Ecological Risk Index and Their Associated Health Risk Evaluation of Toxic Heavy Metals in Cultivated Vegetable and Cereal in Different Peri-Urban Regions of an Indian Metropolitan City, Lucknow

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Research Article

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Ecological Risk Index and their Associated Health Risk Evaluation of Toxic Heavy Metals in cultivated vegetable and cereal in different peri-urban regions of an Indian metropolitan city, Lucknow

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HIGHLIGHTS

- ✓ The level of toxic heavy metals in agricultural soil, irrigation water, and different parts of vegetables and cereals are determined periodically from peri-urban regions of a metropolitan city Lucknow, India; a city with 3.7 million populations.
- ✓ The level of toxic heavy metals e.g. As and Pb were found significantly higher in the edible part of vegetable and cereal samples collected from different agricultural areas.
- ✓ In this study, we found that the phytoaccumulation factor of Cd and Ni was significantly higher in the edible parts of crop plants via irrigation water as compared to the agricultural soil.
- ✓ The carcinogenic health risk of Cr, As, Cd, and Ni on consumers was significantly higher even when present in low concentration in the edible parts of crop plants.

ABSTRACT

The present study investigates the phytoaccumulation factor (PF), Ecological risk index (E_{RI}), and carcinogenic risk factor (CRs) of toxic heavy metals (THM_s) i.e. As, Cd, Cr, Pb, and Ni in the agricultural soil, irrigation water, vegetables and cereals samples collected from peri-urban regions of Lucknow. The level of these metals was within the maximum allowable concentration (MAC) (FAO/WHO 2011) in agricultural soil while it was higher in irrigation water. The phytoaccumulation factor of Cd and Ni was very high in the edible parts of vegetable and cereal samples which show that they might have entered through metal-contaminated irrigation water

even if not available in the soil. The contamination coefficient (${}^{i}_{f}C$) and Ecological risk factor (${}^{i}_{f}E$) of metals was detected in the range of low risk in all agricultural soil, whereas Ecological risk index of metals was found in the moderate risk which indicated a mild impact on the agro-ecosystem. The carcinogenic risk potential of metals was found more than the requisite value of 10^{-4} in tomato, spinach, and wheat samples. This study indicates that the metals possess a moderate ecological risk and high carcinogenic risk potential through the consumption of metal-contaminated vegetables and cereals grown and sold in peri-urban regions and food markets.

Keywords: - Carcinogenic Risk Factor (CR's), Contamination coefficient (${}^{i}_{f}C$), Ecological risk factor (${}^{i}_{f}E$), Ecological risk index (E_{RI}), Phytoaccumulation factor (PF), and Toxic heavy metal (THM_s).

1. INTRODUCTION

Carcinogenic impact of heavy metal contamination in food systems is considered as a major cause of potentially growing environmental and human health concerns throughout the world (Rehman et al., 2017). The THM_s enter in the environment from anthropogenic as well as natural activities (Figure 1) (Oti, 2015; Waqas et al., 2015). During irrigation of crops, with the heavy metal contaminated water it may get accumulated and may enter into the plants cultivated in the vicinity, which increases the potential risk to the environment and human health (Zhiyuan et al., 2011). Vegetable crops provide major nutritional components of the human and animal diet and a rich source of carbohydrate, vitamins, minerals, fiber and cereals are used as stable food for the people (Hu et al., 2013). The absorption of THM_s by the vegetable and cereal plants roots can be resulted in accumulation at high level in its various parts even present in low levels in the soil (Jolly et al., 2013). Therefore, consumption of toxic metals through the food chain is considered a major source of toxic metals contamination in humans and livestock which causes many known and unknown diseases including cancers, gastrointestinal disorders, and neurological problems. The leafy vegetables have been reported to be more prone to absorb, transport, and accumulate toxic heavy metal in its edible parts than other vegetables (Zhou et al., 2016; Rehman et al., 2017). Associated health hazard assessment for THM_s in the human population can provide an assessment of the real survival threat to the people consuming heavy metal contaminated food items (Kooner et al., 2014). Ingestion of toxic metals through food will cause its accumulation in the cells of the consumer organisms, producing serious health concern (Sathawara et al., 2004). Arsenic (As) is associated with abortion, stillbirths, and cardiovascular complications whereas, Lead (Pb) can

adversely affect the mental development of children. The extreme Pb in the blood can induce kidney and liver disfunction, nephropathy, cardiovascular diseases, nervous system disfunction, hypertension, bone diseases, and disorders of the immune and reproductive systems (Khan et al., 2012; Njuguna et al., 2019; Zwolak et. al., 2019).

