

Bio Accretion of Heavy Metals by Okra and Eggplant Grown in Polluted Areas of Jaipur City and Associated Health Risks

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ABSTRACT: Heavy metal pollution in soil has severe consequences on the sustainability of ecological equilibrium. This study emphasizes the effect of heavy metal contaminated soil on okra and eggplant grown in Sanganer and Mathuradaspura areas of Jaipur, Rajasthan, India. The human health risk assessment was done by estimating the transfer factor, daily intake rate, hazard quotient and hazard indices for some metals. The results of the study indicated that the soil of Mathuradaspura dumping ground had elevated concentration Fe, Cu, Zn, Cr in contrast to the soil of Sanganer industrial area where elevated concentration of Pb, Cd and Ni were found. The vegetables were found to have increased levels of heavy metals like Pb, Cd and Ni in the Sanganer and Cu, Zn and Ni in Mathuradaspura. The high level of pollution was indicated by the high levels of hazard index in both the sites.

KEYWORDS: soil pollution, heavy metals, hazard index, health risk assessment, transfer factor

I. INTRODUCTION

There are a many ways through which heavy metal tend to accumulate in the environment, these include irrigation with industrial waste water, indiscriminate dumping of solid waste, sewage farming and various other ways. These heavy metals are extremely persistent as they are non-biodegradable and have tendency to accumulate to toxic levels. Heavy metals in general are not removed even after the treatment of waste water at treatment plants. Due to shortage of water the use of waste water for irrigation purposes has increased tremendously from last two decades. Constant irrigation of agricultural land using industrial waste water and sewage may lead to heavy metal accumulation in the soil and vegetables. Similarly, unsystematic dumping of solid waste also causes accumulation of heavy metals in the nearby agricultural lands[1]. Without any visible change in appearance or yield, plants grown in such contaminated agricultural lands tend to accumulate high concentration of heavy metal which can be greater than the human and animal tolerance range[2][3][4]. Ingestion of heavy metals through the food chain by the human beings has been widely studied throughout the world[5]. Prolonged consumption of hazardous concentration of heavy metal through contaminated food materials may lead to the chronic accretion of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes that may lead to kidney, cardiovascular, nervous or bone diseases[6][7].

Few heavy metals such as Cu, As, Zn, Mn, Co, Mo are essential micronutrients in the plants when present in trace quantities, but when the concentration increases above a certain permissible level[8], they can cause serious health implications. Certain metals such as Cd, As, Cr, Ni, Pb, Hg etc., when present even in trace quantities are harmful to human race. Nickel is associated with high blood pressure, lung cancer, various teratogenic effects etc.[9]. Zinc when absorbed in higher quantities can cause reduced absorption of Cu and Fe.

This research work incorporates the study of heavy metals in the vegetables grown in the selected areas and also the human health implications caused by consumption of such contaminated vegetables. The objectives of the study are: (i) To find out the heavy metal content of the soils of the selected areas (ii) To detect the heavy metal concentration in the

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vegetables grown in the selected area (iii) To assess the risk on human health due to the consumption of such contaminated vegetables with respect to their heavy metal content.

II. RELATED WORK

Esakku et al (2005) assessed the exchangeable, acid extractable, reducible and oxidizable fractions of heavy metal concentration in the decomposed municipal solid waste. Iron was the major metal while the lowest metal concentration was found for cadmium. Descending order of the average total metal contents for these three depth levels was Fe, Cu, Zn, Cr, Mn, Pb, Ni and Cd. The bioavailability order of metals is Zn>Mn>Pb>Ni>Cu>Fe>Cr>Cd. Most of the Fe and Cr were found to be associated with the residual fraction, which is almost inert. Among all the metals determined, Zn has least contribution to the residual or inert phase.

Rattan et al (2005) studied the effect of long term sewage irrigation on heavy metal content in soil and plants. Results of their study reveals that irrigation with waste water for ten years leads to increased level of Zn, Fe, Ni and Pb in the soil. Zn in selected samples crossed the phytotoxicity levels. Tissue metal concentration in the crops studied was generally below critical levels. Their risk assessment showed that the vegetables may be consumed safely by humans grown on sewage irrigated soil in relation to their metal content.

Sharma et al (2009) conducted a similar study to find out heavy metal content in vegetables in Varanasi city of India. Heavy metal content of vegetables was evaluated and it was found that Zn and Cd in certain vegetables exceeded the standard limits. The consumption of vegetables directly from polluted open market areas was found hazardous to human population.

