

# Chronic Daily Intake of Heavy Metals via Consumption of Vegetables grown in soil of agricultural field

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**Abstract:** In India, a large number (more than 50) of vegetables are often consumed because of their advanced nutritional value. However, interruption of biological and metabolic processes in the human body are what cause heavy metal intoxication of vegetables in commercial areas. The health hazard assessment for heavy metals is specially efficient method since it may discover details with respect to possible risks from produce contaminated with heavy metals. Several studies employ various methodological analysis for assessing health hazard. The hazard of health issues due to consumption of common vegetables poses to human healthiness because of the beingness of heavy metals (Cr, Cu, Pb, Cd, and Ni). *Lagenaria siceraria* and *Solanum melongena* that are harvested from the field is represented in the present study. Together with the methodological analysis employed for the health risk assessment, one of the method is the chronic daily intake of metals (CDI). The hazard quotient (HQ) is used to evaluate health risk. All of the measured components predicted daily intakes credibly of low-level.

**Keywords:** Heavy Metals, Hazard, *Lagenaria siceraria*, *Solanum melongena*, Contamination, Risk, Chronic Daily Intake, Hazard quotient.

## 1. Introduction

Vegetables must be patterned for heavy metal impurity because these are important part of the humankind diet [1]. Along with an important source of vitamins, minerals, and fibre, vegetables as well as comprises healthy antioxidants and metabolites that function as buffers for the acidic waste products of digestion [2]. Vegetables consume both essential and harmful components from the soil [3]. Due to consumption of contaminated vegetables with heavy metals (HMs), risk to human health like cancer and renal damage are often documented [4]. But consuming

plants contaminated with heavy metals could be harmful to one's health. Heavy metal contamination of food products is one of the most important prospect of food quality assurance [5]. As a result of a better understanding of the risk these metals provide to food chain contamination, globally and national legislation on food quality have decreased the maximum permissible levels of dangerous metals in food items [6].

The common vegetables *Amaranthus tricolour L.*, *Chenopodium album L.*, *Spinacia oleracea*, *Coriandrum sativum*, *Solanum lycopersicum*, and *Solanum melongena* insignificantly compile the heavy metals Cr, Ni, Co, Cd, and Pb [7]–[14]. Contamination, enrichment, health risk, and heavy metal sources Cr, Co, Pb, Ni, and Cd in two vegetables—*Lagenaria siceraria* and *Solanum melongena*—grown in soil from Hisar city, Haryana, India, are elaborated in the current paper. The rapid and haphazard industrial and urban expansion that has occurred in developing countries like China [15] and India [16] has led to raised levels of heavy metals in the urban surrounds of those countries. Heavy metals are environmental waste matter that are persistent and non-biodegradable. They can be deposited on surfaces and later consumed by vegetables. Plants assimilate heavy metals by depositing them on the part of the plant that are unprotected to the air from polluted environments and contaminated soil [17]. Many investigations have disclosed heavy metals to be one of the main contaminants in vegetables [18–19]. Vegetable heavy metal poisoning may also result from irrigation with tainted water [20–21].

Vegetable surfaces may become contaminated with heavy metal pollutants from numerous industries and vehicles during the processes of production, transportation, and marketing. Scientists have discovered greater levels of heavy metals in vegetables sold in markets in Riyadh, Saudi Arabia, as a result of air deposition [22]. Some reports claim that the levels of heavy metal contamination in the common vegetables sold in Varanasi, India, markets might be considerably increased by air deposition [23].

Chronic accumulation of heavy metals in the human kidney and liver may develop from long-term exposure to dangerous levels of heavy metals through diet, interfering with various biochemical processes and leading to diseases of the heart, nervous system, kidneys, and bones [24,25]. Some heavy metals, like Cu, Zn, Mn, Co, and Mo, function as micronutrients for human and animal growth when present in minute levels, whereas others, like Cd, As, and Cr, act as carcinogens, and Hg is connected to the emergence of anomalies in newborns [26,27,28]. Some assert that chronic Cd use caused ovarian, prostate, and kidney cancers [29].

