Research Paper

Determination of Trace Elements Contents in Rice and Vegetables Cultivated in Selected Districts of Sri Lanka

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Abstract

Rice and vegetables are major components in Sri Lankan meal and the accumulation of trace elements in edible crops is a major concern today. Therefore, this study was conducted to find out the levels of toxic trace elements in rice and vegetables produced in selected districts of Sri Lanka. One hundred rice grain samples were collected using multistage random sampling technique from Ampara, Anuradhapura and Kurunagala districts while 104 vegetable samples were collected from Nuwara Eliya, Kandy and Puttalam districts. Elemental analysis (in their cationic form) was carried using Inductively Coupled Plasma Mass spectrometer (ICP-MS). Arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb) and selenium (Se), cobalt (Co), nickel (Ni), copper (Cu), thallium (Tl), vanadium (V), beryllium (Be), chromium (Cr) and manganese (Mn) were tested according to the standard procedure. The mean concentrations of As (0.045 mg kg^{-1}, 0.005 mg kg^{-1}), Cd (0.027 mg kg-1, 0.007 mg kg^{-1}) and Pb (0.19 mg kg^{-1}, 0.021 mg kg^{-1}) were found in rice and vegetable samples, respectively. Results were reported in fresh weight basis and those were less than the maximum permissible levels reported by FAO/WHO. With the current consumption pattern, the daily human intake of As, Cd, Pb, Hg, Se, Cr, Ni, Cu and Mn ascribed to a diet of rice and vegetables were estimated. Except for Cr in rice, daily intake of all the elements through rice and vegetables were less than the tolerable daily intake values.

Keywords: ICP-MS, Rice, Trace element, Vegetables

Introduction

Rice (*Oryza sativa* L.) is the most widely consumed staple food and main carbohydrate source in Sri Lanka. Vegetables are valuable sources of vitamins, minerals, dietary fiber and anti-oxidants (Kananke *et al*., 2016). Rice and vegetables are the major components of plant origin in Sri Lankan meal, and as such heavy metal contamination of rice and vegetables cannot be underestimated. Rice has been identified as a potential source of heavy metals in some countries (Mondal and Polaya, 2008; Park *et al*., 2011). Intake of heavy metal contaminated food crops may pose a risk to human health; hence heavy metal contamination of food is one of the most important aspects of food quality assurance (Elbagermi *et al*., 2012).

Out of all trace elements, metallic elements such as mercury (Hg), lead (Pb), cadmium (Cd), tin (Sn) and arsenic (As) are considered as toxic trace elements (Emumejave, 2014; Perera, 2018).

Generally toxic trace element concentrations in rice plants are found to be in a descending order as root > leaves > stem > rice grain (Hadif *et al*., 2015). Rahimi *et al*. (2017) reported that Cd possesses high mobility and easy absorption properties in plants while Pb possess less mobility. Both essential and toxic elements are found in soil and irrigation water. Further, vegetables have the ability to absorb toxic elements deposited on plant surfaces exposed to the polluted environments (Kananke *et al*., 2016).

Trace elements in environment may increase due to several natural and anthropogenic activities such as applications of fertilizers and agrochemicals, atmospheric deposition, disposal of solid wastes, application of sewage and slug (Siaka *et al*., 2014; Wijayawardhana *et al*., 2016). Accumulation of toxic trace elements in human body can cause diseases in the digestive system, anemia and chronic renal failure (Rosemary *et al*., 2014). Intake of Cd resulted in stomach irritation, vomiting and diarrhea, while long-term exposure to Cd caused kidney disease, cancer and fragility at birth. Arsenic exposure may cause skin lesions, neuropathy, gastrointestinal diseases, cardiovascular diseases and cancer (Edirisinghe and Jinadasa, 2019). Selenium is one of the important micronutrients. Nutritional functions of Se are attained by 25 seleno- proteins which act as antioxidants and detoxifying agents. However, intake beyond 400 µg per day is considered to be toxic (Diyabalanage *et al*., 2016).

Safer values of Tolerable Daily Intake (TDI) for the selected heavy metals

The FAO/WHO has set a limit for metal intake based on body weight of an average adult *i.e*., 60 kg body weight. The average intake per person per day of rice and vegetables are 300 g and 98 g, respectively. Safer values of provisional tolerable daily intakes (PTDI) are given in Table 1.