Few studies are focused on Pd, Ni, Cr, As and Cd contaminated soil and vegetable species with low heavy metal accumulation (Zhou et at, 2016; Alghobar and Suresha 2017; Adimalla et al., 2018; Kumar et al, 2019). Chabukdhara et al., (2016) have been reported that the vegetable grown around the pre urban and urban industrial area in Ghaziabad city, India has high metal concentration and possess potential health risks to the consumers. Recently Ratnakar et al., (2019) have also reported that the co-contamination of toxic metal i.e., Pb, Cr, Ni, Fe, Cu, Cd, As and Mn in agriculture land located nearly the industrial area around Lucknow, India is present in high concentration especially in case of Cr and Cd. Likewise, Kumar et al., (2019) have also reported the high contamination of Fe, Cu, Cr and Cd in 32%vegetable samples collected from the peri-urban areas of Lucknow. On other hand according to Chen et al., (2020), the direct application of Phosphate fertilizer in the range of 1-400 kg/ha^{-1} would not lead to straight contamination risk of Zn, Cu, Cd, Pb, Cr, Ni, and As in agricultural soil and wheat Grains. The contamination level of THMs in vegetables and cereal in cultivated areas of the peri-urban regions of highly populated areas are available but their place of origin and assessment of its Ecological risk potential and carcinogenic potential along with the other health impacts on the urban consumers have not been previously reported in these peri-urban regions. In this study we have attempted to trace a relationship between the metal levels in the irrigated water, agricultural soil and the vegetables and cereals grown in the vicinity of Lucknow, India and the main objective of this study is to investigate the pathway of toxic metals contamination in cultivation chain and phytoaccumulation of As, Pb, Ni, Cr, and Cd in the edible parts of the different vegetable and cereals plants and assess the probable ecological risk using the Ecological risk index (E_{RI}) and associated health hazards via consumption of vegetable and cereal on population residing in the vicinity of the study area.

2. METHOD AND METHODOLOGY

2.1 Sampling Area and sample preparation

Total 210 samples of agricultural soil, irrigation water as well as vegetable and cereal (*Solanum lycopersicum* (Tomato); *Spinacia oleracea* (Spinach); and *Triticum aestivum* (Wheat)) samples were collected from various peri-urban agriculture areas from Biswan, Shindholi, Pasonda,

Khairabaad, and Mohanlal Ganj at different time intervals (i.e., September to December 2018 and June to September 2019). 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 (1kg/sample) for each sample was collected. Agricultural soil, vegetable, and cereal samples were collected in clean PVC polythene bags and water samples were collected in clean PVC plastic bottles and add 1 ml HNO_3 per liter of water sample for preservation of the heavy metal content in irrigation water. Firstly, the collected vegetable samples were washed using tap water to remove dust and atmospheric deposition and cut into small pieces with the help of a sharp object. After that, the agricultural soil, vegetable and cereal samples were oven-dried at 65°C until a constant weight was not achieved. A commercial blender was used to grind the samples which were homogenized by sieving before acid digestion.

One gram of the dry powdered agriculture soil as well as the vegetable and cereal samples were digested in aqua- mixture (15ml, 70% Conc. HNO_3 and 65% $HClO_4$; 2:1) and 50 ml of irrigation water with 5 ml of Conc. HNO_3 at 80°C until the transparent solution was achieved and cooled at room temperature. Thereafter the solution was diluted up to 50 ml using distilled and deionsed water (Allen et al., 1986). The detection of As, Cd, Ni, Cr and Pb was done in the digested samples through Inductive Coupled Plasma Optical Emission Spectroscopy (ICP-OES, model-ICAP 6300/DUO and Manufactured by Thermo fisher).

2.2 Phytoaccumulation factor (PF)

The Phytoaccumulation factor (PF) was calculated in various parts (root, stem, fruits and grains) of vegetable and cereal samples (dry weight basis) by using the following formulas: -

$$PF = M_c\,(plant) / M_s\,(soil) \quad \text{.....................................} \quad (1)$$

Where M_c *(plant)* represents the concentration of heavy metals present in the different parts of crop plant (stem/root/edible parts) and M_s *(soil)* represent the metal concentration present in agriculture soil respectively. Phytoaccumulation factor is also known as bioaccumulation factor, uptake factor, and concentration factor, for calculating the accumulation capacity of toxic metals from soil and irrigation water to different parts of crop plants (Zeng et al., 2015).

2.3 Ecological risk index (E_{RI})

The E_{RI} was calculated as the sum of individual ecological risk factor ($_{r}^{i}E$) for evaluating the toxicity of heavy metal in sediments and has been calculated extensively applied to the soil (Liang et al., 2015; Adimalla and Wang, 2018).

In this study E_{RI} was calculated by the following equations: -

$$(_{f}^{i}C) = M_n / M_{br} \quad \ldots\ldots (2)$$

$$(_{r}^{i}E) = {_{r}^{i}T} * {_{f}^{i}C} \quad \ldots\ldots (3)$$

$$E_{RI} = \sum (_{r}^{i}E) \quad \ldots\ldots (4)$$

Where $_{f}^{i}C$ is the contamination coefficient of an individual metal; M_n is the toxic metal level present in the soil; M_{br} is the background value for metal; $_{r}^{i}E$ is the Ecological risk index for single metal; $_{r}^{i}T$ is the toxicity factor for single toxic metal introduced by Hakenson (1980). The $_{r}^{i}T$ value of As, Pb, Cd, Ni and Cr are 10, 5, 30, 2 and 5, respectively. The background concentration of toxic heavy metal of As, Cd, Pb, Ni and Cr are 13.37, 0.3, 12.5, 20 and 90. The E_{RI} was classified in five stages according to the value of $_{f}^{i}C$, $_{r}^{i}E$ and E_{RI} (Table 1) (Hakenson, 1980; Adimalla, 2018; Wang et al., 2018).