Cherfi et al (2016) conducted a risk assessment of heavy metals through consumption of vegetables collected from supermarkets of La Rochelle, France. They assessed the daily intake, hazard quotient of Ni, Cu and Zn. The concentration of metals was high enough indicating health risks over a long exposure period. The values for daily intake and hazard quotient surpassed the threshold value for Ni.

III. STUDY AREAS

The state of Rajasthan is situated between 23°3' and 30°12' N latitude and 69°30' and 78°17' E longitude. The capital city is Jaipur which has a humid subtropical climate, receiving over 650 millimeters (26 in.) of rainfall annually but most rains occur in the monsoon months between June and September. Temperatures remain relatively high throughout the year, with the summer months of April to early July having average daily temperatures of around 30°C (86 °F). According to 2011 census the population of Jaipur was 66, 26,178 and about 1000-1100 MT of waste is generated here every day. The areas selected for the current study are-

- **Mathuradaspura** village which lies in the north east part of the Jaipur about 20 km away from the main city, situated in Jamwa Ramgarh Tehsil of Jaipur. The area of the village is about 176 bigha. The total population of is more than 1100 people . The area adjoining the village is used as open dumping ground for non-segregated municipal solid waste. About 800 tons of municipal solid waste is dumped here every day.
- **Sanganer (Amanishah Nallah)** town lies between 26°49' to 26°51' North latitude and 75°46' to 75°51' East longitude. The total area of Sanganer is about 635.5sq.km. Climate is extremely hot and humid and has population between 10000-25000 people. The area is surrounded by many large and small scale industries which release their effluents in Amanishah Nallah and pollute the water body and the nearby agricultural fields.

The vegetables grown in these areas are supplied to the vegetable markets throughout the city for consumption by the local inhabitants.

IV. MATERIALS AND METHODS

Soil samples were collected from the agricultural lands of the two selected sites using Grab sampling technique. Collection of soil samples was done from top soil (depth 0-15 cm) with the help of a spatula and transferred to

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sterilized plastic zip-lock bags. Samples were then, sun dried and before sieving large rocks, organic debris, plastic and metallic pieces were removed. The fractions smaller than 1 mm were ground to a fine powder in a pestle mortar.

For plant samples, 8-10 edible parts from different plants of same species were collected randomly. Sampling was done according to the morphological status of the plant species, normal and healthy plant samples were selected for the analysis. The vegetables collected were *Abelmoschus esculentus* (okra) and *Solenum melongena* (eggplant). To remove adhered soil particles, the fruits were first washed with running tap water followed by distilled water and then they were air dried. To obtain a constant weight sieved soil and crushed plant samples were then kept in oven at $65 \pm 2^\circ\text{C}$ for 24 hour. Soil and plant samples (1 gram each) were allowed to digest with a mixture (4:1 V/V) of HNO_3 and HClO_4 overnight [10]. After this, these samples were slowly digested on the hot plate at $80-90^\circ\text{C}$ until a clear solution was obtained. The digested samples thus obtained were filtered using Whatman filter paper number 42 and then the volume was made up to 100 ml by adding distilled water. Heavy metals Fe, Cu, Zn, Pb, Cd, Cr and Ni were analyzed by AAS (Atomic Absorption Spectroscopy, Thermo fisher ICE3300). All analyses were conducted in triplicate.

Transfer factor (TF): Transfer factor is an expedient method for quantifying the availability and accumulation of heavy metals in the crop plants. It enables us to understand the extent of threat and associated perils as a result of irrigation with waste water and consequential heavy metal accumulation in the edible parts of selected vegetables [11]:

$$\text{TF} = \frac{\text{concentration of metal in edible part}}{\text{Concentration of metal in soil}}$$

Health risk assessment

Daily intake rate (DIR): Daily intake was calculated by the following equation:

$$\text{DIR}(\text{mg/person/day}) = \frac{C_{\text{metal}} \times D_{\text{food intake}}}{B_{\text{average weight}}}$$

where, C_{metal} , $D_{\text{food intake}}$ and $B_{\text{average weight}}$ are the heavy metal concentrations in edible part of the plants (mg/kg), daily intake of vegetables (gm person^{-1}) and average body weight (kg person^{-1}), respectively. To estimate the average daily intake of the selected vegetables from the study area, a survey on 100 people with average bodyweight of 60 kg was conducted [12].

Hazard quotient (or Health risk index): The HQ for non-carcinogenic risk was calculated using the following formula [13]:

$$\text{Health risk index (HRI)} = \frac{\text{DIM}}{R_f D}$$

Where DIM is daily intake of metal and $R_f D$ is oral reference dose for metals. The value of HRI above 1 for metals indicates high risk to the health of consumers through dietary intake [14].

