.0283	0.0672	0.0334	0.0711	0.4886	0.0253	0.0263
Potato	0.0720	0.1009	0.0974	0.1106	0.4135	0.0941	0.0097
Radish	0.0356	0.0140	0.0272	0.0539	0.0606	0.0476	0.0185
French beans	0.0735	0.0628	0.0685	0.2428	0.6613	0.0395	0.0334
Ginger	0.0866	0.0419	0.0969	0.3465	0.6910	0.0164	0.0370
Cabbage	0.0329	0.0150	0.0272	0.2090	0.4971	0.0255	0.0204
Ladies finger	0.0357	0.0368	0.0449	0.0933	0.4710	0.0225	0.0162
Carrot	0.0774	0.0136	0.0912	0.1161	0.1323	0.0454	0.0032
Rice	0.2438	0.1372	0.3292	0.4970	0.6393	0.3269	0.2675
Chilli	0.0595	0.1151	0.1149	0.1462	0.3984	0.1727	0.0434
Cauliflower	0.0471	0.0336	0.0330	0.2364	0.2650	0.0125	0.0100
Dolichos bean	0.0596	0.0625	0.0566	0.1546	0.1827	0.0377	0.0275
Mustard	0.5473	0.0655	0.7214	1.0593	2.5969	1.6720	0.1705
Mean	0.1018	0.0581	0.1270	0.2426	0.5590	0.1834	0.0502

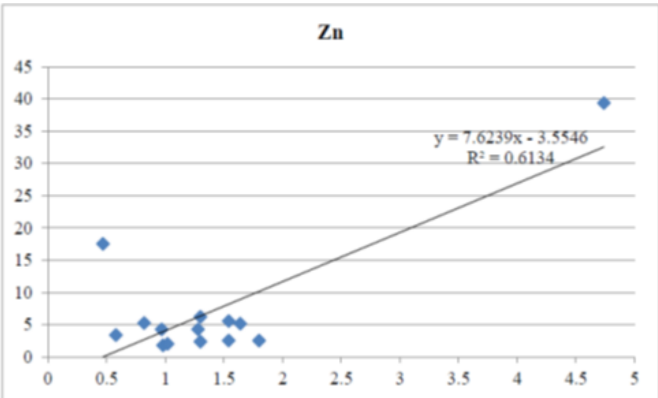
Table 8: Recommended Dietary allowance of Trace metals in Khunti district on the basis of trace metal availability in edible part of plant.

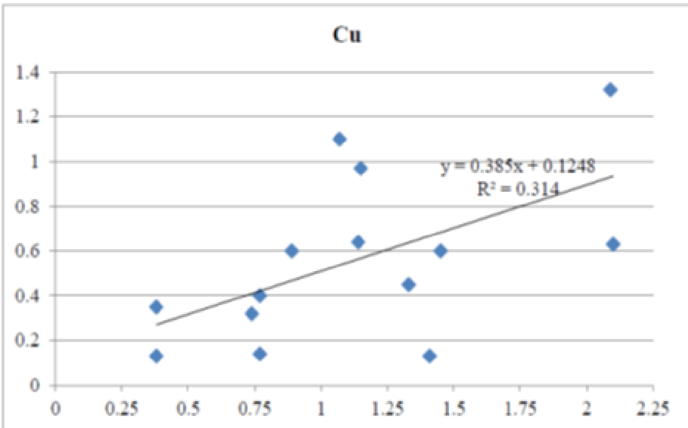
Category	Age (Year)	Fe			Zn		
		Recommended** mg day^{-1}	Intake mg day^{-1}* 250 gm	% gap in nutrition supplement	Recommended mg day^{-1}	Intake mg day^{-1} 250 gm	% gap in nutrition supplement
Children	4-10	10	5.34	46.60	10	1.83	81.70
Male	11+	12	5.34	55.50	12	1.83	84.75
Female	11+	15	5.34	64.40	15	1.83	87.80
Category	**Age (Year)**	**Cu**			**Mn**		
		Recommended mg day^{-1}	**Intake mg day^{-1} 250 gm**	**% gap in nutrition supplement**	**Recommended mg day^{-1}**	**Intake mg day^{-1} 250 gm**	**% gap in nutrition supplement**
Children	4-6	1.0-1.5	0.14	88.80	1.5-2.0	2.04	-
	7-10	1.0-2.0	0.14	90.67	2.0-3.0	2.04	18.40
Adult	11+	1.5-3.0	0.14	93.78	2.0-5.0	2.04	41.71