2.4. Associated health risk assessment for vegetable consumption

The fate of carcinogenicity was calculated in terms of the Carcinogenic risk factor (CRs). The level of the toxic metal in crop plants is used to calculating the Carcinogenic Risk factor (CR's).

2.4.1. Carcinogenic risk factor (CR's)

The CRs is a dimensionless and used to calculate the carcinogenic risk (lifetime cancer risk) by using the USEPA Region III risk-based concentration table method.

$$\boldsymbol{CR's = \frac{Mc*IR*10^{-3}*CPSo*EF*ED}{Bw*ATc}} \quad \ldots\ldots (5)$$

Where; Mc= metal concentration in edible part of crop plants, 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 expectory of male approx. 69 years and female is 71years in India), *CPSo*: - Carcinogenic potency slope, oral (µg/g $Bw\text{-}day^{-1}$). The *CPSo* value of Cr, Cd, As and Pb is 0.5, 15, 1.5 and 8.5×10^{-3} (USEPA; United State Environmental Protection Agency 2015), *ATc*: - Average time for carcinogens (365 days/year × ED).

2.5 Statistical Analysis

The Experimental data were tested for significance by One-way- ANNOVA followed by the Duncan's test at significant level of 5% ($p<0.05$) using the statistical analysis software SPSS version 20.0 and Microsoft excel 2007. The data are presented in a means of three replicates with standard error.

3. RESULTS

3.1 Toxic metals levels in irrigation water, agriculture soil as well as in vegetable and cereal sample.

The level of Cd, Cr, As, Ni, and Pb was found in the range of 0.15-8.10 µg/ml, 0.082-1.473 µg/ml, 0.004-40.47 µg/ml, 2.17-49.37 µg/ml, and 0.004-64.31 µg/ml respectively in the irrigation water used to cultivate the vegetable and cereal. The concentrations were significantly higher than the maximum allowable concentration (MAC) (Figure 2) except the As in tubewell water from Pasonda; Cr & Cd in canal water from Biswan and Shindholi; Cr in Tubewell water from Shindholi and Khairabaad.

The level of THM_s in agricultural soil samples are summarized in Figure 2. The observed concentrations range of As, Pb, Ni, Cr, and Cd in agricultural soil samples were 0.39-56.35 µg/g, 1.04-352.62 µg/g, 0-418.57 µg/g, 5.145-209.0 µg/g, and 0.82-87.34 µg/g which were significantly lower than the MAC except Pd, Cr, Ni & Cd content in wheat cultivated soil from Biswan, Shindholi and Khairabaad, Pb & Ni content in tomato cultivated soil from Shindholi, Pasonda, Khairabaad and Mohanlal Ganj. Pb, Cd &Ni content in Spinach cultivated soil from Pasonda and Mohanlal Ganj showed higher value more than MAC.

The level of THM_s in vegetable and cereals are showed in Figure 2. The THM_s concentration of As, Ni, Cr, Pb, and Cd in vegetable and cereal plants were found in the range of 37.72-2392.05 µg/g, 29.13-82.62 µg/g, 7.14-215.02 µg/g, 2.45-9.23 µg/g, and 38.56-503.86 µg/g in *Solanum lycopersicum* (Tomato); 33.08-50.36 µg/g, 32.95-65.39 µg/g, 9-84.82 µg/g, 0.55-5 µg/g, and 8.75-267.56 µg/g in *Triticum aestivum* (Wheat) and 13.73-60.45 µg/g, 19.96-66.52 µg/g, 19.58-122.30 µg/g, 1.66-18.99 µg/g, and 5.90-48.54 µg/g in *Spinacia oleracea* (Spinach) significantly higher than the MAC

3.2 Toxic metal concentration in various part of vegetable and cereal plants (root, stem and edible parts) samples

The concentration of THM$_s$ (Cd, As, Cr, Pb, and Ni) content in various parts of vegetable and cereal plants is presented in Figure 3. The clear differences in the levels of the toxic metals can be seen in figure 3. The mean concentration of THM$_s$ (Cd, As, Ni, Pb, and Cr) in vegetable and cereals plant roots were found greater than the MAC in all samples collected from the agricultural field of various peri-urban areas around Lucknow city. The observed concentrations of Cd, As, Ni, Pb, and Cr in vegetable and cereal plants root ranged from 0.378-18.46 µg/g, 7.40-66.30 µg/g, 0-466 µg/g, 0.519-150.9 µg/g, and 0.177-85.7 µg/g respectively; on a dry weight basis.

Figure 3 summarizes the data of selected THM$_s$ in stem portion of vegetable and cereal plants. The mean concentrations of THM$_s$ (e.g., Pb, As, Cr, and Ni) in stem were found greater than the MAC except Cd in tomato stem (0.04 µg/g) from Shindholi. The observed ranges of THM$_s$ levels of Ni, As, Cd, Pb, and Cr in stem portion were 0.94-15.19 µg/g, 11.25-24.73 µg/g, 0.04-7.61 µg/g, 0.94-15.19 µg/g, and 2.26-27.80 µg/g respectively.