Hazard index: A sum of the hazard quotients of the metals to which an individual is exposed is Hazard Index. In other words, the sum of multiple metal exposures will be proportional to magnitude of the adverse effect.

$$\text{HI} = \sum \text{HQ} = \text{HQ}_{\text{Fe}} + \text{HQ}_{\text{Cu}} + \text{HQ}_{\text{Zn}} + \text{HQ}_{\text{Pb}} + \text{HQ}_{\text{Cd}} + \text{HQ}_{\text{Cr}} + \text{HQ}_{\text{Ni}}$$

Hence, HI = 0.0 to 1 means no hazard; 1.1 to 10 means moderate hazard while greater than 10 means high hazard or risk [15].

V. RESULT AND DISCUSSION

Heavy metal concentration in soil: The concentrations of heavy metals in soil of Sanganer agricultural field was in the following pattern $\text{Fe} > \text{Ni} > \text{Pb} > \text{Zn} > \text{Cr} > \text{Cd} > \text{Cu}$. Fe was found to be in maximum concentration while Cu was least. Similar results were obtained by Jagariya and Chandel, 2015 [17]; Mathur and Kumar, 2013 [18]. Cadmium was found to be more than both Indian [16] and WHO/FAO [8] standards. The concentration of Ni, lead, Cr and Zn were found to be appreciably high due to the presence of various dyes in the irrigation water as this water is directly supplied to agricultural fields without any treatment.

In Mathuradapura agricultural fields the heavy metal concentration in the soil was found to be in the following sequence $\text{Fe} > \text{Zn} > \text{Cr} > \text{Cu} > \text{Ni} > \text{Pb} > \text{Cd}$. The concentration of iron was maximum while that of cadmium was minimum.

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Similar trend in heavy metal content was obtained by Esakku et al, 2005[19]. The concentration of Nickel, lead, chromium and zinc was found to be significantly high due to the presence of batteries, metal scrap waste, cable sheeting, pigments in paint and ceramics, etc. as the segregation of the waste is not done. The concentration of most of the metals was found under the maximum permissible limit but high enough to accumulate in the vegetables grown in these areas.

Table 1. Concentration of heavy metals in the soil samples collected from the agricultural fields of study areas (mg/kg)

Area	Fe	Cu	Zn	Pb	Cd	Cr	Ni
Sanganer	527.57± 0.08	13.26±0.23	17.92±0.30	18.93±0.12	15.25±0.27	17.64±0.19	29.86±0.26
Mathuradaspura	6874.47±0.36	61.54±0.07	277.66±0.37	8.04±0.21	0.57±0.02	89.26±0.12	19.46±0.31
Standards (mg/kg)	Indian Standards	135-270	300-600	250-500	3-6	-	75-170
	WHO/FAO	-	100	-	-	3	50

Mean± S.E.

Heavy metal concentration in vegetables: Average concentration of metals in the dry matter of okra and eggplant in the polluted areas under study are summarized in the Table 2. On comparing the values with the standards it was found that Fe, Cd and Cr were exceeding the maximum permissible limit[8] in both vegetables in both the sites, while Zn and Cu were found to be more than the permissible limits in both the vegetables from Mathuradaspura as compared to Indian[16] and international[8] standards. In Sanganer, Pb was found to be more than the standard value prescribed by WHO/FAO, 2007 in both the vegetables. Lone et al, 2003[20] reported higher concentration of lead in okra. Parashar and Prasad 2013[21] also stated elevated levels of Pb at Agra in okra and eggplant.

Table 2: Heavy metal concentration in different vegetables grown in different polluted areas (mg/kg)

Area	Vegetable	Fe	Cu	Zn	Pb	Cd	Cr	Ni
Sanganer	Okra	496.38±0.34	8.36±0.18	09.56±0.28	8.54±0.31	3.87±0.14	4.92±0.20	4.83±0.07
	Eggplant	520.86±0.17	11.23±0.32	12.83±0.25	5.83±0.27	4.93±0.28	5.53±0.14	5.24±0.33
Mathuradaspura	Okra	457.12±0.01	50.61±0.36	109.78± 0.16	3.47±0.19	0.48±0.06	9.50±0.39	3.72±0.23
	Eggplant	680.61±0.32	53.86±0.08	130.24±0.19	2.03±0.12	0.44±0.03	11.63±0.30	6.12±0.22
Standards for plants (mg/kg)	Indian Standards	-	30.0	50.0	2.5	1.5	-	1.5
	WHO/FAO	450	40.0	60.0	5.0	0.2	5.0	-

Mean± S.E.

