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Research Paper

Assessment of Accumulation of Heavy Metals in Vegetables in Ranchi, Jharkhand, India

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ABSTRACT

The aim of this study was to assess the accumulation of heavy metals in vegetables in Ranchi, Jharkhand, India. Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg) and copper (Cu) are taken under the study in three common vegetables viz brinjal, cabbage and capsicum. The testing of these heavy metals was carried out as per Food Safety & Standards Authority of India (FSSAI) norms in a food analytical laboratory by using atomic absorption spectroscopy. The study showed that the concentration of Pb, Hg and Cu in all three vegetables are under the permissible limit as per FSSAI standards and only the concentration of Cd in cabbage was found approximately three times (0.14 mg/kg) of the FSSAI standards (0.05 mg/kg). The concentration of Pb, Cd, Hg and Cu in Brinjal are 0.24, 0.13, 0.78, and 0.14 mg/kg, respectively and similarly, in cabbage, these were found to be 0.24, 01.4, 0.65 and 0.05 mg/kg, respectively and in capsicum, the concentrations of Pb, Cd, Hg and Cu were recorded as 0.21, 0.13, 0.98 and 0.19 mg/kg, respectively.

Keywords: Heavy metals; Vegetables; Atomic Absorption Spectroscopy; Food Safety & Standards Authority of India.

INTRODUCTION

Vegetables are affordable and common sources of fundamental supplements and are rich in vitamins, minerals, proteins, carbohydrates, fibres and have antioxidative properties (Rehman et al., 2014). These are known as body protective food but nowadays, these vegetables are getting contaminated either due to excess application of chemical fertilizer, chemical nutrients or chemical pesticides. The use of heavy metals containing fertilizers and pesticides comes in human beings through the water, soil and vegetables themselves and causes adverse effects on human health (Chandini et al., 2019). Heavy metals pose a health risk to humans even in low concentrations due to their poor excretion mechanism and accumulate inside the body. The accumulation of heavy metals causes different types of disease and ultimately leads to cancer since some heavy metals are carcinogenic as per IARCs (International Agency for Research on Cancer). Heavy metal content in the plant body enters through the absorption of contaminated water, soil solution, excess use of pesticides, use of fertilizers, transportation, and aerosol deposition (Alengebawy et al., 2021). Many plants accumulate these metals in higher concentrations than others. Leafy vegetable uptake and accumulation rate is higher than root vegetables, solanaceous vegetables and legume vegetables (Zhou et al., 2016). The objective of the experiment was to assess the concentration of Pb, Cd, Cu, and Hg in three common vegetables brinjal, capsicum and cabbage in the local market of Ranchi city.

Toxic Effects of Heavy Metals

The Assessment of heavy metals such as Lead, Cadmium, Mercury and Cupper in brinjal, cabbage and capsicum are taken under the study which toxic impacts are listed below:

Lead

The Latin name of lead is "Plumbum" and is symbolized as "Pb" whose atomic number is 82 and Atomic Weight is 207.2 in the periodic table as per IUPAC. Since lead is a heavy metal, it reacts with enzymes and causes enzyme population and ultimately leads to toxic to cause muscular, skeletal, neurological, reproductive and developmental effects (Mood et al., 2021). It may cause behavioural, learning and focus problems in kids. The major health impacts of lead are cancer in the kidney, liver and Intestine due to the eating of lead-contaminated vegetables or foods (Jaishankar et al., 2014).

Cadmium

It is symbolized as "Cd" with atomic number 48 and atomic weight is 112.414 in the Periodic table as per IUPAC (International Union of Pure & Applied Chemistry). It is highly toxic non-essential and has no nutritious capacity in the biological process of humans or plants (Genchi et al., 2020). Its lower concentration could be dangerous to living organisms. It can affect the liver, bones, lungs and immunity (Skipper et al., 2016).

Copper

It is symbolized as "Cu" with the atomic number 29 and atomic weight is 65.546. It is an essential micronutrient which functions as a biocatalyst, required for body pigmentation in addition to iron (Elbagermi et al., 2012). If it is under permissible limits, it maintains a healthy nervous system and prevents anaemia and its higher concentration can cause acute stomach, intestine ache and liver damage (Shobha and Kalshetty, 2017).