Chromium, cadmium, nickel, and lead are only a few of the metals to which the general public is now more exposed as a result of the expansion of different industrial sectors and the rise in demand for metals. Chromium compounds have teratogenic, mutagenic, embryotoxic, and carcinogenic long-term consequences. As they enhance the likelihood of trivalent chromium interacting with DNA, internal activities that convert hexavalent chromium to trivalent chromium might be viewed as activating chromium's carcinogenic qualities [30]. Cadmium can alter genetic material, particularly in the chromosomes of mammalian cells. Cadmium accumulates particularly well in the kidneys, which are a vital organ. Nickel compounds are classified by the International Agency for Research on Cancer as a Group 1 carcinogen. Hematopoietic diseases, hemic acid synthesis, suppression of haemoglobin formation, and shortened red blood cell life are examples of how harmful lead is to the human body. Reticulocytosis and anaemia are noted in later stages. Lead also impairs renal functions, the neurological system, and the digestive system [31]. Producers obtain the herbs they utilise from both industrial crops and specific sources, whose herbs may include heavy metal contamination.

The current study provides information on the levels of heavy metals (Cr, Co, Cd, Ni, and Pb) in some important Indian vegetables, including *Lagenaria siceraria* and *Solanum melongena*, which are grown locally in rural regions and sold in open markets in cities. Due to air depositions in urban areas, the amounts of heavy metals during transport and marketing may increase, which would greatly contaminate vegetables at market locations compared to where they were produced. The Prevention of Food Adulteration (PFA) act (30, 50, 1.5, and 2.5 lg/g, respectively; 32) and the European Union's guidelines for food contamination were compared to the levels of Cu, Zn, Cd, and Pb discovered in the vegetables. (EU) (0.1 and 0.3 lg/g, respectively, for Cd and Pb). Based on the amount of vegetables consumed on a daily average, the contribution of heavy metal contamination from dietary intake of the studied vegetables is also evaluated.

## 2. Materials and Methods

### 2.1 Study area

For present investigation soil and plant samples were collected from Haryana (India). The state of Haryana is in the north-west part of India. Though Haryana lies in the sub-tropical belt still climate is Arid to Semiarid.

For the process of soil and crop sampling, area of a field is selected from Hisar district, The normal annual rainfall of the district is 420 mm village. Hisar District is one among 22 Districts of Haryana State, India. Hisar District Administrative head quarter is Hisar. It has been designated as a counter-magnet city for the National Capital Region to emerge as an alternative focus of growth to Delhi and is situated 161.2 kilometres to the west of New Delhi, India. The overall population of the Hisar district is 17,43,931. It is 2nd Largest District in the State by population. Hisar district is divided into 04 Tehsils, 258 Panchayats, 268 Villages. Narnaund Tehsil is the smallest Tehsil with 1,40,880 population. Hisar Tehsil is the Biggest Tehsil with 10,69,309 population. There is total 268 villages in Hisar district. The town chosen for sampling is not a heavy metal-prone region, but for the study, the influence of soil characteristics and the uptake of heavy metals by crops from a normal soil will be an important element of the study.

## 2.2 Sample Collection

Vegetable agricultural samples were gathered throughout the month of April 2021. Food crops were collected during their separate harvesting seasons in order to assess the transfer and translocation factor of heavy metals. The details of the samples collected are given below:

**1. *Lagenaria siceraria* (Bootlegourd/ Lokki):** Samples were collected during its harvesting season (August-September) for the year (2021). A total of 10 samples were collected each weighing 500 - 1000g. The collected samples were cleaned, sealed and stored as discussed above.

**2. *Solanum melongena* (Brinjal):** Vegetable samples from designated sampling locations were gathered throughout the year's harvest season (Dec.–Jan. (2021). Total 10 samples were collected each weighing 500 - 1000g. After removal of extraneous matter like soil pebbles, stones and other debris the samples were sealed in plastic containers, taken to the laboratory and stored till further analysis.