Table 3: Daily Intake Rate of the heavy metals (mg/person/day)

Area	Vegetable	Fe	Cu	Zn	Pb	Cd	Cr	Ni
Sanganer	Okra	0.168	0.00236	0.0026	0.00241	0.00109	0.00139	0.00136
	Eggplant	0.1474	0.00137	0.00363	0.00164	0.00139	0.00156	0.00148
Mathuradaspura	Okra	0.129	0.0146	0.0318	0.00100	0.000139	0.00269	0.001054
	Eggplant	0.1991	0.0156	0.0377	0.000588	0.000127	0.00329	0.001734
Standard values mg/kg/day	TDI	45	3	60	0.214	0.06	-	1.4
	Standards	USEPA 2002	WHO/FAO 2007	WHO/FAO 2007	WHO/FAO 2007	WHO/FAO (1999)	-	WHO/FAO 2007

Statistical analysis: Simple correlation coefficients were estimated between metal contents in plant and soil of both the areas. Results were very much in accordance with the previous studies[22][23]. Zinc was found to be most consistently correlated whereas Fe was found to be non-significantly correlated. The values of the correlation coefficients are given

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in the Table 4. The amount of metal available to the plant highly depends on the plant species, the type of metal, the method of extraction, and the metal solubility in soil which further depends on the soil pH and organic carbon content[24][25].

Table 4: Simple Correlation coefficient (r) between heavy metals in plants and soil

Area	Vegetable	Fe	Cu	Zn	Pb	Cd	Cr	Ni
Sanganer	Okra	0.1217	0.4260	0.9626 [#]	0.1946	0.4735	0.6354 [#]	0.5250
	Eggplant	0.0343	0.9278 [#]	0.9732 [#]	0.3717	0.3276	0.0665	0.4366
Mathuradaspura	Okra	0.0922	0.7576 [*]	0.9228 [#]	0.2249	0.4544	0.2128	0.3369
	Eggplant	0.0867	0.4556	0.9597 [#]	0.1340	0.5251	0.7418 [*]	0.6816 [#]

(#) and (*) significant at 5 and 1% probability levels, respectively.

Transfer factor: We consume a significant amount of vegetables every day so, transfer of metals from contaminated soil and water to the crops is a matter of concern for human health. Higher the transfer factor for a vegetable, high is the rate of accumulation of respective metals by that vegetable. The transfer factor values higher than 0.05 show a higher ability for metal contamination and need to be environmentally monitored.

As indicated in figure 1(b), the transfer factor in Sanganer, for eggplant and okra is maximum for Fe while minimum for Ni. In Mathuradaspura, it is highest for Cr while lowest for Fe in both the plants, as the uptake of metals by plants does not increase linearly with growing concentrations of metals in soils. This is in accordance with the conclusions of Hooda et al. (1997) [26] and Rattan et al. (2005)[22]. Although long term use of contaminated soil and water in agricultural fields may lead to accumulation of metals in soil, but the same concentration may not get transferred to the food chain in the same proportion.

Health risk assessment: The daily intake rate, hazard quotient and hazard index were estimated in order to determine the health risks associated with heavy metal contamination of the selected plants.

Daily intake of metals: For both the plants, the maximum value of DIR was found to be for Iron among all the metals in both the sites. In case of Sanganer agricultural field the DIR of okra showed lowest value for Cd that is 0.00109 mg/person/day. In case of eggplant the lowest DIR was found to be of Cu i.e. 0.00137 mg/person/day. In case of Mathuradaspura okra and eggplant showed lowest daily intake rate for Cd i.e. 0.000139 mg/person/day and 0.000127 mg/person/day respectively (figure 1(c)). All the values in both the sites for both vegetables were found within the range as given by various environmental agencies.

Hazard quotient (or Health risk index): The value of HQ obtained for the two vegetables for both the sites are summarized in the figure 1(a). In okra grown in the Sanganer agricultural land the maximum HQ was for Cd i.e. 1.09 and lowest for Cr, i.e. 9.2×10^{-4} and in case of eggplant the maximum value was for cadmium (1.39) and lowest for Cr (1.04×10^{-3}). Similar results were obtained by Singh et al, (2010) [27] where the HRI value was greater than 1 in case of Cd. In Mathuradaspura agricultural land okra showed the highest value of HQ was for Cu (0.365) and lowest for Zn (0.0859) and in eggplant highest HQ value was for Cu (0.39) and minimum was for Cr (0.015).