As rice and vegetable being major dietary sources even lower contaminations of heavy metals in those food items can provide higher contents to humans. As such contamination of rice and vegetables should be minimized. Therefore, the objective of this study was to find out the levels of 13 trace elements including toxic trace elements in rice and vegetables growing in selected districts of Sri Lanka.

Table 1. Safer values of Tolerable Daily Intake (TDI)

Metal Type	As	Cd	Pb	Hg	Se	Cr	Ni	Cu	Mn
PTWI (µg $kgbw^{-1}$)	15[b]		25[d]	4[b]	35[a]	23.3[d]	35[d]	3500[d]	980[c]
PTMI (µg $kgbw^{-1}$)			25[b]						
TDI (µg $kgbw^{-1}$ day^{-1})	2.14	0.83	3.57	0.57	5	3.33	5	500	140
TDI (mg $kgbw^{-1}$ day^{-1} * 10^{-3})	2.14	0.83	3.57	0.57	5	3.33	5	500	140

PTWI - Provisional tolerable weekly intake; PTMI – Provisional tolerable monthly intake,
a – Magamage et al., 2017; c – Alpaslan et al., 2015; b –FAO/WHO (2019); d – Yousefi et al., 2016;

Materials and Methods

The study was carried out at the Registrar of Pesticides and the Horticulture Crop Research and Development Institute of the Department of Agriculture Sri Lanka. Rice samples were collected from major rice cultivating districts viz. Ampara, Anuradhapura and Kurunagala. Vegetable samples were collected from major vegetable cultivating districts viz. Nuwara eliya, Puttalam and Kandy. All together one hundred (n =100) rice samples have been collected either fields or from their warehouses. Hundred and four (n =104) vegetable samples were collected from farmer fields and vegetable markets at Nuwara Eliya and Kandy. Samples were collected from 2018 February to 2018 April and from 2020 February to 2020 April. Sampling was done using multistage random sampling technique according to the Codex Alimentarius sampling protocols (Codex Alimentarius Commission, 1999). Type of vegetables and number of samples collected are given in Table 2.

Before the analysis, all apparatus and glassware, intended to come into direct contact with the sample, were treated with 1- 2% HNO_3 and then rinsed with high purity water. Rice samples were dried at room temperature, milled and ground to get powdered form. Homogenized samples (0.2 g) were digested separately with 8.0 mL of concentrated nitric acid (69%, Analytical Grade), 0.5 mL conc. hydrochloric acid and one milliliter of hydrogen peroxide (H_2O_2) (30%) in a microwave digester (CEM Gmbh-Jerman model: MARS 6; Serial No. MJ 2941). Elemental analysis was performed as per the laboratory validated method using FDA Elemental Analysis manual for Food and Related Products Analytical Methods.

Table 2. Sampling of vegetables

Vegetable category	Vegetables collected (No. of samples analyzed)	Number of samples
Fruiting	Tomato (12), Beans (10), Bitter guard (9), other (Okra, Brinjal, Cucumber and capsicum) (16)	47
Leafy	Mukunuwenna (9), other (Kankun, cabbage and Gotukola) (11)	20
Roots, bulb and tuber	Leeks (10), Potato (10), Sweet potato (10), other (Beat root and Radish) (7)	37

Vegetable samples were washed, peeled and non-edible parts were removed. Wet samples were ground to get homogenized samples. All the equipment and utensils used for sample preparation were treated with diluted nitric followed by purified water. Contamination and uncontrolled loss of liquid, during operations such as grinding and cutting, were avoided. About 1 g (wet mass) of homogenized sample was digested with 5 ml 69% HNO_3 and 2 ml 30% H_2O_2 and made final volume as 25.0 ml. At the method validation, spiked samples of vegetables were analyzed both in wet and dry methods of FDA (Elemental Analysis manual for Food and Related Products Analytical Methods; Ver. 1.1; 2010, FDA U.S. Food and Drug Administration) and AOAC, 2012.