**3. Soil sample:** The equivalent subsurface soil samples from the rooting zone were also obtained in order to assess the transfer and translocation factor of heavy metals from soil to the various environmental matrices above. Throughout various sampling seasons, a total of 40 soil samples were taken. Four sub-samples of soil from a rectangular grid of 0.5 m<sup>2</sup> area were taken from a depth of 5–10 cm, and they were then combined to create a representative sample. In order to remove the metal contamination, non-metallic spades were used to gather the soil

samples, each weighing 500g. After the removal of foreign bodies, samples were packed in fresh plastic bags. In preparation for further investigation, soil samples were air dried, powdered, and then sieved with a 2.0 mm mesh size.

### 3. SAMPLE PROCESSING

#### 3.1 Soil Samples Processing

Soil samples were air dried, grounded and stored in plastic containers that were air tight for analysis. After removal of extraneous matter like pebbles and plant roots etc. At a temperature of 110°C, soil samples were dried in an oven until the sample weight remained constant. Then the samples were ground in grinder with care to avoid cross contamination. After milling, the whole samples were sieved using 2.0 mm sieve.

- For heavy metals analysis, processed samples were stored in air tight plastic containers to have moisture free conditions till further analysis.

#### 3.2 Agricultural Sample Processing

##### 3.2.1 Vegetable Samples Processing

- The samples' fresh weight was noted shortly after collection.
- Vegetables' various parts (roots, shoots, and fruits) were dried in a drying oven at a temperature of 110°C until the sample weight remained constant.
- Following drying, the sample's dry weight was noted, and 100 g of dry subsamples were heated to 350–400 °C in a muffle furnace until the ash turned white.
- The ashed samples were then stored in moisture free conditions till further analysis

#### 3.3 Sample Analysis

##### 3.3.1 Heavy Metals Analysis

#### 3. Sample Digestion

Atomic Absorption Spectrophotometer (SenSAAGBC, Australia) was used to evaluate the total Cd, Ni, Cr, Co, and Pb contents of agricultural vegetables and soil samples. Concentrations were then represented in mg kg<sup>-1</sup> on a dry weight basis. Each sample of agricultural crop ash weighed 0.2 g, and 5.0 ml of a 9:1 (v/v) diacid (HNO<sub>3</sub> and HClO<sub>4</sub>) mixture was added to it.

Similarly, 5.0 ml of the diacid mixture was added to 0.5g of each soil sample. After taking the sample mixture in clean Teflon containers, it was digested on a hot plate the following day while it was left open at room temperature. When digestion was finished, the containers were quantitatively transferred into glass beakers and chilled to room temperature. The digests were then heated to a temperature of 130 to 150 °C, evaporated to dryness on a hot plate, and the residue was dissolved in double-distilled water to the appropriate volume (50 ml). After being transferred to polypropylene bottles, extracted solutions were stored in the refrigerator until analysis.

To create all of the working standards for analysis, approved standard solutions containing 1000 mg/L were diluted. Atomic Absorption Spectrophotometer (AAS) employed air as support and acetylene gas as fuel. With the exception of chromium, which was measured using a reducing nitrous oxide flame, all examples used an oxidising flame. Using an Atomic Absorption Spectrophotometer (SenSAAGBC, Australia), the extracts were examined for the presence of eight heavy metals, including Cd, Ni, Cr, Co, and Pb. Quality assurance and control procedures were used during the processing and analysis of the samples to guarantee the validity of the findings. Double distilled water was used to prepare standards, prepare samples, and rinse glassware in order to prevent sample contamination. To eliminate analytical bias, reagent blanks were examined, and the data were then blank adjusted. Replicated measurements had relative standard deviations (RSDs) of 0.999. After every ten samples were tested, standards of the relevant metals were run to guarantee the accuracy of the results.

### 3.4 Health Risk Assessment from Consuming fruits in vegetables (Bottlegourd and Brinjal)

#### • Chronic Daily Intake

In terms of mass of a substance per unit body weight per unit time, averaged over a lengthy period of time (a lifetime), CDI represents the population's exposure to a substance.