The level of Ni, Pb, Cd, Cr and As were also detected in the edible parts of crop collected from different agricultural area, i.e. *Salanum lycopersicum* (tomato), *Spinacia oleracea* (Spinach), and *Triticum aestivum* (Wheat) are presented in figure 3 which shows higher concentration than the MAC except Cd in wheat from all sampling sites and spinach from Biswan. The observed concentration range of Pb, As, Ni, Cr and Cd metal in the edible parts were 1.91-23.22 µg/g, 0.19-18.67 µg/g, -22.02-50.68 µg/g, 5.06-46.92 µg/g and 0.01-1.65 µg/g respectively. The THM$_s$ concentrations in edible parts of vegetable and cereal plants from different Agricultural areas were decreased in the order of Ni>Cr>As>Pb>Cd for Biswan and Khairabaad; Ni>Cr>Pb>As>Cd for Pasonda; Ni>Pb>Cr>As>Cd for Shindholi; and Ni>Cr>Pb>As>Cd for Mohanlal Ganj, Lucknow.

3.3 Phytoaccumulation factor (PF) in crop plant through agricultural soil and irrigation water.

PF is a significant indicator of the metal accumulating capability of plants through agricultural soil as well as irrigation water. Phytoaccumulation defined as the ratio of the toxic metal's concentration in the various parts of vegetable and cereal plants to the THM$_s$ concentration in the soil and irrigation water (Zhou et al., 2016). The PF of THM$_s$ in vegetable and cereal plants are presented in table 2. PF calculated by using equation no. 1 and the PF value above the 1 for the THM$_s$ in vegetable and cereals is considered dangerous for the human and animal health (Singh et

al., 2010). The range of PF of Cr, As, Ni, Cd, and, Pb in vegetable and cereal plants samples through agriculture soil were 0.12-32.15, 0.58-620.38, 0.26-5.80, 0.01-7.42, and 0.31-22.40 whereas through irrigation water vegetable and cereal plants samples were 0.3-1953.6, 27.83-29350.6, 0.58-22.39, 0.14-4617.01 and 2.25-3.4.92 which were significantly higher than the tolerance limit. Our study reveals/ concludes that the ability of Phytoaccumulation of THM_s in vegetable and cereal plants through irrigation water is much higher than the ability of phytoaccumulation of THM_s in crop plants through the agriculture soil.

3.4 Phytoaccumulation factor (PF) in various parts of vegetable and cereal plants (root, stem and edible parts) via agricultural soil and irrigation water.

Significant differences were found in the PF value of Pb, As, Cd, Cr and Ni metal in all parts of vegetable and cereal plants (root, Stem and edible parts) through agricultural soil and irrigation water (Table 3 and 4).The PF of Pb, Ni, and Cd were found below the tolerable limit 1 (<1) as compare to As and Cr metal in all parts of vegetable and cereal plants samples except Cd in all vegetable and cereal plants roots via agricultural soil whereas the PF of Pb, As, Ni, Cr and Cd were found much higher than the tolerable limit 1(>1) in different parts of vegetable and cereal plants via the irrigation water respectively. The PF value of As, Cd, Pb, Ni and Cr in root sample were significantly higher than the other parts of crop plants (Stem and Edible parts). In this study we observed that the PF of Cd and Ni metal in different parts of vegetable and cereal plants via irrigation water was much higher than the agriculture soil. Our data indicates that the ability for metal accumulation in the root was higher than the stem and edible parts of vegetables and cereals and the ability of As, Cr and Cd metal accumulation in leafy vegetable were much higher than that for Pb and Ni through irrigation of THM_s contaminated water.

3.7 Ecological risk index (E_{RI}) of toxic metal contamination in agriculture soil samples

The E_{RI} assessment is the toxicity effect of the toxic metal concentration in soil compared with the reference value of toxic metal in the earth's crust. The toxic metal in agricultural soil may cause serious ecological risk and negatively interact with human health via food chain (Santos-Frances et al., 2017). The higher concentration of THM_s in agriculture soil affects the food quality which ultimately leads the risk of serious human diseases like cancer, kidney, liver damage etc. (Suresh et al., 2012). The E_{RI} was calculated by the above given equation 2 to 4. The comprehensive result of contamination factor ${}_{f}^{i}C$, ecological risk factor of individual toxic metal (${}_{r}^{i}E$) and E_{RI} of heavy

metal is listed in the Table 5. The ${}_{r}^{i}\boldsymbol{E}$ and E_{RI} classified in five categories as low risk, moderate risk, considerable risk, high risk and very high risk.

The contamination factor of Pb, As, Cr, and Ni in all soil sample were considered as a low contamination except As in wheat cultivated soil from Biswan (considerable contamination), Wheat and tomato cultivated soil from Khairabaad (moderate contamination), tomato cultivated soil from Pasonda (moderate contamination) and tomato and spinach cultivated soil from Mohanlal Ganj (moderate contamination); Cr in wheat cultivated soil from Pasonda (considerable contamination); Pb in spinach cultivated soil from Biswan (very high contamination), wheat and spinach (moderate contamination) and tomato cultivated soil (very high contamination) from Shindholi, wheat, tomato and spinach cultivated soil from Khairabaad (considerable contamination), Wheat cultivated soil (moderate contamination), tomato and spinach cultivated soil (considerable contamination) from Pasonda; Ni in spinach cultivated soil from Khairabaad (Very high contamination), wheat cultivated soil from Pasonda, tomato and spinach cultivated soil from Mohanlal Ganj (considerable contamination) whereas Cd was considered to have a very high contamination factor in all soil sample collected from various agricultural areas.