Thirteen elements: Arsenic (As), Cadmium (Cd), Mercury (Hg), Lead (Pb) and Selenium (Se), Cobalt (Co), Nickle (Ni), Copper (Cu), Thallium (Tl), Vanadium (V), Berilium (Be), Chromium (Cr) and Manganese (Mn) were selected for the elemental analysis. Elemental analysis was done by using Inductively Coupled Plasma Mass Spectrometer (ICP-MS) (Thermo Fisher Scientific iCAP Q Model, SN-03380R). Prior to sample evaluation, the equipment was allowed to stabilized for 30 minutes. A stability test was performed using tuning standard solution which was produced to cover the whole range of masses. The equipment was calibrated by using Standard Reference Materials of elemental mixture. Linearity of standards was satisfactory for all species (r^2>0.997) over the concentration ranges prepared.

Analytical quality control was verified using analysis of method blanks and spiked samples with each batch of rice and vegetable analysis. All the samples were analyzed with duplicates. Statistical analysis of mean concentrations of trace elements in rice and vegetable samples were done using excel computer package. One way analysis of variance (ANOVA) was used to determine significant differences (P<0.05) between areas of sample collection using Minitab (Version 18).

Estimated daily intake (EDI) was calculated using the given equation by Elbagermi, *et al*., 2012; EDI = (Cmetal x DiR)/Bw

Cmetal – Concentration of the element, DiR – Daily intake of rice or vegetable (kg/day) (rice- 0.3 kg, vegetable- 0.098kg), Bw - Average body weight (kg) (60 kg)

Estimated daily intake of mean concentrations (EDIM) and estimated daily intakes for maximum concentrations (EDIMax) of elements were calculated and compared with the safer values of TDI (Table 6).

Results and Discussion

Concentrations of Cr, Cu, Co, V and Se in rice showed significant differences among districts (Tables 3). Similarly, the concentrations of Cd, Pb and Cr among vegetable samples were differed among districts (Tables 4) (P<0.05). Mean trace element concentrations in tested vegetables are given in Table 5.

There were no significant differences in As concentrations among districts for both rice and vegetable samples (P>0.05). Overall, the mean concentration of As detected in rice was 0.045 mg kg^{-1} which is well below the MPL of 0.2 mg kg^{-1} (WHO/FAO, 2019). Arsenic concentrations observed by Jayasekera and Freitas, (2005), Magamage *et al*. (2017) and Chandrajith *et al*. (2012) in rice are 0.034 - 0.094 mg kg^{-1} 0.01 - 0.1 mg kg^{-1} and 0.01 - 0.09 mg kg^{-1}, respectively. Arsenic concentration detected in vegetables (0.005 mg kg^{-1}) is also much lower than that of in rice, and none of the samples exceed relevant MPLs. Similarly, Silva *et al*. (2016) has reported As levels of 0.001 and 0.003 mg kg^{-1} , respectively in bitter guard and beans grown in Sri Lanka.

Rice grains collected from Ampara contained 0.054 mg kg^{-1} of Cd while *Mukunuwenna* samples contained 0.018 mg kg^{-1} Cd. Cadmium levels reported in all those samples were lower than the permissible levels (0.4 mg kg^{-1} for rice) and (0.05-0.2 mg kg^{-1} for vegetables) (FAO/WHO, 2019). Similar Cd levels have also been reported earlier for vegetables (Kananke *et al*., 2016; Silva *et al*., 2016). Cadmium concentrations reported in rice in different areas in Sri Lanka ranged from 0.01 – 0.192 mg kg^{-1} (Jayasekera and Freitas, 2005; Chandrajith *et al*., 2012; Magamage *et al*., 2017).

Mean concentration of Hg in rice was reported as 0.015 mg kg^{-1} while that in vegetables was <0.001 mg kg^{-1}. There were no significant differences in Hg among districts for both rice and vegetables (P<0.05). Similar Hg levels were reported by Jayasekera and Freitas (2005) and Chandrajith *et al*. (2012). lead (Pb) has become an environmental contaminant resulted from industrial activities, mining and electronic wastes (Lee *et al*., 2016). The mean concentration of Pb reported in this study for rice was 0.19 mg kg^{-1} which is well below the safer level of 0.2 mg kg^{-1} (FAO/WHO, 2019). Significant differences in Pb concentrations were detected among districts in both rice and vegetable samples (P<0.05). Lead concentration in rice samples collected from Ampara (*i.e*., 0.373 mg kg^{-1}) Pb was observed in rice cultivated at Ampara which is exceeded the relevant MPL. In addition, Diyabalanage *et al*. (2016) reported that the mean concentration of Pb in rice from Wet, Intermediate and Dry zones were as 0.257, 0.271 and 0.322 $mgkg^{-1}$, respectively. The concentration of Pb in surface waters collected from Dry zone was 0.005 - 0.03 mg L^{-1} (Bandara *et al*., 2010; Chandrajith *et al*., 2012). Contaminations in rice grains could be due to the presence of Pb in water. These types of analysis have to be carried out continuously as environmental conditions change rapidly.