Mercury

It is symbolized as "Hg" with atomic number 80 and atomic weight 200.59 in the periodic table as per IUPAC. It is more toxic than lead and cadmium (Abbas et al., 2010). Its adverse effects are loss of vision, mental disorder and hearing loss and death occurs due to high accumulation of mercury (Reilly et al., 2010).

The toxicity of heavy metals is also defined by the CAS number across the World. CAS of a few heavy metals is listed here in Table 1 (Podsiki, 2008).

Table 1 CAS number of heavy metals

SN	Name of Heavy Metals	CAS Number
1	Lead	7439-92-1
2	Cadmium	7440-43-9
3	Mercury	7439-97-6
4	Copper	7440-50-8

The value or range which does not give any adverse health impact on living beings is called the permissible limit. Across the globe, there are lots of international and national standards which fix value or range. In India, the Food

Safety and Standards Authority of India (FSSAI) is being followed for quality and health impacts purposes, which are shown in Table 2.

Table 2 Permissible limit of heavy metals in vegetables

SN	Name of Heavy metal	Name of vegetables	Permissible limit
1	Lead	Brassica vegetables	0.3
		Other vegetables	2.5
2	Cadmium	Brassica vegetables	0.05
		Other vegetables	1.5
3	Mercury	Vegetables	1.0
4	copper	Vegetables	30

Material and Methods

Study Area

Jharkhand is one of the good agricultural states in India and a major producer of vegetables. Approximately, 3.2 % of the total agricultural land of the state accounts for vegetable production (Deogharia, 2017). The major vegetable crops in the Kharif season are rainfed and Rabi crop season and Zaid crop seasons are irrigation based across the state. The major crops are Pea, tomato, potato, cabbage, cauliflower; ladyfinger, brinjal, capsicum etc. are majorly grown vegetables of Jharkhand. The study has conducted in a local market viz “Ratu Road Sabgi Mandi" in the Ranchi district of Jharkhand. The Ratu Road Sabgi Market is the place where farmers and vegetable traders across the state have come to sell the vegetables grown in different districts of Jharkhand. So, it is the ideal market for the sampling and study of the accumulation of heavy metals in different vegetables.

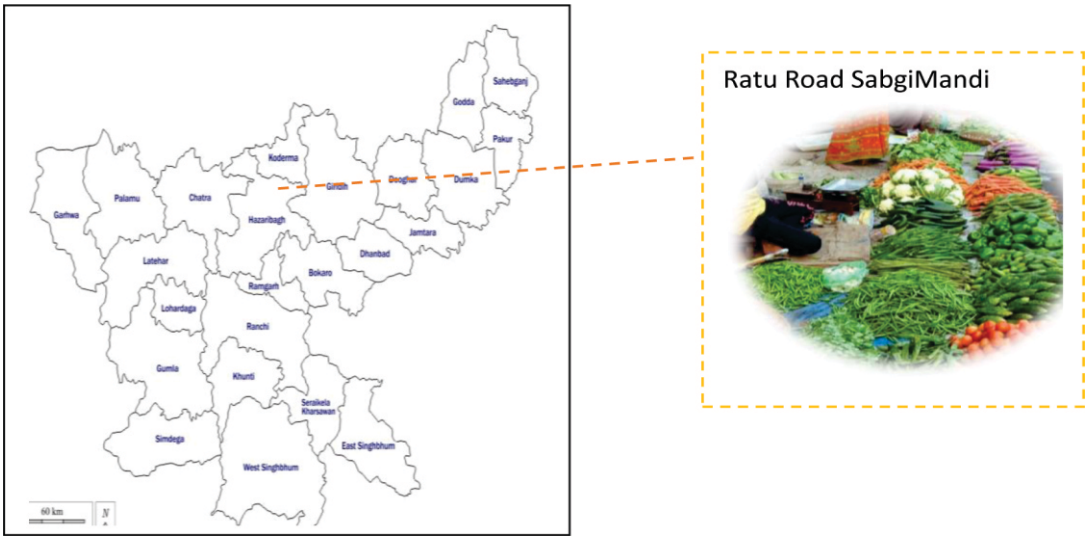

Fig. 1 Ratu Road Sabji Mandi, Ranchi, Jharkhand

Sample Collection

The Fresh vegetables namely Brinjal (Solenum Melongena), Capsicum (Capsicum Annum) and Cabbage (Brassica Oleracea) were collected randomly from Ratu road sabji market, Ranchi in January 2021. The fresh vegetables of 250 gm each are kept in a sterilized zipper poly bag for laboratory analysis. The details of vegetables which are taken under the study are shown in Table 3.