The ${}_{r}^{i}\boldsymbol{E}$ for Pb, Cr, Ni and As in all soil samples were considered to have a low risk contamination except As in wheat cultivated soil (moderate contamination risk) and Pb in spinach cultivated soil (moderate contamination risk) from Biswan; Pb in tomato cultivated soil (considerable contamination risk) from Shindholi However, Cd metal showed considerable contamination risks to high contamination risks in all soil sample collected from the different agricultural areas from peri-urban area around the Lucknow city. The E_{RI} value of all THM_s in soil sample studied, the contamination level was as follows: in Biswan, all soil sample, present low to moderate potential ecological risk contamination. In Pasonda, all soil samples showed low to considerable potential ecological risk. In Khairabaad, all soil samples showed moderate to high ecological risk. In Shindholi, all soil samples showed low to very high potential ecological risk. In Mohanlal Ganj, all soil samples had a moderate potential ecological risk of contamination.

Furthermore, when considering the E_{RI}, the levels of contamination (from low to high) of toxic metals from superficial horizons of soil were as follow: Shindholi>Khairabaad>Pasonda>Biswan> Mohanlal Ganj.

3.8 Carcinogenic risk factor (CRs) of heavy metals

The carcinogenic risk factor (CRs) may promote both the non-carcinogenic and carcinogenic effect depending on many factors like daily intake of heavy metal, body weight of consumer, exposure time and oral carcinogenic risk potential slope (CPSo) of toxic heavy metals. The carcinogenic risk factor (CRs) was calculated using above equation (Eq. 5). The CRs value of As, Pb, Cr, Cd and Ni due to exposure from edible parts of vegetable and cereal plants is presented in table 6. The range value of CRs of Pb, As, Cr, Cd and Ni was 3.25E-05 to 0.0012, 0.0006 to 6.963, 0.0087 to 0.041, 0.00042 to 0.04962 and -0.075 to 0.17502, respectively. The carcinogenic risk factor (CRs) value of Cd, Cr, As, and Ni were found more than the tolerable limit (<10-4) whereas the value of Pb was found below the tolerance limit except in tomato and wheat from Khairabaad; spinach from Shindholi; tomato, wheat and spinach from Pasonda and tomato and spinach from Mohanlal Ganj respectively in edible parts samples collected from different agricultural areas suggesting highly potential CRs from As, Cr, Cd and Ni consumption but less concerning for Pb in Biswan, Shindholi and Khairabaad region.

4. DISCUSSION

The ability of heavy metal uptake and accumulation usually differs in different vegetable species, even among cultivation and verities with the same species (Zhou et al., 2016; Säumel et al., 2016). Yang et al., 2010 reported that the cadmium uptake and accumulation in non-leafy vegetable is less than that in the leafy vegetables. In present study we found significant difference in the toxic metals (As, Cd, Ni, Pb, and Cr) concentration in agricultural soil, irrigation water and different parts of vegetable and cereal plants (root, stem and edible parts). The concentration of Pb and As were found 70 to730 times higher and above the MAC in vegetable and cereal plants samples collected from the different agricultural areas. The observed concentration of THM_s of Cd, Pb, Cr, As, and Ni in all samples were found above the MAC and obvious difference in heavy metal concentration (Pb, As, Ni, Cr and Cd) was found in the similar vegetable and cereals collected from different agricultural areas in various peri-urban areas around Lucknow, India.

The Phytoaccumulation factor (also known as bioaccumulation factor) from soil to plant is an index for evaluating the transfer potential of toxic metals from soil to plant (Zeng et al., 2015). Some previous study reported that PF of toxic metals from agricultural soil to crop plants and irrigation water to crop plants is a key process for human exposure to THM_s via the food chain (Onsanit et al., 2010). Our data suggest that the phytoaccumulation ability of crop plant through

irrigation is much higher than the agricultural soil and PF of As, Cd, and Cr have higher mobility from irrigation water and agriculture soil in root, followed by Pb and Ni. Because of their mobility, the concentration of As, Cd, and Cr in soil would pose a major health risk.

The ecological risk index (E_{RI}) was widely used to calculate the ecological risk caused by THM_s and their impact to an ecosystem (Mamat et al., 2016; Adimalla and Wang, 2018). The contamination factor of agriculture soil through the THM_s was found Cd>As>Pb>Cr>Ni in Biswan and Shindholi; Ni>Cd>Pb>Cr>As in Khairabaad; Cd>As>Pb>Cr>Ni in Pasonda and Cd>Ni>As>Cr>Pb in Mohanlal Ganj. On the other hand, individual ecological risk factor ($_{r}^{i}E$) of THM_s in this study areas were recorded as Cd>Pb>As>Cr>Ni in Biswan, Pasonda, Shindholi and Khairabaad and Cd>As>Pb>Cr>Ni in Mohanlal Ganj respectively. The overall Ecological risk index (E_{RI}), of the all the study area due to THM_s contamination was order as Shindholi>Khairabaad>Pasonda>Biswan> Mohanlal Ganj. A similar study conducted by Diami et al., 2016 on E_{RI} and associated health hazards of toxic metals in agricultural soil was observed the E_{RI} in the range of 44 to 128, which were indicating a low risk.

