



# High Contamination of Toxic Heavy Metals in Vegetables and Their Associated Health Risk Assessment from Different Vegetable markets of the Metropolitan City, Lucknow, India

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## Abstract

This study was conducted to monitor the locational variability of the contamination of toxic metals such as Cr, Cd, Pb, Ni, Cu, Co, Zn, Mn, and Fe and their associated health risks by the consumption of the metal-contaminated vegetables available in different vegetable markets of Lucknow, India. Total 294 samples were detected by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) for estimation of heavy metals in edible parts of eight vegetables. The study revealed that the presence of lead (Pb) was 2–240 fold higher above the maximum allowable concentration (MAC). The other heavy metals such as Cd, Co, Cu, Ni, Cr, Fe, Zn, and Mn were also found in a range of 0.06–1.89 µg/g, 0.16–1.70 µg/g, 3.19–23.99 µg/g, 0.57–23.29 µg/g, 4.16–40.01 µg/g, 153.48–2817.5 µg/g, 22.03–252.10 µg/g and 4.50–214.26 µg/g which was significantly higher than the maximum allowable concentration. The carcinogenic and non-carcinogenic health risks were calculated in terms of the hazard quotient (HQ), hazard index (HI), and carcinogenic risk factor (CRs). The Hazard quotient (HQ) and hazard index (HI) were found to be more than the requisite value of 1 (> 1) in all vegetables through the consumption of daily intake of vegetables by people, which indicate a long term health risk in this densely populated area through the consumption of heavy metal contaminated vegetables obtained from the local vegetable markets. The corresponding carcinogenic risk factor (CRs) potential for Ni, Cr, and Cd was found significantly high in the vegetables sold in three vegetable markets of Lucknow.

## Article Highlights

- The levels of toxic heavy metals in ready to use vegetables are determined periodically in different street vegetable markets of a city with 2.9 million populations.
- Exposure risk model was used to calculate associated health hazard risks of potentially toxic metals reported in the vegetables.
- The level of toxic heavy metal e.g. Cr and Pb were found significantly higher in vegetables sold in the different street vegetable markets.
- In this study we found that the carcinogenic health risk of Ni on consumers was significantly higher even if is present in low concentration in the vegetables.

**Keywords** Carcinogenic risk factor · Heavy metals · Health index · Total hazard quotient · And vegetables contamination

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## Introduction

Vegetables are an essential part of the human diet and rich in vitamins, minerals, proteins, antioxidants and nutritious metabolites. It also works as a buffering agent for acidic substances produced during respiration (Yusuf and Oluwole 2009; Ramteke et al. 2016). Food safety is one of the most desirable public concerns worldwide and risks associated

with food contamination like- pesticides, heavy metals and other agrochemicals are required to be assessed periodically to restrict the consumption of unhealthy food items by the public (Gebrekidan et al. 2013; Shaheen et al. 2016). Heavy metal contamination is considered a major cause of food toxicity and it affects human health are a great concern of food safety all over the world (Rehman et al. 2017). According to recent studies reported by Rai et al. (2019) and Cheng et al. (2020) some metals and metalloids (e.g. Pb, Cd, As and Ni) classified as non essential to metabolic and other biological functions have been included in the list of top 20 hazardous substances by United State Environmental Protection Agency (USEPA) and the Agency of Toxic Substances and Disease Registry (ATSDR) (Gall et al. 2015; Xiong et al. 2016a, b; Khalid et al. 2017; Rai et al. 2018, 2019). Certain other metals like Mn, Fe, Cu and Zn are considered to carry a lesser health risk for human if compared to Pb, Ni and Cd as these nutrient metals are required for microbial, plant and human metabolism at a lower concentration (Zhou et al. 2016; Kumar et al. 2019) However, excessive accumulation and ingestion of these metals may also cause adverse health risks to human and animals.

The unique properties of heavy metals such as non-biodegradability, long biological life and high potential of uptake and bioaccumulation make it a serious threat for all life forms including human being (Singh et al. 2010). The continued exposure of toxic metals through the food-stuff even in low quantity is considered as a major cause of chronic accumulation of the metals in the liver and kidney of humans, cattle's and birds (Ali and Qahtani 2012). Lead (Pb) can cause cardiovascular disorders, disfunction in the nervous system, kidney and liver, bone diseases, impairment of the immune systems, and disturbs the metabolic process by replacing iron, zinc, and copper etc. (Njuguna et al. 2019; Zwolak et al. 2019; Rai et al. 2019; Chen et al. 2020). The carcinogenic, mutagenic and teratogenic effects of these toxic metals are well known since long (Jarup 2003). Turkdogan et al. (2002) reported long back that the high levels of Cu, Cd, and Pb in fruits and vegetables cause cancer in the upper gastrointestinal part of human consumers.

At present several anthropogenic outcomes as industrial and municipal discharges and transport-related emissions are the major contributors of heavy metals levels in different ecosystems including agroecosystems. The Industrial fumes, waste incineration and vehicular emission load of heavy metals are increasing its levels in water, soil and air. Yusuf and Oluwole (2009) have pointed out that the rules and regulations to control emission and discharges of industrials origin in various countries are not implemented efficiently due to multiple reasons and executive flaws.