The Chronic Daily Intake of Heavy Metals through the Consumption of Grains (Wheat and Rice) was determined utilising the (USEPA, 2010).

$$\text{CDI (Ingestion)} = \frac{\text{C}_m * \text{F}_i * \text{E}_f * \text{E}_d}{\text{WAB} * \text{TA}}$$

Where CM is the amount of a heavy metal present in fruits (such as bottlegourd and brinjal) per kilogramme of dry weight.

FIR is the ingestion rate for an adult residing in the study area (0.147 kilogramme per day for bottlegourd and 0.178 kg per day for brinjal). (FAO, 2014)

EF is the exposure frequency (365 days year<sup>-1</sup>)

ED is the exposure duration (70 years for adults)

WAB is the average body weight (60 kg for Indian adults) (NNMB, 2002)

TA is the average exposure time for non-carcinogenic effects (ED × 365 days year<sup>-1</sup>).

The oral reference dose for Hg, As, Cd, Pb, Cu, Mn, Zn, Cr and Fe reported was 0.0001, 0.0003, 0.001, 0.004, 0.04, 0.14, 0.3, 1.5 and 15 mg/kg/day, respectively [16].

#### • Total Hazard Quotient

RfDo is the oral reference dose (mg kg<sup>-1</sup> day<sup>-1</sup>) and is an estimation of the daily exposure to which the human population is likely to be exposed without any appreciable risk of deleterious effects during a lifetime (USEPA, 2010). The RfDo values used were 1.010<sup>-3</sup>, 2.010<sup>2</sup>, 4.010<sup>3</sup>, and 1.5. THQ has been calculated as the ratio between the estimated dose of a contaminant and the dose level below which there will not be any appreciable dose (USEPA, 2010).

$$\text{THQ} = \frac{\text{CDI}}{\text{RfDo}}$$

Where CDI stands for chronic daily intake

RfDo stands for oral reference doses

## 4. Results & Discussion

### 4.1. Heavy Metal Concentration in Soils

Each soil sample was examined in triplicate, and Table 1 shows the mean concentrations of the heavy metals Cr, Co, Cd, Ni, and Pb. The soils' Cr, Co, Cd, Pb, and Ni concentrations varied from 0.221 to 0.221, 5.341 to 6.152, 3.856 to 4.336, 8.468 to 9.644, and 8.211 to 8.534 mg/kg, with mean values (p = 0.05) of 0.119 to 0.066, 5.642 to 0.230, 4.242 to 0.150, 9.243 to 0.448, and 8.327 to 0.073, respectively. In the soil of the study area, Co, Pb, and Ni were three metals that were much more enriched than other heavy metals.

**Table 1. Range and mean of heavy metals in agricultural soil**

Statistics	Metals				
	Ni	Pb	Cd	Cr	Co
Min.	8.211	8.468	3.856	0.121	5.341
Max.	8.534	9.644	4.336	0.221	6.152
Mean $\pm$ SD	8.327 $\pm$ 0.073	9.243 $\pm$ 0.448	4.242 $\pm$ 0.158	0.119 $\pm$ 0.066	5.642 $\pm$ 0.230

**Concentration of Heavy Metals in Vegetables**

Each vegetable has two species that were examined. In the veggies, the permissible levels for Cr, Co, Cd, Pb, and Ni were 2.3, 0.2, 0.1, 0.2, and 67.9 mg/kg, respectively. The study area's brinjal was found to include elements such as Cr, Ni, Cd, Pb, and Co. Angiosperm *Solanum melongena* (Brinjal), a member of the Solanaceae family, is a widely produced vegetable crop throughout the tropics and subtropics, even in areas with high levels of pollution. The average concentration of Pb (0.183 - 0.061) was higher than that of Ni (0.174 - 0.136), Co (0.064 - 0.053), Cd (0.032 - 0.008), and Cr (0.00) (n = 5). The findings make it evident that the samples of tested brinjal vegetables had no Cr and a significant Pb concentration respectively mg/kg. The study area's brinjal was found to have equivalent levels of Cr, Cd, Co, Pb, and Ni to those reported for other regions of the nation [33].