The carcinogenic risk assessment is based on the carcinogenic risk factor (CRs) method. The carcinogenic risk factor (CRs) value of As, Ni, Cd and Cr were found more than the tolerance limit ($<10^{-4}$) whereas the value of Pb was found below the tolerance limit in all vegetable and cereal samples collected from different agriculture field suggesting high potential CRs from As, Cr, Cd and Ni consumption but less concerning for Pb. In a previous study, Krishna and Mohan, (2016) were observed that the less carcinogenic risk hazards in adults than children via agricultural surface soil around an industrial area, India. In few other studies, similar results were observed in several other regions of the world (Diami et al., 2016; Adimalla et al., 2018; Narsimha and Ranjitha, 2018; Stevanovic et al., 2018; Zhaoyong et al., 2018; Adimalla and Wang, 2018). According to Rapant et al., (2011) the high health risk levels in form of carcinogenic and non-carcinogenic were observed basically in each area, where high soil contamination of toxic heavy metals has been detected.

5. CONCLUSION

The present study presents toxic metals contamination of Pb, As, Cr, Cd and Ni in agriculture soil, irrigation water and different parts of crop plants collected from the different agriculture fields of various peri-urban areas near Lucknow city of Uttar Pradesh, India. The heavy metal concentrations in all samples were detected above the permissible limit, Pb and As were recorded

70 to 730 fold higher than the safe limit in tomato, spinach and wheat samples. The accumulation of heavy metal from agricultural soil to various parts of vegetable and cereal plants can have an adverse effect on human health and environmental ecology. According the Phytoaccumulation factor (PF) of As, Cr and Cd are most readily absorbed and accumulated THM_s in the edible parts of vegetable and cereals plants. The contamination factor $^{i}_{f}C$, ecological risk factor ($^{i}_{r}E$) and Ecological risk index (E_{RI}) were found in low to moderate risk category in almost 70% of the studied samples. The carcinogenic risk factor (CRs) value of As, Ni, Cd, Pb, and Cr was found more than the tolerance limit ($<10^{-4}$) in all vegetable and cereal plants samples collected from different agriculture field suggesting highly potential CRs from As, Cr, Cd, Pb, and Ni through the consumption of the toxic metal contaminated vegetables grown in the vicinity of densely populated (Lucknow) city of Uttar Pradesh.

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AUTHORS CONTRIBUTION

Pradeep Kumar: Investigation, Conceptualization, Methodology, Formal analysis, Validation, Data curation, Writing - original draft. **Dipti Rawat**: Validation, Data curation, Writing - review & editing. **Sunil Kumar**: Writing - review & editing, Resources. **Rana Pratap Singh**: Project administration, Supervision, Writing - review & editing, Resources.

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DECLARATION OF COMPETING 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.

CONFLICT OF INTEREST

The author declares no conflict of interest.