The bioaccumulation of the heavy metals in the vegetables also takes place due to its atmospheric depositions, high presence of toxic metals in soil, irrigation with the

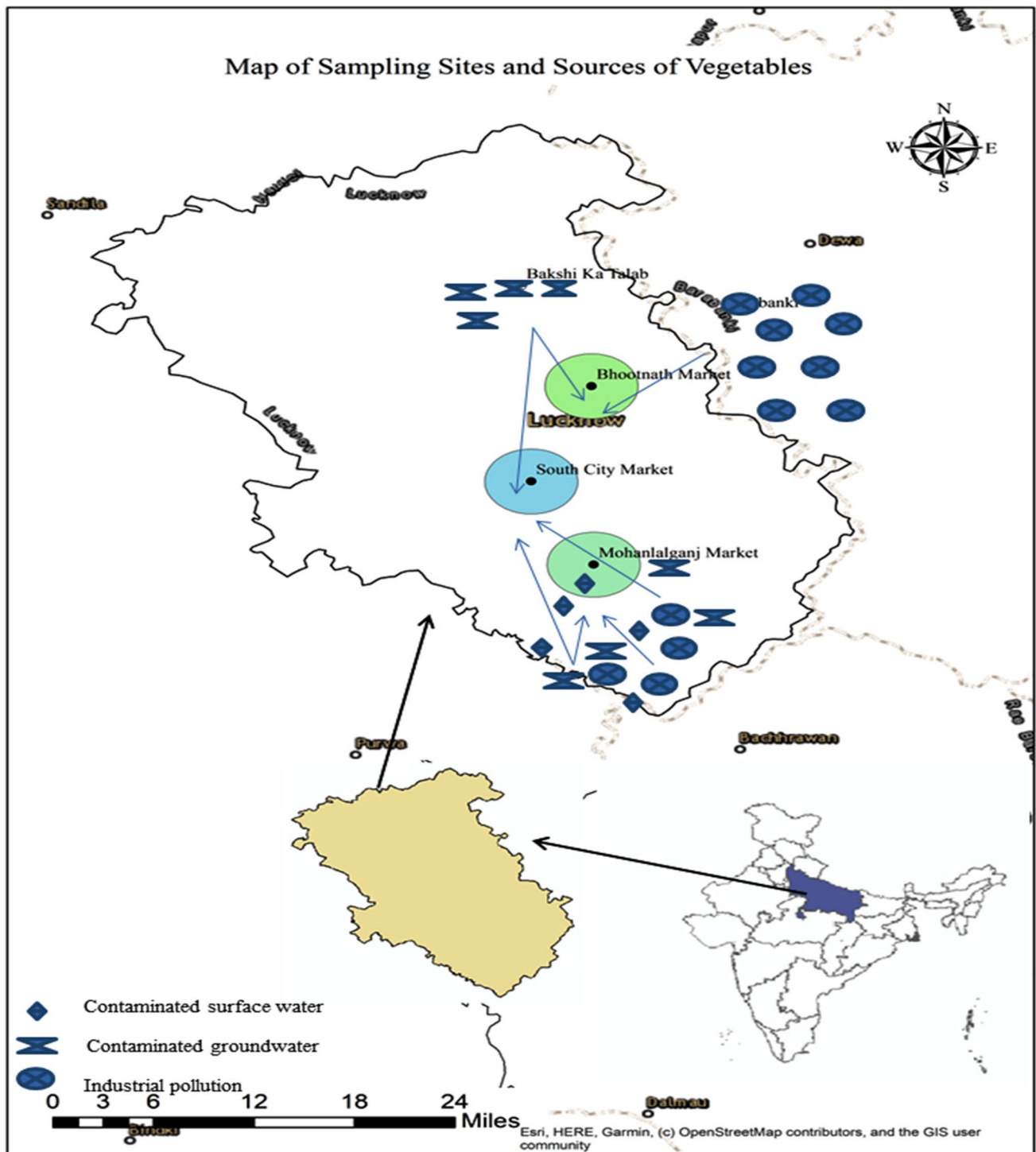
metal-contaminated water and use of metal-containing fertilizers, pesticide and other agro chemicals (Sharma et al. 2008a, b; Yusuf and Oluwole 2009). Different types of vegetables may accumulate different levels of one or multiple heavy metal levels depending on the agro-climatic conditions and cultivation practices but they all reach collectively in the common vegetable markets in the villages, towns and cities and cause severe health risk on the unidentified consumers. Shaheen et al. (2016) have reported that the health risk on the consumers in Bangladesh was measured high even with lower-level contamination of heavy metals in the vegetables. Recently Kumar et al. (2019) have also reported the high contamination of Fe, Cu, Cr and Cd in 32% vegetable samples collected from the pre-urban areas of Lucknow and have presented an analysis of daily intake in adults and children.

The contamination level of heavy metals in vegetables available in the public markets of the highly populated areas irrespective of their place of origin and assessment of its carcinogenic potential along with the other health impacts on the urban consumers have not been reported previously from this region. The present study has been undertaken with the following objectives, firstly in this work we assess the levels of various toxic metals in the vegetables available in different vegetable markets, and then we evaluated the health risk analysis that indicates the consumption of many vegetables by human being has serious health risk on the consumers of this densely populated city and its peri-urban regions.