Table 3 Vegetables and their scientific name

SN	Vegetables	Scientific name	Vegetable type	Growing season
1	*Brinjal*	*Solanum melongena*	*Solanaceous*	*Rabi Crop*
2	*Capsicum*	*Capsicum Annum*	*Solanaceae*	*Rabi crop*
3	*Cabbage*	*Brassica oleracea var. capitata*	*Brassica*	*Rabi Crop*

Sample Preparation and Procedure

Vegetables were washed with Distilled water. Chopped into smaller pieces and dried at temperature 105°C for 4 days in the oven. Dried samples were grinded and made into fine powder. The vegetables were digested using TKN (Total Kjeldahl Nitrogen) digester with concentrated Nitric Acid (Conc. HNO_3) and Sulphuric Acid (H_2SO_4) at 80°C. The total time taken for the sample digestion is 3 to 4 hours. Mixing of 0.5 gm of the powdered sample with 50 ml of distilled water was carried out and added to a total of 15 ml Conc. HNO_3 and 10 ml H_2SO_4 in the mixture to the solution. The solution was heated to make the digestion of the sample up to a volume of 40 ml. In a volumetric flask, the solution was made up to 50 ml by adding distilled water and then filtered. The digested solution of the sample was used to test the Lead (Pb), Cadmium (Cd), Mercury (Hg) and copper (Cu) with the help of the Atomic absorption spectrophotometer in the laboratory.

RESULTS

The analysis of the vegetables shows the different concentrations of Pb, Cd, Hg and Cu in Brinjal, Cabbage and Capsicum (Table 4).

Table 4 Concentrations of heavy metals in vegetables

SN	Parameters	Vegetables					
		Brinjal		Cabbage		Capsicum	
		Permissible limit	Result	Permissible limit	Result	Permissible limit	Result
1	Lead	2.5	0.24	0.3	0.24	2.5	0.21
2	Cadmium	1.5	0.13	0.05	0.14*	1.5	0.13
3	Mercury	1.0	0.78	1.0	0.65	1.0	0.98
4	Copper	30	0.14	30	0.05	30	0.19

Unit: All units are in mg/kg, Standards: FSSAI

The concentration of Pb, Hg and Cu in brinjal, cabbage and Capsicum are under the permissible limit as per FSSAI standards whereas the concentration of cadmium (0.14 mg/kg) in the cabbage is beyond the permissible limit (0.05 mg/kg). The concentration of Cadmium in brinjal and Capsicum is also under the permissible limit as per FSSAI (Fig. 2).