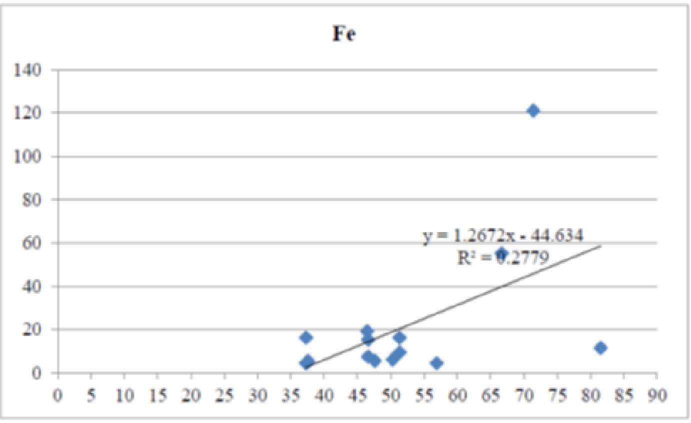
*Calculation of daily intake of trace metal based on mean value of content and moisture percent in edible part of 250 g fresh mixed edible part of plant. **Recommended dietary allowance reported by Food and Nutrition Board (1989)

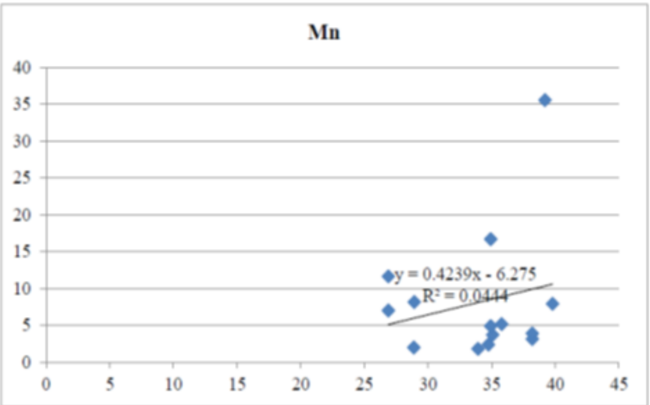
Correlation between available content of heavy metals in soils and heavy metals in plants

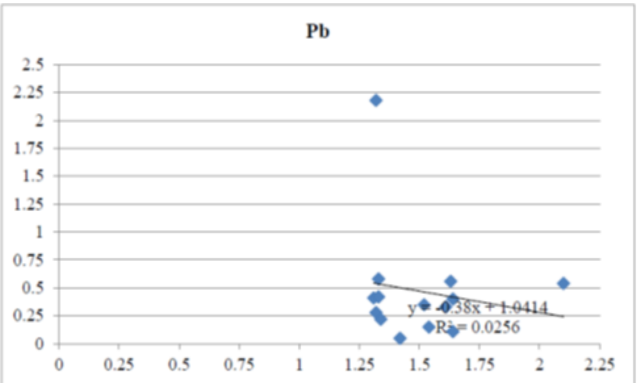
In order to evaluate the possible impact of soils on heavy metals accumulation in plants, Spearman's correlation coefficient between the available heavy metals in soils and the same heavy metals in plants were determined. Significant positive correlation at the level of $P \leq 0.01$ was found for Zn (r=0.783) and at the level of $P \leq 0.05$ for Cu (r=0.560) (Fig. 4). No significant correlation were found for Fe (r=0.527), Mn (r=0.211) Pb (r=-0.160), Ni (r=0.091) and Co (r=-0.331). Consistent with our results, Ahmad *et al.* 2015 and Demkova *et al.* [29] reported significant positive correlation between plant and soil heavy metals for Zn and Cu. They also reported significant positive correlation between plant and soil for Ni, which was not confirmed in our study. Demkova *et al.* [29] also reported no significant correlation between plant and soil for Fe and Co, which was confirmed in our study. Moreover, Kloke [30] reported that usually Pb is tightly fixed in soils and that Zn and Cu absorbed readily by plants.