## Method and Methodology

### Sample Collection and Preparation

Total of 294 fresh samples of highly consumed vegetable species such as Tomato (*Solanum lycopersicum*), Spinach (*Spinacia oleracea*), Cucumber (*Cucumis sativus*), Cabbage (*Brassica oleracea* var. *capitata*), Green pepper (*Capsicum annum* L), Mint (*Mentha arvensis*), Bitter gourd (*Momordica charantia*), Beet root (*Beta vulgaris*), and Cauliflower (*Brassica oleracea* var. *botrytis*) were collected from three commercial vegetable markets of Lucknow city; Bhoothnath vegetable market (BVM), South city vegetable market (SVM) and Mohanlal Ganj vegetable markets (MVM) on different days during the two subsequent years i.e. August to September 2018 and March to June 2019 (Fig. 1). The time and frequency of sampling were selected simultaneously according to the availability of seasonable vegetables in different vegetable markets in Lucknow, India. From each sampling site, a composite of at least 9 samples (1 kg/sample) for each vegetable item was prepared. First, to remove the dust and atmospheric deposition, the collected samples were washed thoroughly with tap water followed by the two subsequent washes of distilled water and then were cut into small pieces



**Fig. 1** Locational map of sampling site where vegetable samples collected from different vegetable markets of a metropolitan city, Lucknow, India. Blue arrow indicates the way vegetables are supplied from various agricultural field to different vegetable markets. Circle

shows the buffer zone around the vegetable market. And different symbols show the source of metal contamination in vegetable in the agricultural field

with help of a clean knife. The pieces were oven dried at 65 °C until a constant weight was achieved and grinded in a commercial blender following sieving to homogenize the plant material and then subjected to the acid digestion.

One gram of dry powder of each vegetable was digested in aqua- mixture (15 ml, 70% HNO<sub>3</sub> and 65% HClO<sub>4</sub>; 2:1) at 80 °C until a transparent solution was achieved and was cooled at room temperature. Thereafter the solution was filtered and diluted up to 50 ml using deionised water (Allen et al. 1986). Determination of the heavy metals such as Cu, Cd, Ni, Co, Zn, Mn, Fe, Pb and Cr in the digested samples was done using ICP-OES (Model No-ICAP 6300/DUO; Manufactured by Thermo fisher). The results are expressed as a mean of 18 (9 sample per year) samples over a period of two subsequent years.

### Analysis of Associated Health Risk Assessment for Vegetable Consumption

The detected level of these heavy metals in vegetables was taken for calculation of non carcinogenic Hazard Quotients (HQ), Hazard Index (HI) and Carcinogenic risk factor (CRs) as mention below: -

#### Hazard Quotient (HQ)

The hazard quotient, a dimension less calculation analyzes the human health risk on the consumption of vegetables contaminated with toxic substances e.g. heavy metals in this case. It is based on US Region III risk-based concentration table (FAO/WHO 2011).

$$HQ = \frac{Mc \times IR \times 10^{-3} \times EF \times ED}{Bw \times RfD \times ATn}$$

where: Mc = metal concentration in vegetables, IR = Ingestion rate of vegetables in gram per day (e.g. 130 g/day), BW = Average body weight (e.g. 65 kg), EF = Exposure frequency (365 days/year), ED = Exposure duration (70 years) (life expectancy of male approx 69 years and female is 71 years in India), RfD is reference amount of individual metal (µg/g/day). The reference amount of Co, Ni, Cu, Cd, Pb, Fe, Mn, Zn and Cr is  $3.0 \times 10^{-4}$ ,  $2.0 \times 10^{-2}$ ,  $4.0 \times 10^{-2}$ ,  $1.0 \times 10^{-3}$ ,  $3.5 \times 10^{-3}$ , 15, 0.14, 0.3 and  $1.5 \times 10^{-3}$  (USEPA; United State Environmental Protection Agency 2015), ATn = average time for non carcinogens (365 days/year × ED).

#### Hazard Index (HI)

To calculate the total potential health risk posed by more than one metal, HI is calculated by the sum of the hazard

quotient (HQ) of each metal using the equation below (Chabukdhara et al. 2016).

$$HI = HQCr + HQPb + HQCo + HQCu + HQNi + HQCd + HQFe + HQMn + HQZn.$$

#### Carcinogenic Risk Factor (CRs)

The carcinogenic risk factor (CRs) is also a dimensionless indicator and applied to calculate the carcinogenic risk (lifetime cancer risk) using the USEPA Region III risks-based concentration table method.

$$CR's = \frac{Mc \times IR \times 10^{-3} \times CPSo \times EF \times ED}{Bw \times ATc}$$

where; CPSo:—Carcinogenic potency slope, oral (µg/g Bw-day<sup>-1</sup>). The Carcinogenic potency slope (CPSo) value of Ni, Cr, Cd and Pb is 1.7, 0.5, 15 and  $8.5 \times 10^{-3}$ , respectively (USEPA; United State Environmental Protection Agency 2015), ATc:—Averaging time for carcinogens was 365 days/year. Carcinogenic Slope factor (CPSo) have yet not established for Co, Cu, Fe, Mn and Zn because they do not cause any carcinogenic effect.

