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RISK ASSESSMENT OF CARCINOGENIC METALS IN SOILS AND FOOD CROPS NEAR BRICK KILN CLUSTER

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Abstract

A study was conducted in the Charia area, Hathazari, Chattogram district, Bangladesh to determine the levels of carcinogenic metals Cd and Pb in soils and crop plants in the vicinity of brick kiln clusters. The health risk was evaluated by computing cancer risk using the US EPA model. The amounts of Cd and Pb in the soils and the parts of crop plants were determined by AAS. The soils of the study area were acidic. Metal concentrations indicating the anthropogenic input of Cd and Pd in the soils was in the range from 0.27 to 1.07 mg/kg dry soil and from 19.07 to 52.07 mg/kg dry soil respectively. Accumulation of Cd (0.00 to 0.27 mg/kg) and Pb (0.09 to 0.13 mg/kg) in the studied crops. A significantly high correlation (r = 0.89, p < 0.001) of the elements between soil and plant suggests that the source of contamination is the soil under study. 72% of all the studied edible plant parts exceeded the recommended threshold risk limit of the cumulative cancer risk (ΣILCR), which was higher in the edible part of fruit crops than in root crops. Cd was the dominant carcinogen in the study area.

Keywords: Agricultural soils, Brick kiln, Heavy metals, Incremental lifetime cancer risk, Transfer factor

Introduction

The environmental impact of brick production has become a significant concern in Bangladesh. The brick sector in Bangladesh is distinguished by its use of soil as a necessary raw material, highly energy-intensive burning technique, and reliance on human labor (Biswas *et al*., 2018). The incineration technique used in brick production significantly increases the mobility and bioavailability of heavy metals from burning components. Heavy metals produced in brick furnaces (Ravankhah *et al*., 2017; Ismail *et al.,* 2012) are released into the atmosphere, where they are then deposited and dispersed throughout soils and water sources. Because of their toxicity, bioaccumulation, and persistence, heavy metals as soil contaminants can be potential sources of pollution in soil (Chowdhury and Rasid, 2021).

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Different plant species were found to accumulate Cd and Pb in edible plant parts near metal-contaminated sites (Hamoud *et al*., 2024; Sulaiman and Hamzah, 2018; Rashid *et al*., 2023; Gajbhiye *et al*., 2022; Siaka *et al*., 2014; Sikder *et al.*, 2016). Regular intake of Cd-contaminated vegetables can cause damage to the liver and kidney (Tuzen, 2009) cardiovascular system and bones (Fang *et al*., 2014). High Pb consumption through vegetables can cause pathological changes in organs and the central nervous system, which can affect intelligence quotients in children. Moreover, consumption of Cd and Pb even at very low doses can develop cancer in the human body (Michalczyk *et al*., 2023) therefore, they are categorized by the International Agency for Research on Cancer (IARC) as carcinogenic agents (Sultana *et al*., 2017).

Bangladesh, following China, India, and Pakistan, is the world's fourth-largest manufacturer of clay-fired bricks. Over 8,000 brick kilns are in operation, producing roughly 50 billion bricks a year (UNDP, 2011). According to Ferdausi *et al*. (2008), traditional kilns in Bangladesh use 20–22 tons of coal for every 100,000 bricks produced, and their particle emissions exceed 1,000 mg m^{-3}. Many studies (e.g., Mizan *et al*., 2023; Rahman *et al*., 2021; Shammi *et al*., 2021; Alam *et al*., 2020; Hasan *et al*., 2020; Proshad *et al*., 2019) have been conducted on heavy metal pollution in Bangladeshi agricultural soils. A few research (Islam *et al*., 2018; Tasrina *et al*., 2015; Zakir *et al*., 2014) concentrated on the heavy metal contamination of agricultural soils by metal-contaminated airborne deposits from high traffic. Nevertheless, no thorough investigation into the effects of brick kiln clusters on the buildup of carcinogenic heavy metals in crop plants and agricultural soil has yet been carried out. In Hathazari, Chattogram, there are numerous massive clusters of brick kilns. Fumes from these kilns can contaminate the surrounding vegetation and soil with carcinogens like Cd and Pb. There are potential health risks associated with crop consumption and metal exposure for the local population. With this background, the objectives of this research were to analyze the contamination level of Cd and Pb in soils and crop plants, subsequent plant transfer factor, estimate daily intake of Cd and Pb and the extent of potential carcinogenic health risk from the crops consumed that grow in the vicinity of brick kiln cluster in Hathazari, Bangladesh.