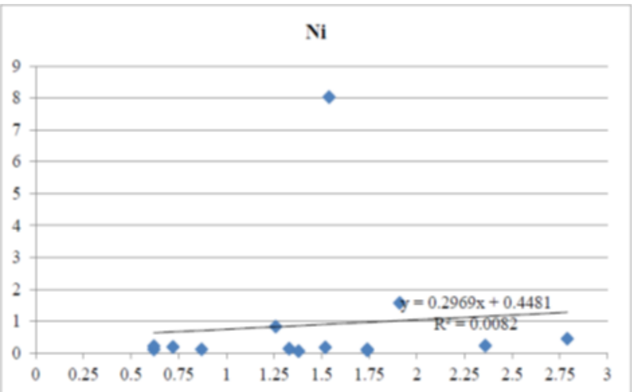












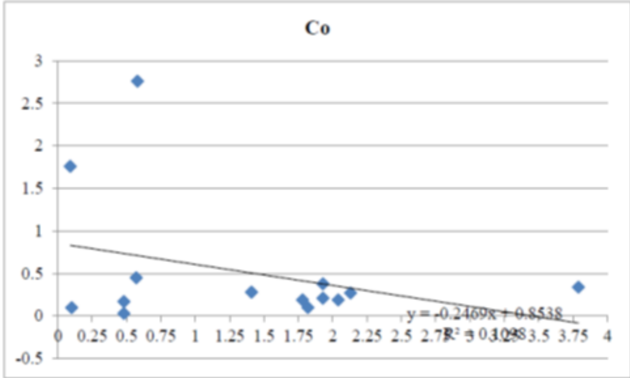


Figure 4. Relationships between available forms of heavy metal content in soil (x axis) and plant heavy metal (y axis) in mg kg^{-1} FW.

Conclusion

Several national and international health associations are working all over the world for creating novel health standards. But under developed countries like India still have a little information regarding maintaining the standard composition. Experimental result clearly reflected that in study area trace elements content in edible part of different varieties of crop were found low and that not supplement the daily requirement of trace metal in human body. On the other hand all the heavy metals content (Pb, Ni and Co) in edible part of various type of crop grown in this area was safe for human consumption except mustard that belongs to brassica family and is a heavy accumulator of heavy metals. Agronomical and genetical approaches should be adopted for increase the transfer factors of essential micronutrient for human health and also to restrict the uptake of toxic metal in plant.

Acknowledgements

Authors are grateful to the Indian Council of Agricultural Research, New Delhi for providing necessary financial assistance and also department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi-834006, Jharkhand, India for all laboratorial supporting to this research work.

References

1. DMello JPF. Food safety: Contaminants and Toxins. CABI Publishing, Wallingford, Oxon, UK, Cambridge, MA, 2003, 480.
2. Gholizadeh-Abdollatif A, Ardalan M, Mohammadi MT, Hosseini HM, Karimian N. Solubility Test in Some Phosphate Rocks and their Potential for Direct Application in Soil. World Applied Sciences J 2009; 6:182-190.
3. Berrow ML, Burridge JC. Uptake, Distribution and Effects of Metal Compounds on Plants. In: (ed. Merian E.). Metals and Their Compounds in the Environment. Weinheim, New York, 1991, 399-407.
4. Siegel FR. Environmental Geochemistry of Potentially Toxic Metals. Springer, Berlin, 2002.
5. Tsoumbaris P, Tsoukali-Papadopoulou H. Heavy metals in common foodstuff: daily intake. Bulletin of Environmental Contamination and Toxicology 1994; 53:67-70.
6. Davies BE, White HM. Trace elements in vegetables grown on soils contaminated by base metal mining. Journalof Plant Nutrition 1981; 3:387-396.
7. Pendias AK, Pendias H. Trace Elements in Soils and Plants. CRC, Press Boca Raton, FL.