The highest mean Pb concentration in vegetables was reported in potato (0.066 mg kg^{-1}). Moreover, the mean Pb concentration detected in *Mukunuwenna* (0.051 mg kg^{-1}) was much lower than that was reported earlier (2.96 mg kg^{-1} from Colombo district, Kananke *et al*., 2016). Particles of Pb in air could be deposited on soil, water and plants; this may be a reason for Pb contaminations observed in vegetable fields (Elbagermi *et al*., 2012; Emumejaye, 2014; Kananke *et al*., 2016).

The mean concentration of Se detected in rice grains was 0.045 mg kg^{-1} while that in vegetables was 0.146 mg kg^{-1}. Moreover, the concentration of Se detected in potato (0.56 - 0.575 mg kg^{-1}) was much higher than that in other vegetables.

The concentration of Mn was considerably higher than other elements in rice (22.3 mg kg^{-1}) and vegetables (3.1 mg kg^{-1}). Among vegetables the highest concentration of Mn was detected in *Mukunuwenna* (9.451 mg kg^{-1}). According to Diyabalanage *et al*. (2016) Mn concentration detected in rice grains was in the ranged from 13.4 – 20.7 mg kg^{-1}. Moreover, the mean concentration of Mn in paddy soil in the Dry and Wet zones were 283 mg kg^{-1} and 147 mg kg^{-1}, respectively (Chandrajith *et al*., 2012).

The MPLs reported for Cr was 2.3 mg kg^{-1}, Ni was 4 mg kg^{-1} and Cu was 40 mg kg^{-1}(Silva *et al*., 2016), and reported concentrations in this study were in the safer levels

There were no significant differences in the mean concentrations of Cu, V, Co, Ni and Mn in vegetables among districts, and the values were 4.8, 0.052, 0.022, 0.097 and 3.1 mg kg^{-1}, respectively. These values were much lower than their MPLs. The highest Cu concentration was reported in leeks (6.799 mg kg^{-1}) while lowest in potato (0.992 mg kg^{-1}). Moreover, thallium (Tl) and berelium (Be) were hardly determined in rice and vegetables samples (<0.001 mg kg^{-1})

Table 3. The concentrations of trace elements detected in rice grain (±SD) with ranges (mg kg^{-1})

Area			Ampara	Anuradhapura	Kurunegala	Total
			65	20	15	100
Elements	**LOD**	**MPL**				
As	0.008	0.2[a]	0.036a ± 0.006 (<LOD - 0.127)	0.05a ± 0.038 (<LOD – 0.160)	0.052a ± 0.017 (<LOD – 0.09)	0.045
Cd	0.001	0.4[a]	0.054a ± 0.018 (0.014 - 0.801)	0.017a ± 0.016 (<LOD – 0.073)	0.025a ± 0.009 (0.002 – 0.059)	0.027
Pb	0.012	0.2[a]	0.373a ±0.218 (<LOD - 2.246)	0.104a ± 0.105 (<LOD – 0.281)	0.046a ± 0.073 (<LOD – 0.464)	0.190
Hg	0.002	0.1[d]	0.004a ±0.001 (<LOD-0.044)	0.014a ± 0.013 (<LOD – 0.05)	0.028a ±0.025 (<LOD – 0.073)	0.015
Se	0.038	0.3[d]	0.045a ± 0.023 (<LOD-0.271)	ND <LOD	0.008b (<LOD – 0.044)	0.018
Co	0.001		0.044a ± 0.007 (0.011-0.115)	0.079b ± 0.017 (0.027 – 0.188)	0.062ab ±0.016 (0.016 – 0.1)	0.064
Ni	0.03	4[c]	0.346a ± 0.129 (<LOD -1.916)	0.365a ± 0.267 (0.081 – 1.436)	0.263a ±0.066 (<LOD-0.817)	0.333