DATA AVAILABIITY

All relevant data are within the paper and its supporting information file

COMPLIANCE WITH ETHICAL STANDARDS

Ethical Approval: Not applicable

Consent to Participate: Not applicable

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Figures

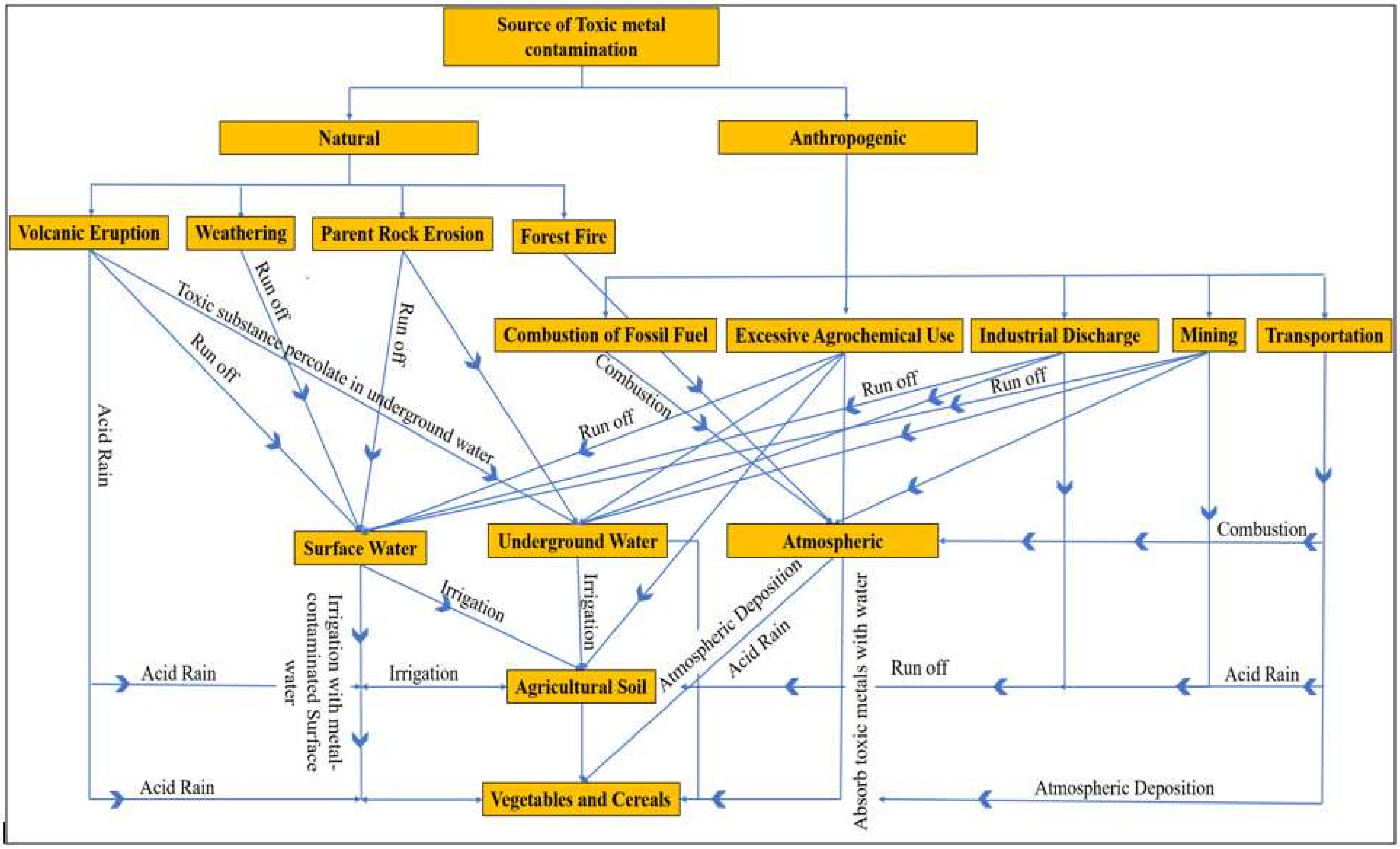

Figure 1

Direct or indirect pathway of Toxic Heavy metals (THMs) contamination in vegetables and cereals by a different source of toxic metal contamination.