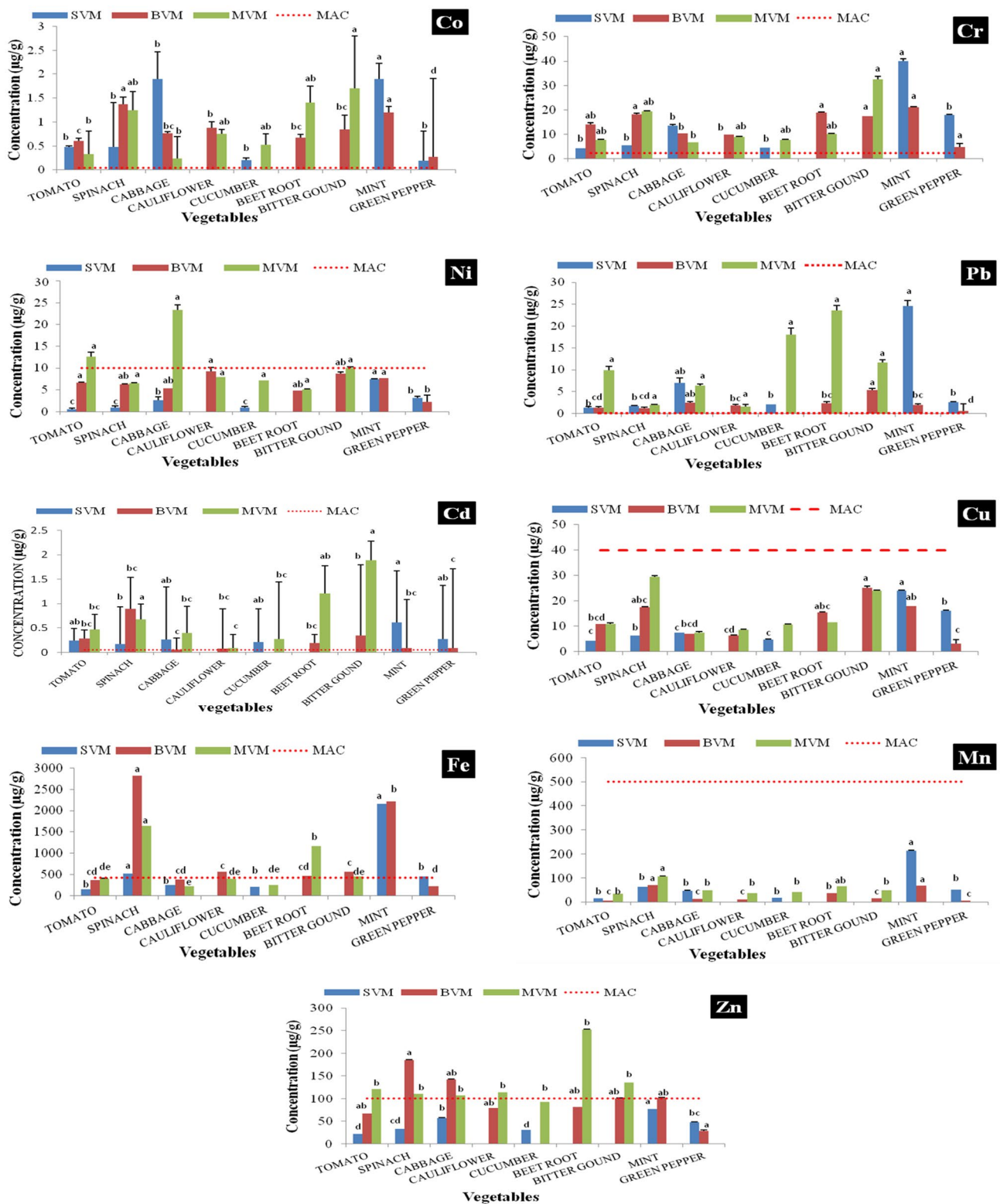
#### Statistical Analysis

The experimental data were tested for significance by a one way-ANOVA followed by Duncan's test at a significance level of 5% ( $P < 0.05$ ) using statistical analysis software SPSS version 20.0 and Microsoft Office 2007. The data are presented as means of three replicates with their standard error. The principle component analysis was performed using Past326b statistical software.

## Results and Discussion

### Level of Heavy Metals in Vegetables

A total of 294 samples of about 8 vegetables which were ready to sell in the market to consumers were collected from the vendors directly from the different vegetable markets of the city. The vegetable samples did not show any consistent trend in the level of different toxic heavy metals. Cadmium (Cd) was higher to the Maximum Allowable Concentration (MAC) in spinach only and that too only in the samples from Bhoothnath vegetable market (BVM) and Mohanlal Ganj vegetable markets (MVM), whereas it was below the MAC in the samples collected from south city vegetable market (SVM) (Fig. 2). The use of phosphate fertilizers, industrial discharges, Cd-containing fungicides, and Cd-contaminated



**Fig. 2** Average heavy metal levels in the vegetable samples collected from different vegetable markets. The data represent mean  $\pm$  standard error, MAC# Maximum Allowable concentration, SVM\* South City vegetable market, BVM\* Bhoothnath vegetable market, MVM\*

Mohanlal Ganj vegetable market, Small alphabets in a graph show a significant difference in heavy metal concentration in vegetables at temporal scale at  $P < 0.05$