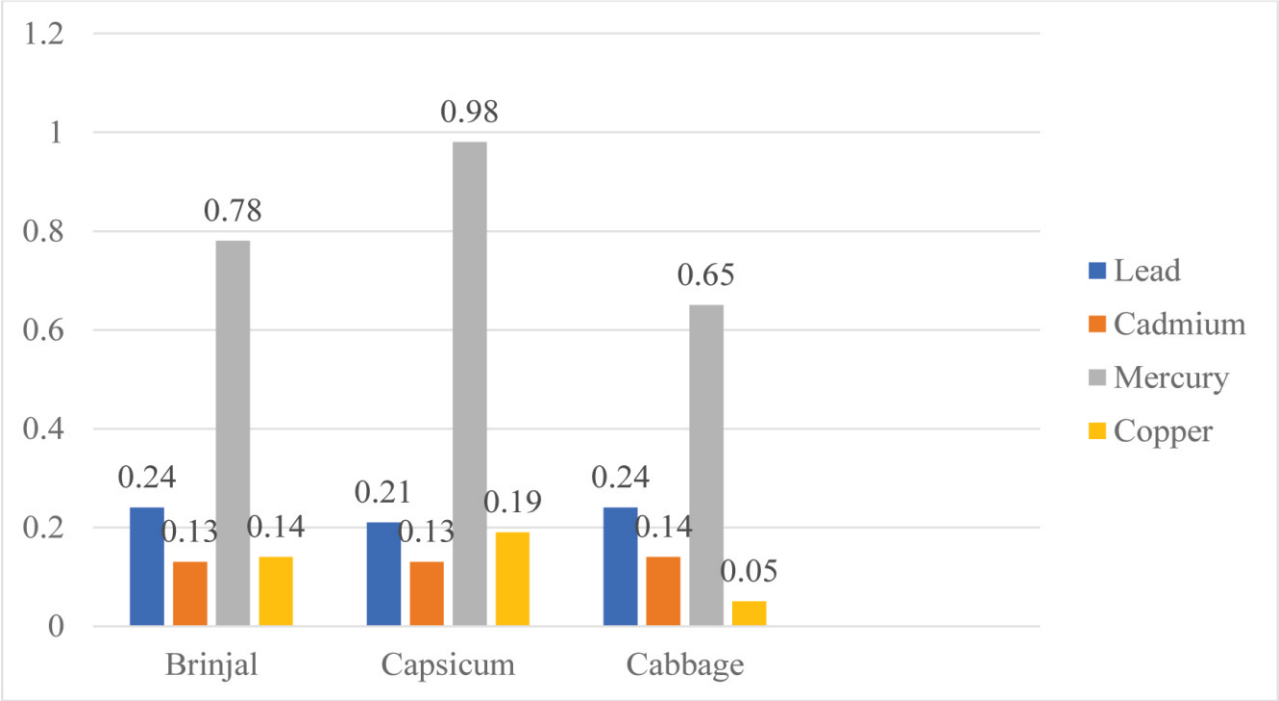

Fig. 2 Concentration of heavy metals in different vegetables

DISCUSSION

The accumulation rate of heavy metals varies from vegetable to vegetable. Some vegetables are higher accumulators of metals, which are not suitable for being planted on contaminated soil; whereas some vegetables are bad accumulators of heavy metals which can be cultivated in contaminated soil (Zhou et al., 2016). The vegetable sequence of uptake of heavy metals in vegetables is as follows: Leafy vegetables > solanaceous/root > legume vegetables. In the present study, it is shown that cadmium taken up in Brassica vegetables is higher than in others.

Accumulation of Lead in Vegetables

Lead is a dangerous and unsafe element for living beings. It can easily affect the central nervous system (Mason et al., 2014). The range of concentration in vegetables under study is 0.21 to 0.24 mg/kg, which is under the permissible limit as recommended by FSSAI. The maximum permissible limit set by FSSAI is 0.3 mg/kg for Brassica family and for others; it is up to 2.5 mg/kg (Fig. 3). Sequence of Lead accumulation in the vegetables is Cabbage (0.24 mg/kg) = Brinjal (0.24 mg/kg) > Capsicum (0.21 mg/kg).