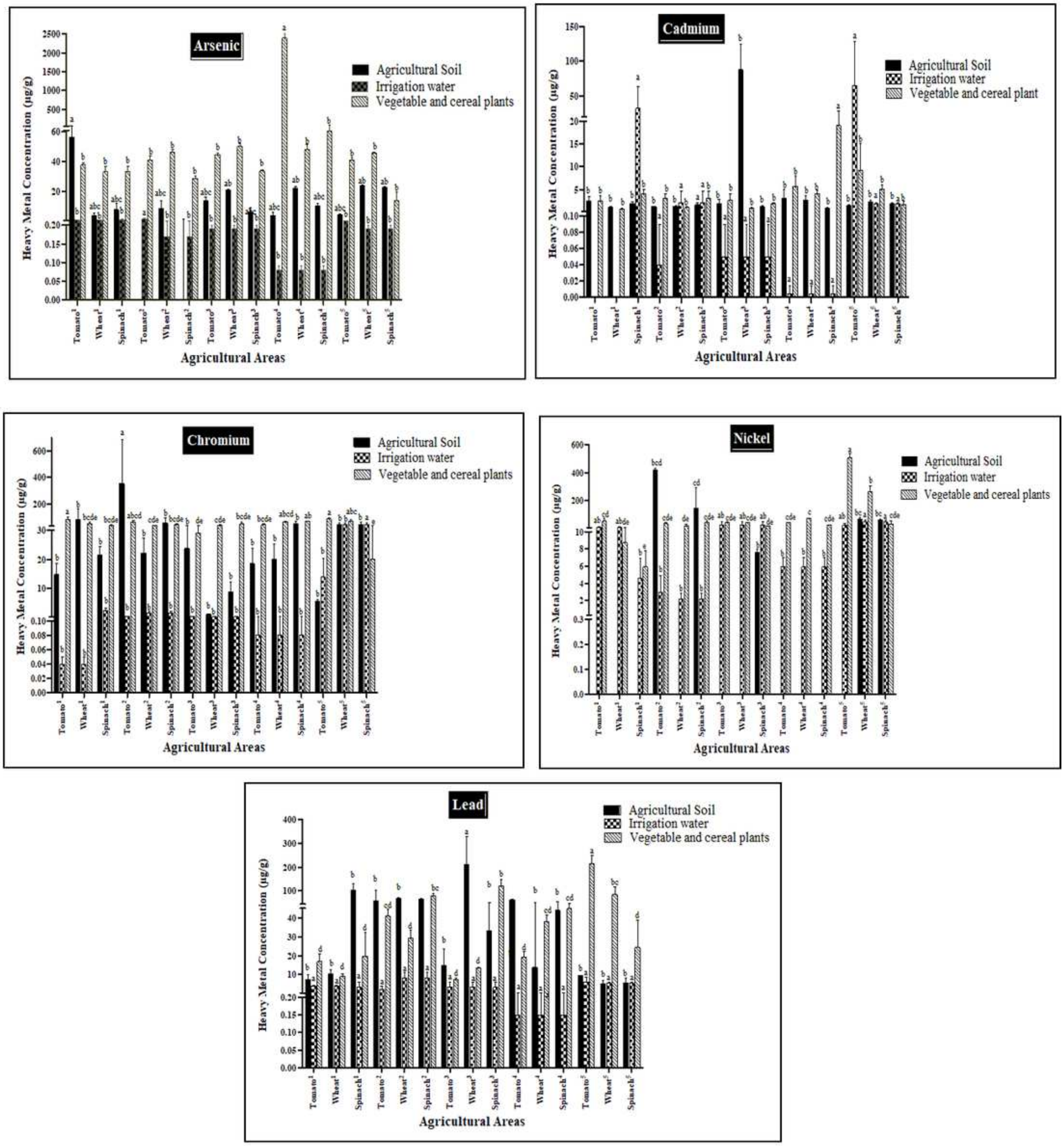

Figure 2

Average THMs concentration in different agriculture soil, irrigation water, vegetable and cereal plants samples collected from different pre-urban agriculture areas around Lucknow city, India. The data represent mean ± standard error, Small alphabets in a graph show significant difference in heavy metal concentration in irrigation water at temporal scale at $p<0.05$. Numbering on X-axis shows the sampling area i.e., 1) Biswan; 2) Khairabaad; 3) Shindholi;4) Pasonda and 5) Mohanlal Ganj.

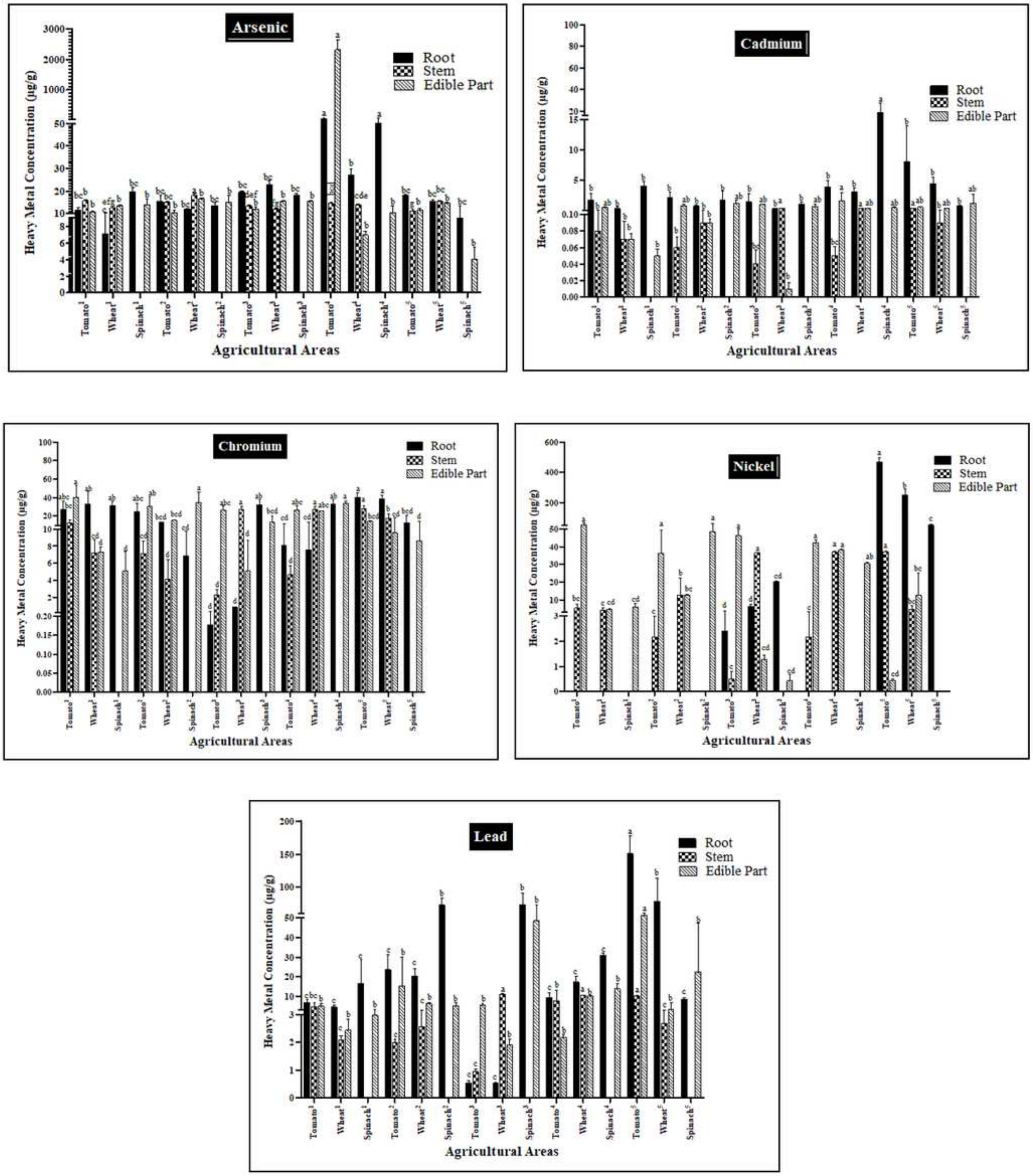

Figure 3

Average THMs concentration in different parts (root, stem, and edible parts) of vegetable and cereals plants samples collected from different pre-urban agriculture areas around Lucknow city, India. The data represent mean ± standard error, Small alphabets in a graph show significant difference in heavy metal concentration in irrigation water at temporal scale at $p<0.05$. Numbering on X-axis shows the sampling area i.e., 1) Biswan; 2) Khairabaad; 3) Shindholi; 4) Pasonda and 5) Mohanlal Ganj.