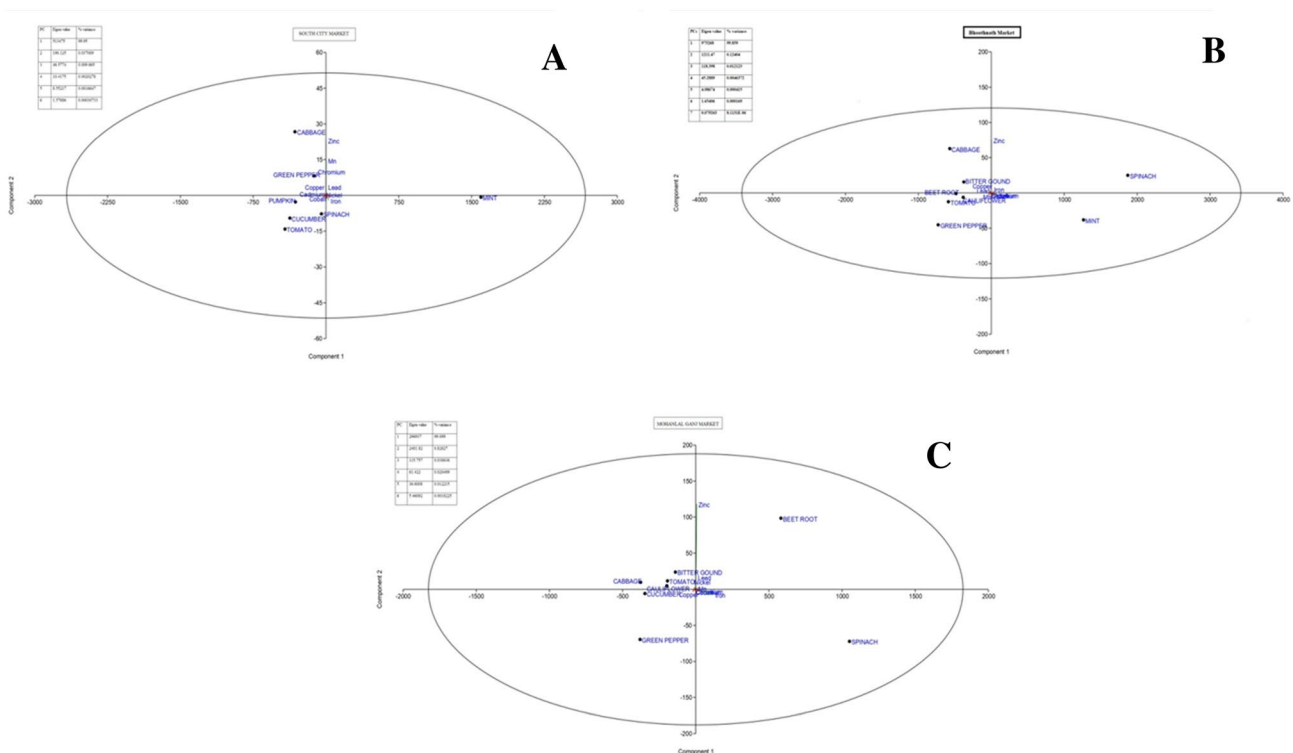


irrigation water are the major source of Cd contamination in vegetables (Adu et al. 2014; Kumar et al. 2019). Cobalt (Co) on the other hand was higher to MAC in mint from SVM, in spinach from BVM and MVM, as well as in beetroots and bitter gourd from MVM.

Chromium is at low concentration (e.g., 0.05–1  $\mu\text{g/g}$ ) is a growth promotor and increases yield but at high concentration (e.g., 1–5  $\mu\text{g/g}$ ) inhibits growth, decreases chlorophyll synthesis, and cause chlorosis in plants (Kumar et al. 2019). The level of chromium (Cr) was higher in all samples which indicates that these vegetables are grown in the agriculture fields irrigated with Cr contaminated industrial wastewater which is a common practice in the region due to discharges from multiple tanneries in the vicinity of vegetable cultivation areas. Iron (Fe), Copper (Cu), Zinc (Zn) and Manganese (Mn) is an essential metal but the application of different micronutrient fertilizer enhanced the concentration in soil and vegetables (Orbovic et al. 2007). On the other hand, levels of Cu, Mn, and Ni were below the MAC but Ni was higher in tomato from MVM. Zn and Fe contents were higher in spinach, green pepper, mint, bitter gourd, and beetroot in all the samples collected with varied magnitude. The Zn was higher than MAC in most of the vegetables collected from MVM but for cucumber which was lower in the vegetables from BVM. Cu and Fe concentration in vegetables have been reported earlier viz. Cu in spinach (20.6  $\mu\text{g/g}$ ),