8. Mohammed N, Khamis F. Assessment of heavy metal contamination in vegetables consumed in Zanzibars. Natural Sciences 2012; 4:588-594.
9. Jackson ML. Soil Chemical Analysis. Prientice Hall of India Pvt. Ltd. New Delhi. Lindsay, W.L. and Norvell, W.A. (1978) Development of DTPA soil test for Zn, Fe, Mn and Cu. Soil Science Society of America Journal 1973; 42:421-428.
10. Walkley AJ, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science 1934; 37:29-38.
11. Lindsay WL, Norvell WA. Development of DTPA soil test for Zn, Fe, Mn and Cu. Soil Science Society of America Journal 1978; 42:421-428.
12. Gupta SK, Stewart JWB. The extraction and determination of plant available boron in soils. Schweiz Landwirtsch Forsch. 1975; 14:153-169.
13. Piper CS. *Soil and Plant Analysis*. Indian Edn. Hans Publisher, Bombay, 1966.
14. Tsafe I, Hassan LG, Sahabi DM, Alhassan Y, Bala BM. Evaluation of Heavy Metals Uptake and Risk Assessment of Vegetables Grown in Yargalma of Northern Nigeria. Journal of Basic and Applied Scientific Research 2012; 2:6708-6714.
15. Singh A, Sharma RK, Agrawal M, Marshall FM. Risk assessment of heavy metal toxicity through contaminated vegetables from wastewater irrigated area of Varanasi, India. Tropical Ecology 2010; 51:375-87.
16. Cui YJ, Zhu YG, Zhai RH, Chen DY, Huang YZ, Qui Y *et al*. Transfer of metals from soil to vegetables in an area near a smelter in Nanning. China Environment International 2004; 30:785-791.
17. USEPA (United States Environmental Protection Agency), Region 9, Preliminary Remediation Goals, 2002. Available at: http://www.epa.gov/region09/waste/sfund/prg.
18. Ahmad K, Khan ZI, Ashfa A, Khan A, Shad HA, Sher M, *et al*. Assessment of metals and metalloids in vegetable crop irrigated with domestic wastewater in Peri-Urban areas of Khushab City, Pakistan. Fresenius Environmental Bulletin 2015; 243:404-3408.
19. Jena V, Dixit S, Gupta S. Risk assessment of heavy metal toxicity through edilbe vegetables from industrial area of Chhattisgarh. International Journal of Research in Environmental Science and Technology 2012; 2:124-127.
20. Mahakalkar AS, Gupta RR, Nandeshwar SN. Bioaccumulation of Heavy Metal Toxicity in the Vegetables of Mahalgaon, Nagpur, Maharashtra (India). Current World Environment. 2013; 8:463-468.
21. Islam Md S, Hoque MF. Concentrations of heavy metals in vegetables around the industrial area of Dhaka city, Bangladesh and health risk assessment. International Food Research Journal. 2014; 21:2121-2126.
22. FAO/WHO. Joint FAO/WHO Food Standards Program Code Alimentarius Commission 13th Session," Report of the Thirty Eight Session of the Codex Committee on Food Hygiene, Houston, Texas, USA, 2007. ALINORM 07/30/13.
23. Awasthi SK. Prevention of food Adulteration Act No. 37 of 1954. Central and State Rules as Amended for 1999, third ed. Ashoka Law House, New Delhi, 2000.
24. Ghosh R, Xalxo R, Ghosh M. Estimation of heavy metal in vegetables from different market sites of tribal based Ranchi city through ICP-OES and assess health risk. Current World Environment. 2013; 8:435-444.
25. European Union. Heavy Metals in Wastes, European Commission on Environment, 2002. Available at: http://ec.europa.eu/ environment/waste/studies/pdf/heavymetalsreport.pdf.
26. Kumar A, Kumar K, Singh MK, Denre M, Sarkar AK. Trace Metal Content in Plants and Potential Risk for Human Health in Subarnarekha Command Area of Ghatsila (East Singhbhum), Jharkhand. Journal of the Indian Society of Soil Science. 2016; 64:193-197.
27. Mahmood A, Malik RN. Human health risk assessment of heavy metals via consumption of contaminated vegetables collected from different irrigation sources in Lahore, Pakistan. Arabian Journal of Chemistry. 2014; 7:91-99.
28. Singh MV. Micronutrient nutritional problems in soils of India and improvement for human and animal health. Indian Journal of Fertilizers. 2009; 5:11-16.
29. Demkova L, Arvay J, Bobulska L, Tomas J, Stanovic R, Losak T *et al*. Accumulation and environmental risk assessment of heavy metals in soil and plants of four different ecosystems in a former polymetallic ores mining and smelting area (Slovakia). Journal of Environmental Science and Health Part A 2017; 52:479-490.
30. Kloke A, Sauerbeck DR, Vetter H. The contamination of plants and soils with heavy metals and the transport of metals in terrestrial food chains. Changing Metal Cycles and Human Health. 1984; 28:113-141.
31. USEPA (United States Environmental Protection Agency). USEPA Regional Screening Level (RSL) Summary Table: November 2011. Available at: http://www.epa.gov/regshwmd/risk/human/Index.htm.
32. USEPA (United States Environmental Protection Agency). EPA Region III Risk-Based Concentration (RBC) Table 2008 Region III, 1650 Arch Street, Philadelphia, Pennsylvania, 2012, 19103.
33. US EPA (United States Environmental Protection Agency). Reference dose (RfD): Description and use in health risk assessments, Background Document 1A, Integrated risk information system (IRIS); United States Environmental Protection Agency: Washington, DC, 15 March 2013, http://www epa.gov/iris/rfd.htm.
34. WHO (World Health Organization). Evaluation of Certain Food Additives and Contaminants. In: Forty-First Report of the Joint FAO/WHO Expert Committee on Food Additives, WHO, Geneva, Switzerland, 1993. (WHO Technical Series, 837).
35. Food and Nutrition Board.. Dietary Reference Intakes [DRIs]: Recommended Intakes for Individuals. National Academy of Sciences, Washington, DC, USA, 2004.