LOD – Limit of Detection; ND – Not Detected; MPL - Maximum Permissible Level a FAO/WHO, 2019; b Silva et al., 2016; c Kananke et al., 2016; d EFSA (2006)

Table 4. Mean trace element concentrations (±SD) in vegetables with range (mg kg^{-1})

Area			Nuwara Eliya	Kandy	Puttalam	Total
n			44	40	20	104
Elements	LOD	MPL				
As	0.008	1.0[b]	0.004a ±0.007 (<LOD – 0.02)	0.007 a ± 0.016 (<LOD – 0.133)	0.003a ± 0.004 (<LOD – 0.015)	0.005
Cd	0.001	(0.05 – 0.2)[a]	0.006a ± 0.008 (<LOD – 0.045)	0.003a ± 0.008 (<LOD – 0.046)	0.018b ± 0.025 (<LOD – 0.081)	0.007
Pb	0.012	(0.05 – 0.3)[a]	0.008a ± 0.016 (<LOD – 0.065)	0.038b ±0.065 (<LOD – 0.276)	0.014a ±0.018 (<LOD – 0.062)	0.021
Hg	0.002	0.1[d]	NDa (<LOD – 0.003)	NDa (<LOD – 0.003)	0.001a ± 0.002 (<LOD – 0.008)	0.001
Se	0.038		0.034a ± 0.052 (<LOD – 0.247)	0.331a ± 0.611 (<LOD – 2.254)	0.025a ± 0.03 (<LOD – 0.133)	0.146
Co	0.001		0.021a ± 0.027 (<LOD – 0.114)	0.024a ± 0.042 (<LOD – 0.196)	0.021a ± 0.031 (0.001 – 0.1)	0.022
Ni	0.03	4[c]	0.086 a ±0.103 (<LOD – 0.528)	0.120a ± 0.177 (<LOD – 0.764)	0.074a ±0.096 (0.001 – 0.358)	0.097
Cu	0.01	40[b]	5.391a ± 4.523 (0.167 – 14.347)	3.917a ± 4.947 (0.115- 17.898)	5.374a ± 6.077 (0.971 – 24.833)	4.821
Tl	0.001		0.002a ± 0.004 (<LOD – 0.014)	0.002a ±0.004 (<LOD – 0.014)	0.004a ±0.008 (<LOD – 0.036)	0.002
V	0.001		0.036a ± 0.056 (<LOD – 0.228)	0.086a ± 0.154 (<LOD – 0.695)	0.021a ± 0.023 (0.003 – 0.082)	0.052
Be	0.001		NDa <LOD	0.002a ±0.015 (<LOD – 0.093)	NDa <LOD	0.001
Cr	0.017	2.3[b]	0.386a ± 0.405 (<LOD – 1.737)	0.235a ± 0.28 (<LOD – 0.807)	0.388b ± 0.396 (<LOD – 1.170)	0.329
Mn	0.268		2.509a ± 1.878 (0.2 – 8.171)	3.628a ± 4.961 (0.007 – 21.704)	3.572a ± 3.704 (0.081 – 12.889)	3.144

Table 5. Mean trace element concentrations (±SD) in different vegetables (mg kg^{-1})