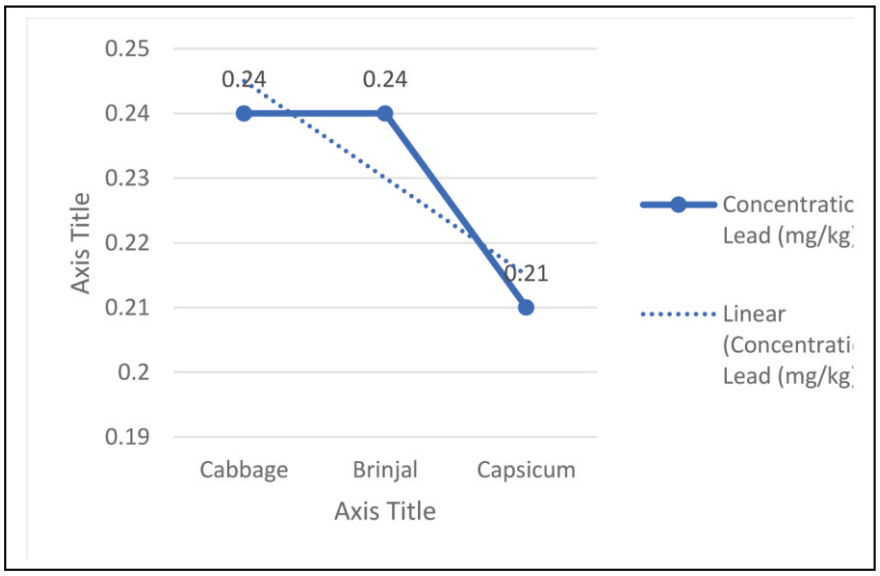

Fig. 3 Lead Concentration in Vegetables

Accumulation of Cadmium in Vegetables

Cadmium is a toxic non-essential and non-advantageous element with no nutritious capacity. Range of cadmium concentration is from 0.13 to 0.14 mg/kg. The maximum concentration was observed in Cabbage (0.14 mg/kg) followed by Brinjal and Capsicum (both have equal concentrations of 0.13 mg/kg). The study reveals that the concentration of cadmium exceeds the limit only in Cabbage than the maximum permissible limit of 0.05 mg/kg set by FSSAI (Fig. 4). The concentration of cadmium in Brinjal and Capsicum is under the permissible limit (0.1 mg/kg) set by FSSAI. Sequence of cadmium concentration in the vegetables is Cabbage (0.14 mg/kg) > Brinjal = Capsicum (0.13 mg/kg).

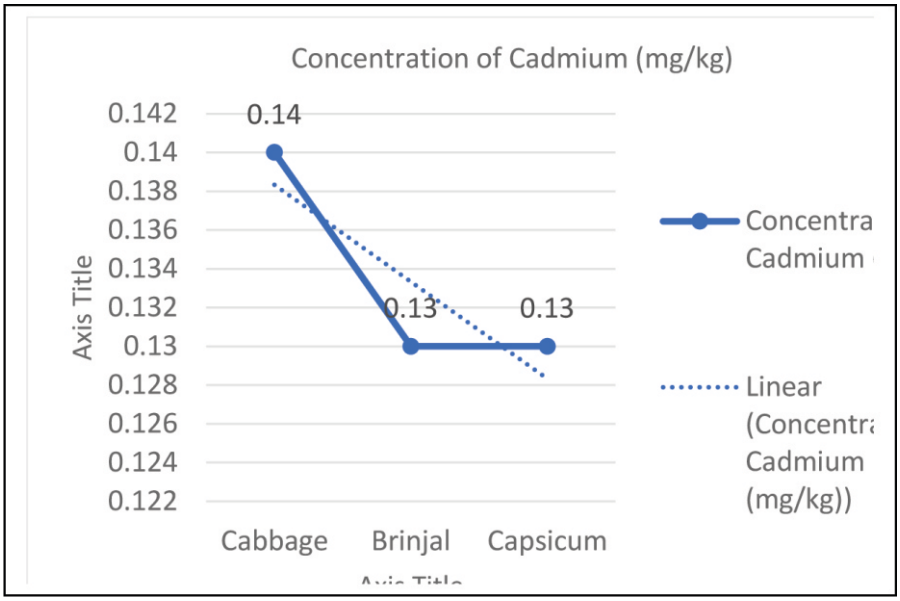

Fig. 4 Concentration of Cadmium in Vegetables

Accumulation of Mercury in Vegetables

The result reveals that the concentration of mercury ranges is from 0.65 to 0.78mg/kg. Maximum concentration of mercury (Hg) was found in Capsicum (0.98 mg/kg) followed by Brinjal (0.78 mg/kg) and Cabbage (0.65 mg/kg). But, all these three vegetables are under the permissible limit recommended by FSSAI, which is 1 mg/kg (Fig. 5). The sequence is Capsicum (0.98 mg/kg) > Brinjal (0.78 mg/kg) > Cabbage (0.65 mg/kg).