Materials and Methods

A cluster of brick kilns in the Charia area, Hathazari, Chattogram district, Bangladesh surrounded by crop fields were chosen. Since brick kilns are the main source of air pollution during the manufacturing season, which runs from October to March dependent on the monsoonal rains, the research area's sampling was done during the dry season. Six distinct locations for soil sample (Fig. 1, Table 1) were chosen from the area surrounding the brick kiln cluster, each at a varying distance. The agricultural soils 1.5 km away from the brick kiln cluster served as the reference sites (C). Soil samples were taken (0-30 cm) from the soil's surface down to the root zone. Plant samples (fruit crops, root crops and rice) growing in the sampled soils was collected. The direction of wind movement was taken into account when assessing how fume and fly ash deposition affected the soil.

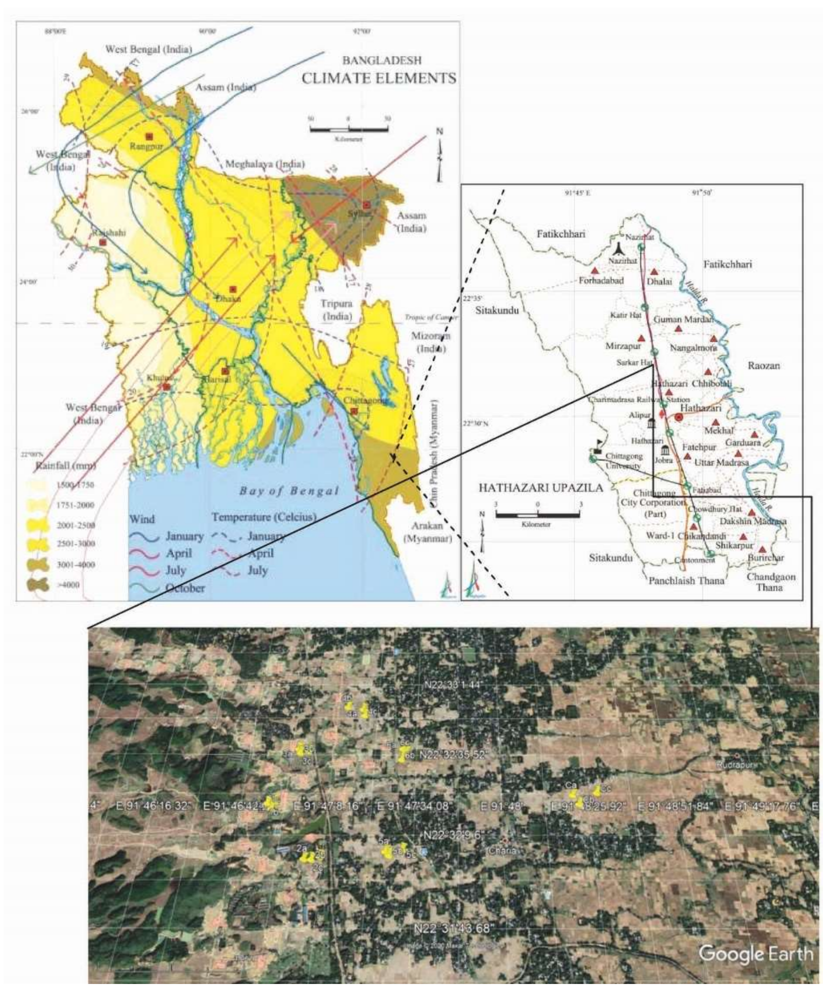

Fig. 1. Study sites in Hathazari, Chattogram, Bangladesh. In the satellite view, brick kilns are clearly visible. Wind flow as a component of the country's climate depicted on the map of Bangladesh (Banglapedia, 2012).