	As	Se	Cd	Hg	Pb	Cr	Mn	Ni	Cu
Category									
Fruiting (MPL)	**1.0[b]**	**0.3[d]**	**0.05[a]**	**0.1[d]**	**0.05[a]**	**2.3[b]**		**4[c]**	**40[b]**
Tomato	ND	0.026±0.024	0.003±0.004	0.001±0.001	0.018±0.02	0.195±0.346	1.780±1.093	0.095±0.211	3.451±2.832
bitter guard	ND	0.023±0.001	ND	ND	0.007±0.012	0.197±0.297	2.426±1.918	0.138±0.222	5.091±3.813
Beans	ND	0.059±0.064	0.002±0.002	ND	0.014±0.024	0.330±0.365	4.312±1.449	0.202±0.08	5.295±4.033
other	ND	0.023±0.051	ND	ND	0.007±0.017	0.197±0.451	2.426±3.034	0.138±0.092	5.091±6.625
Bulb, root & tuber (MPL)	**1.0[b]**	**0.3**	**0.1[a]**	**0.1[d]**	**0.1[a]**	**2.3[b]**		**4[c]**	**40[b]**
Leeks	0.01±0.007	0.045±0.071	0.005±0.004	0.001±0.001	ND	0.677±0.447	1.886±1.242	0.069±0.087	6.799±5.929
Potato	0.01±0.011	0.560±0.766	0.003±0.004	0.001±0.001	0.066±0.091	0.371±0.268	1.865±1.842	0.130±0.126	0.992±1.063
Sweet potato	0.018±0.027	0.575±0.878	0.003±0.004	ND	0.015±0.024	0.298±0.283	1.185±1.279	0.015±0.016	4.305±6.714
other	0.006±0.01	0.080±0.071	0.007±0.004	0.001±0.001	0.005±0.009	0.633±0.29	3.518±2.516	0.143±0.181	5.148±4.518
Leafy (MPL)	**1.0[b]**	**0.3**	**0.2[a]**	**0.1[d]**	**0.3[a]**	**2.3[b]**		**4[c]**	**40[b]**
Mukunuwenna	0.005±0.006	0.051±0.052	0.018±0.022	0.002±0.002	0.051±0.088	0.085±0.123	9.451±7.669	0.058±0.048	2.859±2.056
Other	0.003±0.004	0.069±0.085	0.017±0.027	0.001±0.001	0.015±0.024	0.124±0.142	3.391±4.033	0.061±0.111	5.012±5.553
LOD	0.008	0.038	0.001	0.002	0.012	0.017	0.268	0.03	0.01

ND- Not detected (<LOD)
Maximum Permissible Level (MPL); a FAO/WHO (2019); b Silva et al., 2016; c Kananke et al., 2016; d EFSA (2006)

Table 6. Estimated daily intake of heavy metals

		Rice (Total)		Vegetable (Total)	
Element	**Safer Values of TDI x 10-3 (mgday^{-1}kgbw $^{-1}$)**	**EDI x 10-3 (mg day^{-1} kgbw $^{-1}$)**		**EDI x 10-3 (mg day^{-1} kgbw $^{-1}$)**	
		EDIM	**EDIMax**	**EDIM**	**EDIMax**
As	2.14	0.225	0.8	0.008	0.217
Cd	0.83	0.135	4.005	0.011	0.132
Pb	3.57	0.95	11.23	0.034	0.451
Hg	0.57	0.075	0.365	0.002	0.013
Se	5	0.09	1.355	0.238	3.682
Ni	5	1.665	9.58	0.158	1.248
Cu	500	20.155	72.845	7.874	40.561
Mn	140	111.29	190.16	5.135	35.45

TDI- Tolerable daily intake; EDIM – Estimated daily intake of mean concentrations; EDIMax – Estimated daily intake of maximum concentrations

Estimated daily intakes of mean concentrations (EDIM) and estimated daily intake of maximum concentrations (EDIMax) of rice and vegetables were compared with the Tolerable daily intakes (TDI) of the relevant elements (Table 6). If the mean level of Pb (0.19 g kg^{-1}) found in rice are consumed daily, the contribution of heavy metal intake for an average human being by the rice diet is 0.95 µg day^{-1} kg bw^{-1}, and well below the TDI of 3.57 µg day^{-1} kg bw^{-1} of FAO/WHO. Further though the mean content of Cr in rice is at safer levels, considering the daily intakes it shows that, EDIM of Cr (4.27 µg day^{-1} kg bw^{-1}) in rice exceeded the safer values of TDI of 3.33 µg day^{-1} kg bw^{-1} for chromium, while all the EDIMs of other elements for rice and vegetables are well below the safer-levels. But in worst case if the maximum levels of elements found in rice of Cd, Pb, Hg, Cr and Ni (0.801, 2.246, 0.073, 2.435 and 1.916 mg kg-1 respectively) consumed daily, the contribution of heavy metal intake for an average human being by the rice diet exceed the safer levels, TDIs of FAO/WHO.

conclusion

It reveals that the rice samples collected from all three districts were safer from almost all toxic trace elements analyzed. Further it revealed that vegetable samples are also safer from elements analyzed. Though Cr contents detected in rice are below permissible level, evaluation of TDIs shows that, EDIM of Cr (4.27 mg day^{-1} kg bw^{-1}) in rice exceeds the safer values of TDI of 3.33 mg day^{-1} kgbw^{-1} while all the EDIMs of other elements for rice and vegetables are in safer levels.

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