Originally from tropical Africa, the bottlegourd (*Lagenaria siceraria*), also known as white-flowered gourd or calabash gourd, is a climbing or running vine of the gourd family (Cucurbitaceae) that is grown in warm climates all over the world for its attractive and practical hard-shelled fruits. The young fruits can be consumed and are typically prepared like vegetables. Vegetable samples from ten sampling stations from the study area were collected during harvesting season. All the collected samples were analyzed for Ni, Pb, Cd, Cr and Co content. Heavy metals in the samples of brinjal collected during April - May, 2021 was: (Pb) 0.123 - 0.185 mg kg<sup>-1</sup>, (Ni) 0.024 - 0.03 mg kg<sup>-1</sup>, (Cd) 0.024 - 0.04 mg kg<sup>-1</sup>, (Co) 0.026 - 0.044 mg kg<sup>-1</sup> and Cr was not measurable. The following was the order of the mean value of the heavy metal concentration (mg kg<sup>-1</sup>) in the bottlegourd samples that were taken: According



to Table 3, Pb (0.136 - 0.013) is followed by Co (0.026 - 0.024), Ni (0.034 - 0.008), Cd (0.029 - 0.003), and Cr (0.00). The findings make it abundantly evident that the above-mentioned vegetable sample Pb and Cr level was highest and lowest, respectively.

**Table 2. Concentration of heavy metals (mg kg<sup>-1</sup>) in fruit of *Solanum melongena***

S. No.	Heavy Metals	Mean
1	Ni	0.174 ± 0.136
2	Pb	0.183 ± 0.061
3	Cd	0.032 ± 0.008
4	Cr	0.00±0.000
5	Co	0.064 ± 0.053

**Table 3. Concentration of heavy metals (mg kg<sup>-1</sup>) in fruit of *Lagenaria siceraria* able 3.**

S. No.	Heavy Metals	Mean
1	Ni	0.034 ± 0.008
2	Pb	0.136 ± 0.013
3	Cd	0.029 ± 0.003
4	Cr	0.00 ± 0.000
5	Co	0.026 ± 0.024

### Heavy metal Chronic Daily Intake (CDI) with consumption of bottlegourd fruit

For identifying the underlying health hazards, estimation of the exposure amount and tracking the pathways of contaminants to the target species are crucial. By consuming bottlegourd fruits (2021) grown at studied sampling locations in the study area an adult will intake 0.00013645 – 0.0000727 mg kg<sup>-1</sup> day<sup>-1</sup> of Ni, 0.00094436 – 0.0006163 mg kg<sup>-1</sup> day<sup>-1</sup> of Pb, 0.00010645 – 0.000121 mg kg<sup>-1</sup> day<sup>-1</sup> of Cd, 0.00025745 – 0.0000858 mg kg<sup>-1</sup> day<sup>-1</sup> of Co and Cr value was nil and with mean CDI (mg kg<sup>-1</sup> day<sup>-1</sup>) of heavy metal via bottlegourd fruit (2021) ingestion was in order: Co (0.000183325) > Ni (0.000124725) > Cd (0.000100494) > Pb (0.00073833), (table 4). Maximum permissible limits (mg kg<sup>-1</sup> day<sup>-1</sup>) of Cd, Pb, Ni, Co and Cr through ingestion of vegetables are 0.2, 0.3, 67.9, 50 and 0.1 respectively. The current study's findings showed that the mean CDI of metals ingested was lower than the threshold CDI values.

**Table 4. Chronic daily intake (mg kg<sup>-1</sup> day<sup>-1</sup>) of heavy metals via ingestion of bottle gourd fruit**

Statistics	Metals				
	Ni	Pb	Cd	Cr	Co
Min.	0.0000727	0.0006163	0.000121	0	0.0000858
Max.	0.00013645	0.00094436	0.00010645	0	0.00025745
Mean	0.000124725	0.00073833	0.000100494	0	0.000183325