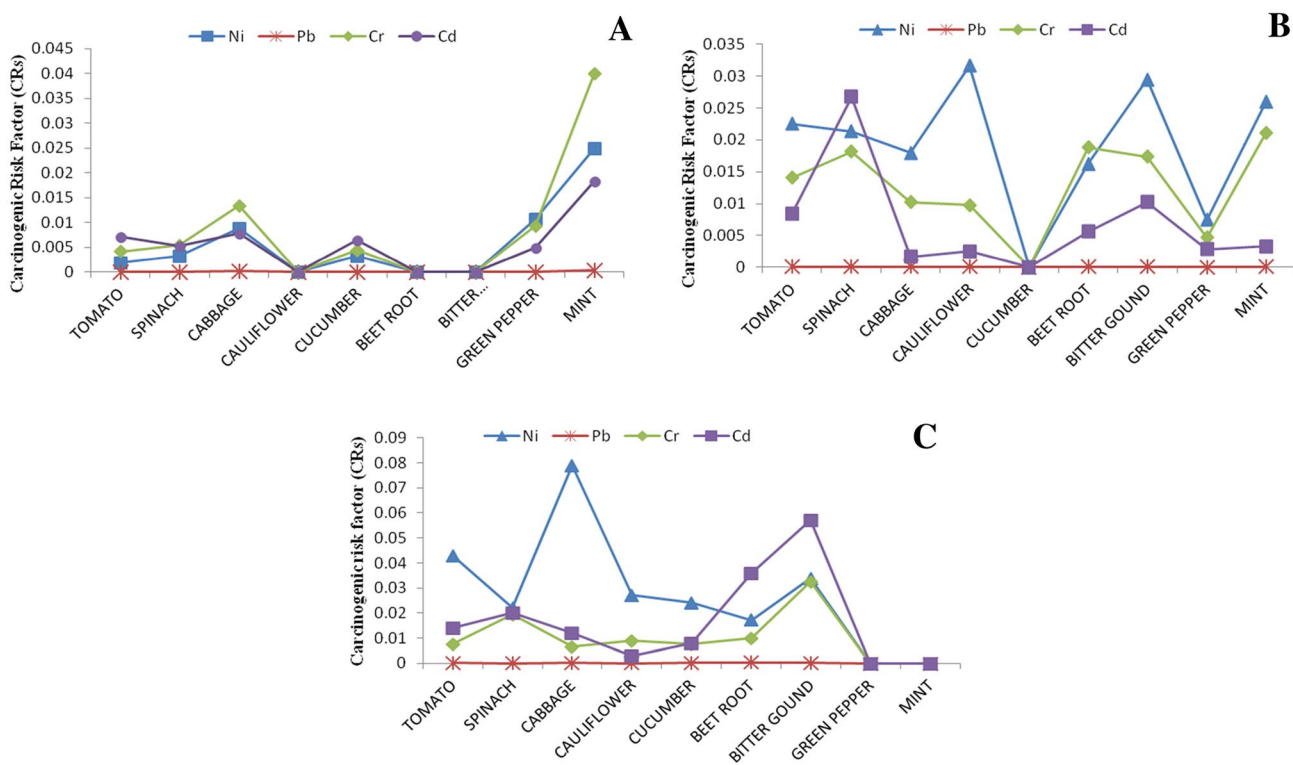
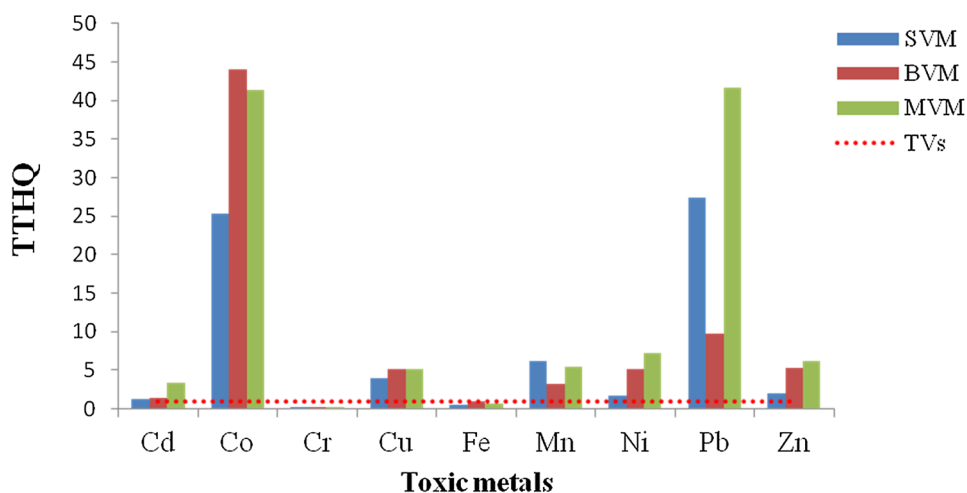
Indian mustard (5.42  $\mu\text{g/g}$ ), cauliflower (10.8  $\mu\text{g/g}$ ) and Fe in cabbage (90  $\mu\text{g/g}$ ), spinach (120  $\mu\text{g/g}$ ) and beetroot (60  $\mu\text{g/g}$ ) by Chabukdhara et al. (2016) and Kumar et al. (2019). The level of Pb in vegetables was found much higher than the MAC as prescribe by the FAO/WHO and Indian standard by the CPCB in all vegetable samples collected from different vegetable markets.

The local vegetable vendors of these markets purchase vegetables from different sources e.g., central market, directly from the growers and the chain of local vendors. The vegetables sampled might have been cultivated in different agro-climatic conditions and with different cultivation practices. The ability of heavy metal uptake and accumulation can be different in different soil, irrigation water, and different types of vegetables even among the different cultivars and varieties within the same species (Zhu et al. 2007; Säumel et al. 2012). In a recent study, Ratnakar and Shikha (2019) have reported that the co-contamination of heavy metal i.e., Pb, Cr, Ni, Fe, Cu, Cd, As, Mn, and Hg in agricultural lands situated around industrial areas around Lucknow (Mohanlal Ganj, Barabanki, Kamla pur, and Unnao) are present in high concentration especially in case of Cr and Cd. There are reports which indicate that even a lower amount of toxic heavy metal intake for the longer-term can be hazardous to human health (Shaheen et al. 2016).



**Fig. 3** Principle Component Analysis (PCA) of Heavy Metal Contamination in a vegetable sample collected from different Lucknow vegetable markets, India, **A** SVM, **B** BVM, **C** MVM

**Fig. 4** Total Target Hazard Quotient (TTHQ) of heavy metals of generally using vegetables from different markets. SVM\* South City vegetable market, BVM\* Bhoothnath vegetable market, MVM\* Mohanlal Ganj vegetable market, TV<sub>s</sub>\* Tolerance limits



**Fig. 5** Carcinogenic risk Factors (CRs) of heavy metals due to consumption of metal contaminated vegetables from different markets. A SVM; B BVM; C MVM

According to our analysis data revealed that the concentration of heavy metals i.e., Fe, Mn, Cu, Pb, Zn, Co, Cd, Ni, and Cr in vegetable samples show the discontinuity in accumulation of heavy metal in the vegetable. In this research article, we find the all metals in all vegetable samples collected from different vegetable markets from Lucknow are found higher than the Indian standard prescribe by the CPCB (Supplementary Table 1) and show high toxicity on

consumers by the consumption of metal contaminated vegetables. In our own analysis presented in this paper, the principal component analysis, hazard quotient, Hazard index, and carcinogenic risk factor have indicated similar hazard indices to the life of the consumers in this region (Figs. 3, 4 and 5) (Table 1).