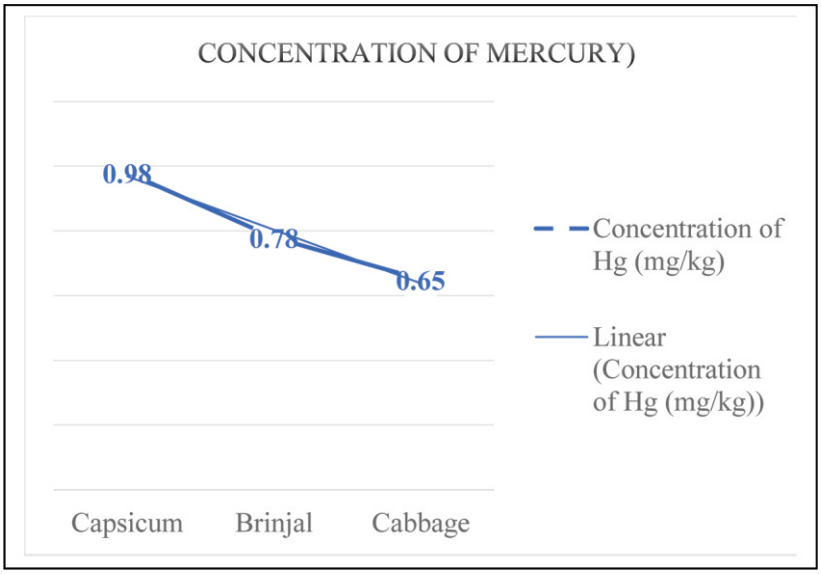

Fig. 5 Concentration of Mercury in Vegetables

Accumulation of Copper in Vegetables

The range of Copper concentration which is an essential micronutrient recorded from 0.05 to 0.19 mg/kg. Cu was found in Capsicum (0.19 mg/kg) followed by Brinjal (0.14 mg/kg) and Cabbage (0.05 mg/kg). The Cu concentration is within the limit suggested by FSSAI in all three vegetables (Fig. 6).

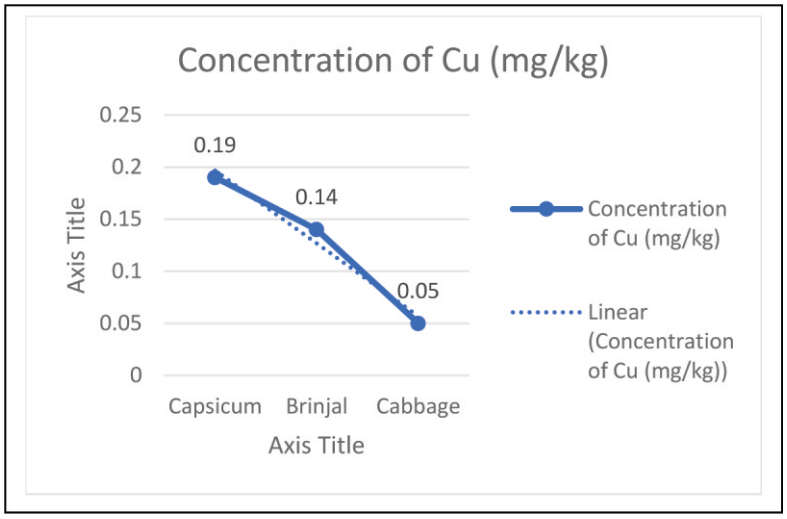

Fig. 6 Concentration of Copper in Vegetables

CONCLUSIONS

The result confirms that all the studied metals in the selected vegetables are within the limits suggested by FSSAI except cadmium in cabbage, which exceeds the limit set by FSSAI. The study showed that the concentration of Pb, Hg and Cu in all three vegetables are under the permissible limit as per FSSAI standards and only the concentration of cadmium (Cd) in cabbage is found approximately three times (0.14 mg/kg) of the FSSAI standards (0.05 mg/kg). The concentration of Pb, Cd, Hg, Cu in Brinjal are 0.24, 0.13, 0.78 and 0.14 mg/kg, respectively and similarly in Cabbage, these were 0.24, 01.4, 0.65, and 0.05mg/kg, respectively and in Capsicum, the concentrations of Pb, Cd, Hg, Cu were recorded as 0.21, 0.13, 0.98, and 0.19mg/kg, respectively. Heavy metals have a harmful effect, although negative effects do not surface until long -term ingestion of vegetables polluted with heavy metals. Therefore, it is recommended that regular heavy metal monitoring be done in order to prevent an excessive buildup of these heavy metals in the human food chain in vegetables and other dietary products.

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