Table 1. Site legend, crop species and locations of agricultural soils adjacent to the brick kiln cluster.

Site no.	Crop species name		Geographical Coordinate	
	Scientific	Local	Latitude	Longitude
1A	*Solanum tuberosum*	Potato	22°32ʹ15.33ʺN	91°46ʹ51.10ʺE
1B	*Artemisia vulgaris*	Mugwort	22°32ʹ17.58ʺN	91°46ʹ51.98ʺE
1C	*Ipomoea batatas*	Sweet potato	22°32ʹ17.16ʺN	91°46ʹ49.66ʺE
2A	*Capsicum species*	Chilli	22°32ʹ0.36ʺN	91°47ʹ2.47ʺE
2B	*Oryza sativa*	Rice	22°32ʹ0.37ʺN	91°47ʹ4.71ʺE
2C	*Solanum tuberosum*	Potato	22°32ʹ1.02ʺN	91°47ʹ7.08ʺE
3A	*Oryza sativa*	Rice	22°32ʹ35.02ʺN	91°46ʹ56.82ʺE
3B	*Trichosanthes anguina*	Snake gourd	22°32ʹ33.76ʺN	91°46ʹ57.44ʺE
3C	*Raphanus sativus*	Radish	22°32ʹ34.28ʺN	91°46ʹ59.85ʺE
4A	*Oryza sativa*	Rice	22°32ʹ49.48ʺN	91°47ʹ15.71ʺE
4B	*Brassica nigra*	Mustard	22°32ʹ50.25ʺN	91°47ʹ10.83ʺE
4C	*Capsicum species*	Chilli	22°32ʹ47.26ʺN	91°47ʹ16.43ʺE
5A	*Capsicum species*	Chilli	22°32ʹ2.60ʺN	91°47ʹ25.55ʺE
5B	*Artemisia vulgaris*	Mugwort	22°32ʹ1.44ʺN	91°47ʹ26.56ʺE
5C	*Raphanus sativus*	Raddish	22°32ʹ3.06ʺN	91°47ʹ30.38ʺE
6A	*Artemisia vulgaris*	Mugwort	22°32ʹ35.20ʺN	91°47ʹ27.24ʺE
6B	*Solanum lycopersicum*	Tomato	22°32ʹ31.54ʺN	91°47ʹ28.95ʺE
6C	*Brassica nigra*	Mustard	22°32ʹ34.08ʺN	91°47ʹ30.32ʺE
CA	*Oryza sativa*	Rice	22°32ʹ19.90ʺN	91°48ʹ20.71ʺE
CB	*Solanum tuberosum*	Potato	22°32ʹ17.01ʺN	91°48ʹ22.38ʺE
CC	*Vigna mungo*	Faba Bean	22°32ʹ20.62ʺN	91°48ʹ27.99ʺE

All of the samples that were collected by a stainless steel spade (alcohol cleansed before every sample) were wrapped in polythene bags and brought to the laboratory on the day of sampling. To prepare the composite soil samples for physical and chemical examination, they were homogenized, sieved through a 2 mm sieve, and air-dried. General soil characteristics (pH, textural classes, organic matter) were determined following the standard procedures (Huq and Alam, 2005). After strong acid-digestion (1:1 mixture of concentrated nitric and perchloric acids) of the soil samples, the total amounts of Cd and Pb were measured using an Atomic Absorption Spectrophotometer (AAS) (Agilent 240). Following Ure (1990), the digested samples were filtered and collected in 5 milliliters of 2.0 M HCL. After washing off any remaining soils using running tap water, the plant samples were oven-dried for 48 hours at 80°C. Using a laboratory stainless steel grinder, each sample of the dried plant materials was ground into a fine powder and passed through a screen with a 1 mm hole. Aqua regia was used to extract the metals from the plant samples before the AAS analysis.