**Table 1** Calculated Hazard quotient (HQ) and Hazard index (HI) (non-carcinogenic risk factor) of heavy metals on consuming vegetables from different Lucknow vegetable markets ( $n = 18$ )

Vegetable	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	TTHQ
<b>(A) South city vegetable market (SVM)</b>										
Tomato	0.15705	3.2053	0.00555	0.21039	0.02046	0.21222	0.05687	0.76943	0.14684	4.784111
Spinach	0.11538	3.1873	0.0072	0.31489	0.07009	0.89771	0.09687	0.96681	0.21727	5.873507
Mint	0.4095	12.6524	0.05335	1.19772	0.28803	3.06087	0.73914	14.0744	0.51129	32.98676
Cucumber	0.1423	2.68081	0.00585	0.24026	0.02714	0.23966	0.09558	1.19835	0.20576	4.835706
Cabbage	0.1729	1.20972	0.01792	0.37008	0.03362	0.67391	0.26282	3.99606	0.38122	7.118255
Green pepper	0.17905	1.28924	0.0237	0.80483	0.06038	0.722	0.31339	1.46397	0.32033	5.17689
TTHQ	1.17618	24.2251	0.11357	3.13817	0.49972	5.80638	1.56467	22.46903	1.78271	HI=60.775
<b>(B) Bhoothnath vegetable Market (BVM)</b>										
Tomato	0.187	4.093	0.019	0.541	0.048	0.064	0.663	0.774	0.442	6.832
Spinach	0.593	9.101	0.024	0.878	0.376	0.988	0.626	0.657	1.235	14.478
Cabbage	0.037	5.038	0.014	0.352	0.050	0.187	0.528	1.424	0.949	8.579
Beet root	0.125	4.485	0.025	0.771	0.062	0.529	0.477	1.362	0.544	8.380
Bitter gourd	0.227	5.582	0.023	1.257	0.076	0.201	0.866	3.080	0.672	11.985
Cauliflower	0.056	5.851	0.013	0.322	0.075	0.149	0.928	1.011	0.530	8.935
Mint	0.074	8.023	0.028	0.892	0.295	0.953	0.762	1.117	0.681	12.824
Green pepper	0.063	1.820	0.006	0.160	0.030	0.065	0.218	0.335	0.196	2.893
TTHQ	1.362	43.994	0.152	5.172	1.012	3.137	5.067	9.761	5.250	HI=74.87
<b>(C) Mohanlal ganj vegetable market (MVM)</b>										
Tomato	0.31615	2.22484	0.01029	0.54756	0.05378	0.48843	1.25654	5.63008	0.80104	11.32871
Spinach	0.44999	8.2925	0.0258	1.48354	0.21972	1.52605	0.6543	1.10716	0.7365	14.49556
Cabbage	0.26762	1.60486	0.00895	0.37811	0.0293	0.67946	2.32867	3.62627	0.71506	9.638306
Cauliflower	0.06148	4.98972	0.01192	0.4335	0.05325	0.5121	0.78949	0.88158	0.76117	8.494201
Cucumber	0.17981	3.50991	0.01019	0.53109	0.03331	0.57459	0.71683	10.3197	0.61861	16.49402
Beet root	0.80601	9.4	0.01347	0.57435	0.15626	0.93534	0.50575	13.5001	1.68066	27.57191
Bitter gourd	1.25939	11.3639	0.04339	1.19938	0.06079	0.68006	0.99839	6.64175	0.90292	23.14994
TTHQ	3.34044	41.3857	0.124	5.14752	0.60641	5.39604	7.24997	41.7066	6.21595	HI=111.13

TTHQ\* Total Target Hazard Quotients, HI\* Hazard Index

### Principal Component Analysis (PCA)

The principal component analysis (PCA) was applied using PAST software version 9.0. PCA of SVM showed total variability of 99.95% (Eigenvalue 513,475) for PC1 and 0.037% (Eigen Value 190.12) for PC2 (Fig. 3A). The total variability of leftover PCs (PCs 3–6) was 0.043%. These PCs seemed irregular and didn't put into any logical explanation of spatial patterns. Therefore, the biplot graph was made for PC1 or PC2. The heavy metal concentration in spinach and tomato show a negative loading score while mint showed a conclusive loading score value for PC1 and PC2. The total variant of PC1 and PC2 in BVM was 99.85% (Eigenvalue 975,268) and 0.124% (Eigenvalue 1211.47), respectively (Fig. 3B) and PCA biplot for heavy metal concentration in BVM was visualized somewhat similar to the SVM biplot (Fig. 3B).

The loading value for lead (Pb) in biplot was also at the unassertive side ( $-0.00027$  for PC1 and  $0.0161$  for PC2) of selected PCs. Percentage variability of PC1 and PC2 in MVM was 98.82% (Eigenvalue 278,072) and 1.04% (Eigenvalue 2938.79) (Fig. 3C). The loading value for nickel (Ni) in the MVM biplot was also at the unassertive side ( $-0.00039218$  for PC1 and  $0.0227$  for PC2) for all preferred PCs. PCs Score value of Heavy metal in tomato, cabbage, cauliflower, beetroot, bitter gourd, and green pepper for all market biplot of this study were closer to the center of plot recommended maximum correlating. Our study suggested that the associated health hazard risk is probably driven by the long-term consumption of the heavy metal contaminated vegetables from the different vegetable markets of Lucknow. To generate the predictive model of the essential and toxic heavy metals contamination in vegetables PCA 3A, PCA 3B, and PCA 3C were



created. The toxicity of heavy metal contamination on consumers has a significant share of the in vegetables consumption even if the vegetables have lower levels of heavy metal contaminations.