Hazard index(HI): Hazard index was calculated to find out the possible threat of more than one heavy metals to human health. The value of HI in Sanganer for Okra is 2.05544 and for Eggplant is 2.17467 whereas in Mathuradaspura HI for Okra is 1.07871 and for Eggplant is 1.13918 indicating moderate hazard.

VI. CONCLUSION

The study has contributed in creating valuable supplementary information regarding heavy metal uptake and their transfer to food plants in Sanganer and Mathuradaspura areas of Rajasthan (India) and the risks associated with the health of the local residents, derived from the DIR, HQ and HI. From the current study it is concluded that irrigation with waste water and open dumping of municipal solid waste are potential sources of Pb, Cu, Zn, Cd, Cr, Ni and Fe in the soil which further leads to bioaccumulation of these heavy metals in the plants. The analysis reveals that the eggplant is a hyper-accumulator of most of the metals. The low level of daily intake rate is attributed to the eating habits of the people and their low average body weight. Though there is an appreciable difference in the metal content

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of the soil and the plants, but incessant increase in the metal content of the soil can modify its properties and may lead to critically high levels of heavy metals. Hence, it is highly recommended that the entry routes of heavy metals in the soil must be monitored closely, especially around the agricultural fields.

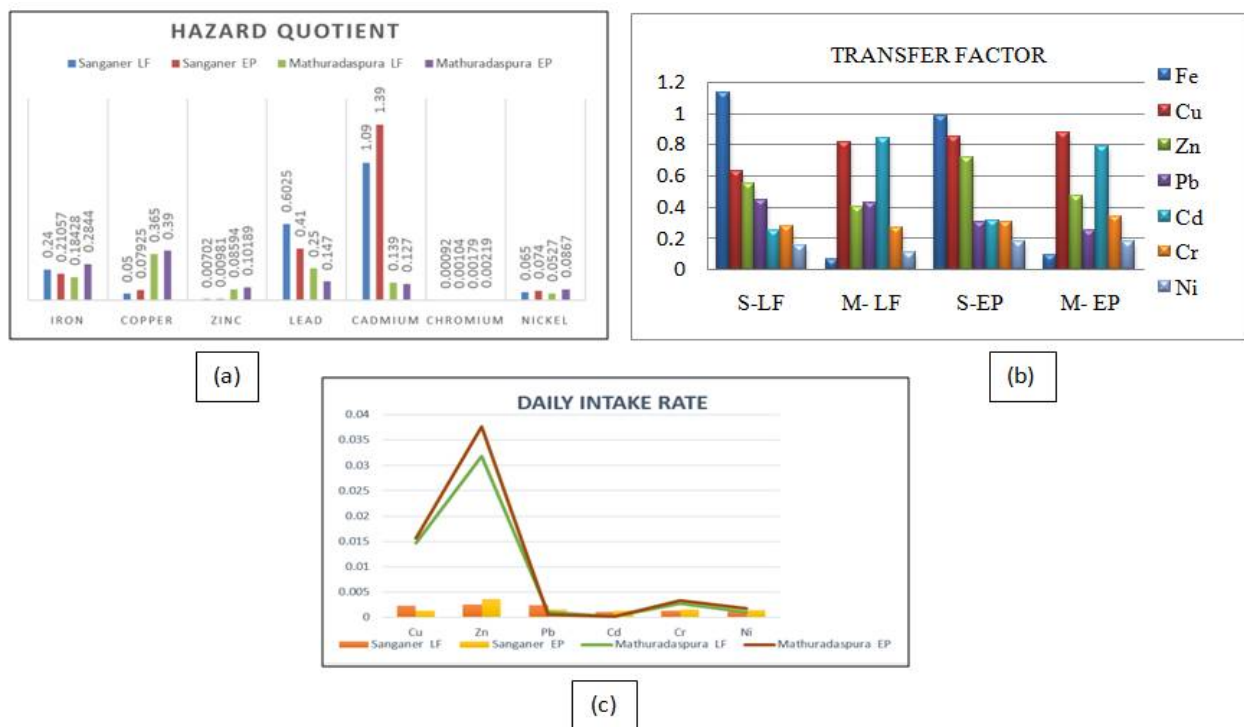


Fig.1 (a) shows Hazard Quotient, (b) shows Transfer Factor and (c) shows Daily Intake Rate of the heavy metals in Sanganer (S) and Mathuradaspura (M) in Eggplant (EP) and Lady Finger (LF)

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