Health risk levels of Cd and Pb in the plant samples were evaluated using risk indices, such as transfer factor (TF), estimated daily intake (EDI), and target carcinogenic risk factor (lifetime cancer risk, ILCR) which are widely used to assess the risk levels of heavy metals in the crops (Islam *et al*., 2016).Transfer factor (TF), one of the primary factors regulating human exposure to metals through the food chain, can be used to assess a plant's capacity to transfer metals from soil to edible tissues. The following formula was used to compute TF:

$$TF = \frac{C_{Plant}}{C_{Soil}}$$

where, TF = transfer factor, C_{Plant} = heavy metal content in the edible parts of the crop plant, C_{Soil}= total heavy metals concentration in soils on a dry weight basis.

The formula utilized to calculate the estimated daily intake (EDI) of metal through the consumption of food crops is as follows:

$$EDI = \frac{FIR \times C}{BW}$$

where EDI = estimated daily intake, FIR = food crop ingestion rate (g/person/d), C = metal concentration in crop samples [mg/kg, fresh weight (FW)], BW = body weight assuming 60 kg for adult residents in the present study (FAO, 2006). On a fresh weight basis, the average daily food crop consumption rate for adult dwellers is 170.04 g.

The following equation (US EPA, 2002) was used to estimate the target carcinogenic risk factor (lifetime cancer risk):

$$ILCR = \frac{EFr \times ED \times FIR \times C \times CSFo}{BW \times AT}$$

where $ILCR$ = incremental lifetime cancer risk, EFr = 365 d/year of exposure frequency, ED = 70 years of exposure, FIR = rate of food ingestion (g/person/d), C = food metal concentration on the fresh weight (FW) basis [mg/kg], $CSFo$ =According to US EPA (2002) database oral carcinogenic slope factor [15 and 8.5×10^{-3} (mg/kg/d) for Cd and Pb, respectively]. BW = body weight in the current study, with adult residents assuming 60 kg (FAO, 2006) AT = the average duration of carcinogens (365 days'/year × ED).

The Microsoft Excel 2016 application was used to determine the standard deviation and correlations between the selected parameters. One-way analysis of variance (ANOVA) was used to determine the effects of Cd and Pb, and the multiple range test with the least significant difference at $p < 0.05$ was used to test the significance of the parameters. IBM SPSS was used to perform the dendrogram grouping for the cluster analysis.

Results and Discussion

Cd and Pb distribution in agricultural soil: The results of the Cd and Pb concentrations in the soil sample are shown in Fig. 2. The agricultural soils had Cd concentrations ranging from 0.25 to 1.05 mg/kg dry soil and Pb concentrations ranging from 19.05 to 52.10 mg/kg dry soil. The average concentrations of Cd and Pb, which were higher than the reference background level, were 0.64 and 29.97 mg/kg, respectively. The values for Cd and Pb in reference soils were 0.15 mg/kg dry soil and 8.06 mg/kg dry soil, respectively. Specifically, the mean concentrations of Cd and Pd in the study area were 3.7 and 4.3 fold higher than those of the reference sites. Thus, the Cd and Pb contamination in the agricultural soils may be caused by anthropogenic activities associated with brick kiln operations. The Chinese Environmental Quality Standards for Soil (Act No. 220/2004 Coll. of Laws) provide guidelines for Pb and Cd levels in dry agricultural soil at pH < 6.5. The heavy metal concentrations in the study area were also compared to these values (Chen *et al*., 2018). The average metal concentration showed a diverse variation among the sites. There was an uneven distribution of Cd and Pb in the area as the fumes from the brick kiln cluster spread out over the agricultural fields in the wind and settled on the crop plants and soils. Soil Cd concentration showed strong significant correlations with soil Pb ($r = 0.89$, $p < 0.001$) suggesting that the two may have a common origin in the soil.