For identifying the underlying health hazards, estimation of the exposure amount and tracking the pathways of contaminants to the target species are crucial. By consuming brinjal fruit (2021) grown at studied sampling locations in the study area an adult will intake 0.00013645 – 0.0000757 mg kg<sup>-1</sup> day<sup>-1</sup> of Ni, 0.00094425 – 0.0006152 mg kg<sup>-1</sup> day<sup>-1</sup> of Pb, 0.00010645 – 0.000121 mg kg<sup>-1</sup> day<sup>-1</sup> of Cd, 0.00025745 – 0.0000828 mg kg<sup>-1</sup> day<sup>-1</sup> of Co and no value was observed in Cr with mean CDI (mg kg<sup>-1</sup> day<sup>-1</sup>) of heavy metal via brinjal fruit (2021) ingestion was in order: Pb (0.000224735) > Ni (0.000204735) > Co (0.000184315) > Cd (0.000102495) (Table.5). Vegetables may include up to the following maximum permitted levels of Cd, Pb, Ni, Co, and Cr: 0.2, 0.3, 67.9, 50, and 0.1, respectively. The current study's findings showed that the mean CDI of metals ingested was lower than the threshold CDI values.

**Table 5. Chronic Daily Intake (CDI) of heavy metals via ingestion of brinjal fruit**

Statistics	Metals				
	Ni	Pb	Cd	Cr	Co
Min.	0.0000757	0.0006152	0.000121	0	0.0000828
Max.	0.00013645	0.00094425	0.00010645	0	0.00025745
Mean	0.000204735	0.000224735	0.000102495	0	0.000184315

#### **Total Hazard Quotient (THQ) of heavy metals via ingestion of bottlegourd fruit**

The THQ of individual heavy metal to the target population via ingestion of bottle gourd fruit (2021) was in the range of 0.009585 – 0.00676 (Ni), 0.269824 – 0.1828 (Pb), 0.037023 – 0.0323 (Cd) and 0.488147 – 0.343 (Co)). The mean value of overall THQ of discrete heavy metal to the aim population via ingestion of bottlegourd fruit (2021) was in the order: Co (0.61205) > Pb (0.210945724) > Cd (0.033498323) > Ni (0.00623665) and Cr value was nil (Table 6). The target group is unlikely to experience negative health consequences from

consuming brinjal fruit on a daily basis because the THQ of the examined heavy metals was less than unity.

**Table 6. Total hazard quotient of heavy metals via ingestion of bottlegourd fruit**

Statistics	Metals				
	Ni	Pb	Cd	Cr	Co
Min.	0.00676	0.1828	0.0323	0	0.343
Max.	0.009585	0.269824	0.037023	0	0.488147
Mean $\pm$ SD	0.00623665	0.210945724	0.033498323	0	0.61205

#### **Total Hazard Quotient (THQ) of heavy metals via ingestion of brinjal fruit**

The THQ of discrete heavy metal to the marked population via ingestion of brinjal fruit (2021) was in the range of 0.098243 – 0.057537 (Ni), 0.497766 – 0.180347 (Pb), 0.057253 – 0.0525 (Cd) and 1.3298343 – 0.636 (Co) respectively and no value was observed for Cr. The mean value of overall THQ of every heavy metal to the aimed population via ingestion of brinjal fruit (2021) was in the order: Co (0.745033) > Pb (0.278515714) > Ni (0.04563645) > Cd (0.03837) (Table 7). The target group is unlikely to have negative health consequences from ingesting examined heavy metals on a daily basis because their THQ was less than unity.

**Table 7. Total hazard quotient of heavy metals via ingestion of brinjal fruit**

Statistics	Metals				
	Ni	Pb	Cd	Cr	Co
Min.	0.05737	0.180347	0.0525	0.111	0.636
Max.	0.098243	0.497766	0.057253	0.201	1.3298343
Mean	0.04563645	0.278515734	0.03837	0	0.745033

#### 4. Conclusion

Co, Cr, Cd, Pb, and Ni were the most harmful metals found in the soil in the study area. They can accumulate in vegetables, and extended consumption of them may interfere with a person's biological and metabolic functions. It was discovered that all of the studied veggies had no harmful effects on the persons consuming these. As all studied veggies has low CDI and THQ values. To map the risks to local residents' health, a thorough analysis of the CDI values for the numerous green vegetable varieties growing in the study area can be done. Through this study it was concluded that there is no risk of consuming veggies grown on this field.

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