### Hazard Quotient (HQ) and Hazard Index (HI)

The HQ and HI are the non-carcinogenic risk factors. The health risk from intake of vegetables in the adult population was assessed on the basis of HQ. The HQ is the ratio of the determined dose of the toxic metal to a reference dose level. HQ value is associated with many factors like per day intake of the metal, the average body weight of the consumer, exposure time and oral reference dose ( $R_fD$ ) of toxic heavy metals (Zhou et al. 2016). If the  $HQ > 1$ , the screening population will likely experience a noxious effect (Shaheen et al. 2016). Significant difference was found in the HQ value of toxic heavy metals in all the vegetable samples collected from the different markets. The Total target hazard quotient (TTHQ) value of toxic heavy metals (Pb, Cu, Cd, Ni, Mn, Zn and Co) was much higher than the tolerance limit ( $< 1$ ) in all vegetable samples except Cr and Fe in vegetables from SVM (Table 1A), Cr in BVM (Table 1B) and Cr and Fe in MVM (Table 1C). The Hazard Index (HI) value was found much higher than the tolerance limit ( $< 1$ ) in all the samples. The HI value of samples from SVM, BVM, and MVM is 60.775, 74.87, and 111.13 (Table 1A, B, and C) were found much higher inferring the significant non-carcinogenic health impacts on the large population of this city through vegetable consumption. HQ ranking order for all vegetable samples are as follows: Spinach > mint > bitter gourd > cauliflower > cabbage > beet root > tomato > green peeper in BVM sample, mint > cabbage > spinach > green peeper > cucumber > tomato in SVM samples and beet root > bitter gourd > cucumber > cucumber > spinach > tomato > cabbage > cauliflower in MVM. TTHQ of Cr and Fe was found  $< 1$  in BVM, SVM, and MVM based samples (Fig. 4); it appears that the consumption of these vegetables may cause a considerable health risk to the consumers. However, The Total target Hazard Quotient (TTHQ) through consuming other vegetables were  $\leq 1$  indicating no or less considerable health risk in the expenditure of these vegetable items. The HI values indicate that the adult population may experience adverse health effects by the expenditure of vegetables from BVM, SVM, and MVM.

### Carcinogenic Risk Factor (CRs) of Pb and Ni

The calculated CRs derived from the intake of Pb and Ni may promote both the non-carcinogenic and carcinogenic effects depending on various factors like daily intake of heavy metal, bodyweight of consumers, exposure time, and oral carcinogenic risk potential slope (CPSo) of toxic

heavy metals. The CRs value of Pb, Cr, Cd and Ni due to exposure from different vegetables is presented in Fig. 5. The range of CRs for Pb from  $9.9780E-06$  to  $4.2368E-05$  in BVM,  $2.289E-05$  to  $4.18E-04$  in SVM and  $3.29E-0$  to  $4.01E-04$  in MVM; Cr from 0.0046 to 0.02104 in BVM, 0.0067 to 0.0325 in MVM and 0.00416 to 0.040 in SVM; Cd from 0.00102 to 0.0267 in BVM, 0.003 to 0.057 in MVM and 0.0049 to 0.0184 in SVM, whereas 0.00741 to 0.03155 in BVM, 0.00193 to 0.02513 in SVM and 0.0172 to 0.07917 in MVM, for Ni. The carcinogenic risk factor (CRs) value of Nickel (Ni), Chromium (Cr) and Cadmium (Cd) were found higher than the tolerance limit ( $< 10^{-4}$ ) whereas the value of Pb was found below the tolerance limit in all vegetable samples collected from Lucknow suggesting highly potential CRs from Ni, Cr and Cd consumption but less from Lead (Pb). Induced carcinogenicity through the consumption of vegetables collected from BVM, SVM and MVM indicate no CRs for the Pb consumption in all studied vegetables in the consumers, but high anxiety for Ni, Cr, Cd-induced CRs does exist, particularly from consumption if all vegetables species from a different market of Lucknow. In a recent report of All India Institute of Medical Science, New Delhi (AIIMS) (2019) it also has been found that 16% of 216 patient had a high level of toxic metals As, Fe, Cr, Pb and Cd in human blood and urine which causes a sudden rise in certain health disorders, including cancer, neurological disorder, multiple sclerosis, arthritis, cardiac diseases, chronic kidney diseases and infertility etc.

### Conclusion

The present study showed that the levels of heavy metals e.g. Cd, Cr, Cu, Pb, Co, Ni, Mn, Fe and Zn in various vegetables collected from different markets of the highly populated city Lucknow, India though do not show a definite trend are generally higher to MAC. Assessment of the health risks on its consumption in terms of Hazard Quotient (HQ), Hazard Index (HI), and Carcinogenic Risk Factor (CRs) indicate that the contaminations in these vegetable were a serious and immediate concern. It appears that these vegetables would be unsafe for the consumers as HI value were much higher than the threshold levels of  $< 1$  i.e. 60.775, 74.87 and 111.13 in the vegetables from these three (SVM, BVM and MVM) Street vegetable markets. This indicates a possible adverse non-carcinogenic health impact on the vegetables consumption from these local markets of the city. The CRs value of Ni, Cr and Cd were shown the high potential of carcinogenesis through the consumption of the vegetables having high Ni, Cr and Cd level. The study reveals an immediate concern about

the cultivation practices, storage of vegetables and health hazards associated with the ready-to-eat vegetables in the city and caution for a strict regulatory framework to reduce the risk.

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**Data Availability** All relevant data are within the paper and its supporting information file.

## Declarations

**Conflict of interest** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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