Concentrations of Cd and Pb in selected crop plants: There were significant differences in the Cd and Pb concentrations of different food crop species in different sites. The result presented in Fig. 2 showed that the Cd and Pb status of food crops in the study area ranged from 0.00 to 0.22 mg/kg and 0.00 to 1.41 mg/kg dry wt respectively in agricultural soils near brick kiln cluster. No Cd and Pb were detected in the food crops growing in reference soil. The average maximum concentrations of Cd and Pb were recorded as 0.09 mg/kg and 0.02 mg/kg fresh wt respectively in *Solanum tuberosum* at site 2C. *Solanum tuberosum* in site 1A was also higher in Cd (0.02 mg/kg FW) and Pb (0.05 mg/kg FW) concentrations than the other agricultural sites. In other plants, Cd and Pb content were negligible or not detected. There was a significant ($p < 0.001$) high positive correlation between soil Cd and Pb contents to the corresponding Cd (r = 0.80) and Pb (r = 0.51) contents in crop plants, which proved metal uptake by crop plants. The concentration levels of Cd and Pb in our study were lower than the allowable levels as set by the Commission of the European Communities (EC) (EC, 2006) and World Health Organization (WHO) (FAO/WHO, 2005). EC set the Pb as 0.3 mg/kg fresh weights for brassica and leaf vegetables, and 0.1 mg/kg fresh weights for all remaining food crops. EC and WHO set the allowable level of Cd as 0.2 mg/kg fresh weights for leafy vegetables and fresh herbs, 0.1 mg/kg for stem and root vegetables (Naser *et al*., 2009). Although the mean carcinogenic metal levels were low, the detectable level of the metals was a concern as it may be magnified if the brick kiln operation continued.

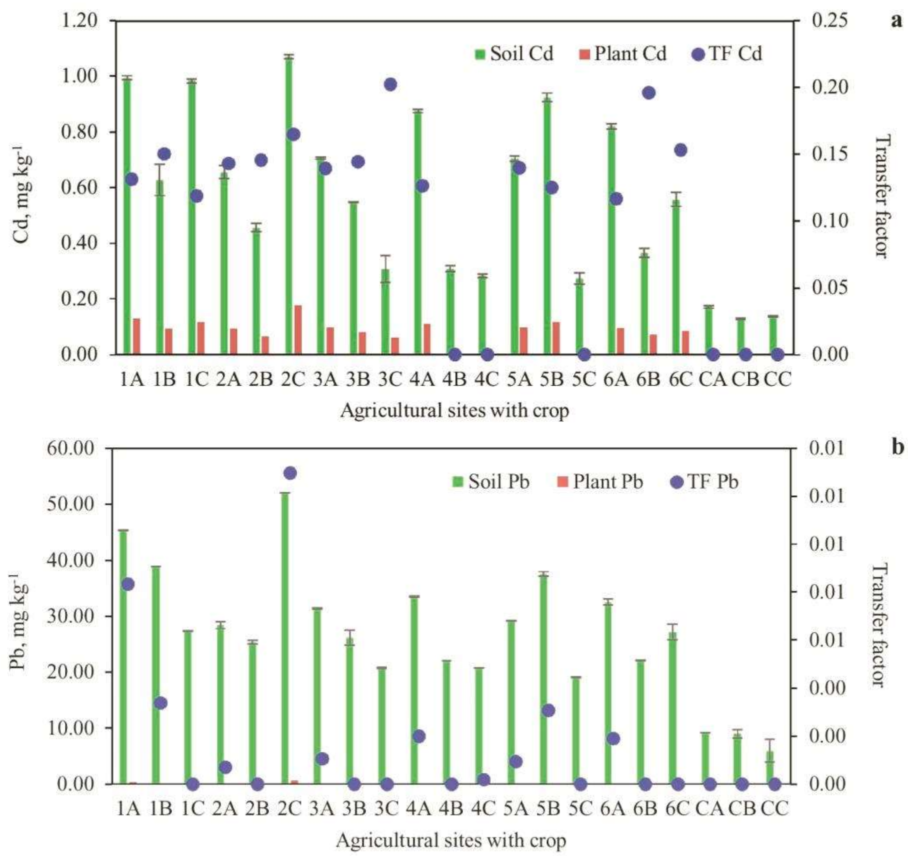

Fig. 2. Concentration (mg/kg) of Cd (a) and Pb (b) in agricultural soil adjacent to the brick kilns and selected food crop species and their subsequent transfer factor. Legends for plant names are detailed in Table 1.

There were significant differences in the sampling sites for soil Cd contents of the same sampling location, but in the case of a plant, it was not, except for *Solanum tuberosum* at 1A and 2C sites (Fig. 2a). The findings of this study showed that the concentrations of Cd and Pb were substantially lower than the reference soils. This may be ascribed to the root system which acts as a barrier to the upward movement of metals. The average concentration of Cd and Pb was observed to be higher in the edible part of fruit crops than in root crops (Fig. 3). Fumes containing different contaminants from brick chimneys are distributed to the surrounding area, after deposition some Pb may be absorbed in the plant through areal parts. Although both Cd and Pb are deposited in soil, Pb uptake through plant roots is not common in contaminated soil as Pb is immobile, whereas Cd is easily translocated to the aerial parts (Radovanovic *et al*., 2020). Detected Pb concentration varied from 0.01 to 0.06 mg/kg in the edible parts of *Solanum tuberosum* (1A, 2C), *Capsicum species* (2A), *Artemisia vulgaris* (5B, 6A). Cd was detected in the edible part of *Artemisia vulgaris* as 0.02 mg/kg (5B) and 0.01 mg/kg in *Solanum tuberosum* (1A, 2C), *Artemisia vulgaris* (1B, 6A), *Capsicum species* (2A, 5A), *Trichosanthes anguina* (3B), *Solanum lycopersicum* (6B) and *Brassica nigra* (6C).

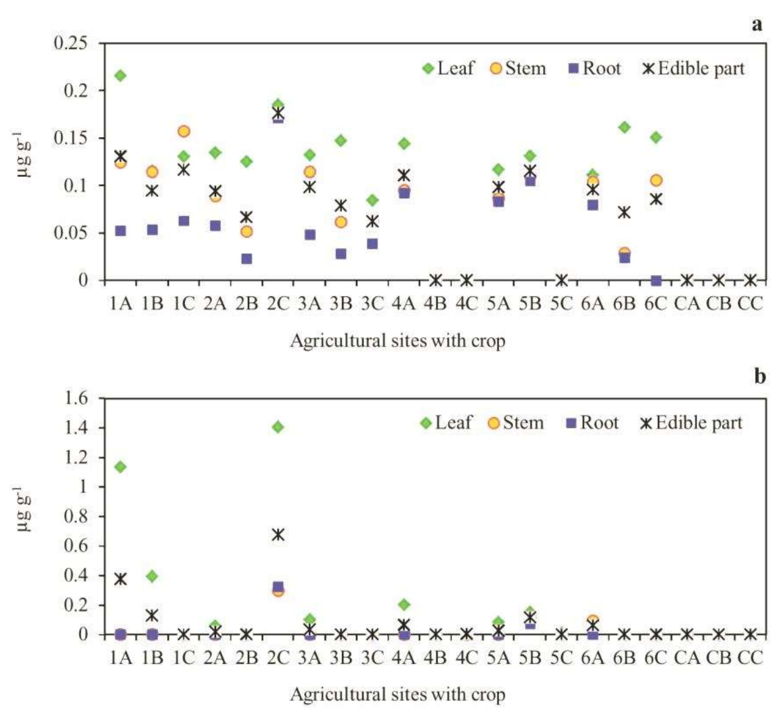

Fig. 3. Distribution of Cd (a) and Pb (b) in different plant parts. Legends for plant names are detailed in Table 1.

Heavy metal transfer from soil to food crops: The capability of plants that allow them to transfer metals to edible tissues can be evaluated by the metal's transfer factor (TF). Metals with high TF are easily transferrable compared to ones with low TF. The TF values for Cd and Pb varied from 0.000 to 0.002 and 0.000 to 0.020, respectively (Fig. 2). The TF values of Pb were lower than Cd. Transfer of both Cd and Pb were detected in *Capsicum species* (2A), *Artemisia vulgaris* (5B, 6A). No transfer of Cd and Pb from soil was detected for the vegetable *Ipomoea batatas* (1C), *Oryza sativa* (3A, 4A), *Capsicum species* (4C) and *Raphanus sativus* (5C). The difference may be due to variations in metal concentration in the soil and divergent capacities of heavy metal uptake by different crops (Sultana *et al*., 2017). Generally, the TF of heavy metals is controlled by the soil properties, such as pH and salinity and plant species (Nasircilar *et al*., 2024; Thien *et al*., 2021; Alengebawy *et al*., 2021; Islam *et al*., 2015). In the plant system, the root cell wall mainly controls the transfer of metal ions, the ion transmembrane transport occurs in the endoderm cytoplasm membrane and the water transports through the xylem vessel.

Estimated daily intake from contaminated crops: A reliable method for examining a population's diet in terms of metal intake levels is the dietary exposure approach to food crop consumption, which offers crucial details regarding the potential exposure to food contaminants (WHO, 2004). The estimated daily intake (EDI) of carcinogenic metal Cd and Pb for the local people close to the brick kiln cluster area is shown in Table 2. The calculated EDI for Cd and Pb for the food crops were compared with R_fD value established by USEPA (2002) [R_fD is the chronic oral reference dose for the metals (mg/kg of body weight per day), which does not cause a lifetime deleterious effect]. EDI for Pb and Cd was above the R_fD value in the edible part of *Solanum tuberosum* (1A, 2C), *Capsicum species* (2A) and *Artemisia vulgaris* (5B, 6A) which corresponded to high soil metal contents. On the other hand, the higher EDI of Cd was also associated with *Oryza sativa* (2B), *Trichosanthes anguina* (3B), *Raphanus sativus* (3C), *Brassica nigra* (4B, 6C) and *Solanum lycopersicum* (6B).The result suggests that residents near the brick kiln cluster were most likely exposed to some possible health concerns due to consuming locally cultivated crops containing Cd. Food crops did not provide a substantial concern for Pb consumption. The possible health concerns associated with consuming local crop consumption should not be disregarded when the total amount of metals ingested through diet is considered.

Carcinogenic health risk assessment: The acceptable carcinogenic risk level for these heavy metals was set to be lower than 1×10^{-5}, as defined in the Polish Regulation of the Minister of the Environment (Polish Regulation of the Minister of the Environment, 2016). The safe limit for carcinogenic risks recommended by the US EPA is below 10^{-4}

Table 2. Estimated daily intake (EDI) of Cd and Pb for the study area's inhabitants through crop intake (mg/kg/day) and subsequent incremental lifetime cancer risk (ILCR) and cumulative cancer risks (ΣILCR) for the region's adult inhabitants.

Site no.	Vegetable species	Estimated daily intake (EDI)		Incremental Lifetime Cancer Risk (ILCR)		
		Cd	Pb	$ILCR_{Cd}$	$ILCR_{Pb}$	ΣILCR
1A	*Solanum tuberosum*	5.46E-03	4.71E-03	5.35E-03	2.61E-04	5.61E-03
1B	*Artemisia vulgaris*	4.23E-03	0.00E+00	4.14E-03	0.00E+00	4.14E-03
1C	*Ipomoea batatas*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2A	*Capsicum species*	3.23E-03	5.76E-03	3.16E-03	3.19E-04	3.48E-03
2B	*Oryza sativa*	4.30E-04	0.00E+00	4.21E-04	0.00E+00	4.21E-04
2C	*Solanum tuberosum*	3.65E-03	8.30E-03	3.57E-03	4.61E-04	4.03E-03
3A	*Oryza sativa*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3B	*Trichosanthes anguina*	3.14E-03	0.00E+00	3.08E-03	0.00E+00	3.08E-03
3C	*Raphanus sativus*	1.24E-03	0.00E+00	1.22E-03	0.00E+00	1.22E-03
4A	*Oryza sativa*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4B	*Brassica nigra*	1.22E-03	0.00E+00	1.19E-03	0.00E+00	1.19E-03
4C	*Capsicum species*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5A	*Capsicum species*	2.96E-03	0.00E+00	2.90E-03	0.00E+00	2.90E-03
5B	*Artemisia vulgaris*	7.20E-03	1.41E-02	7.05E-03	7.85E-04	7.83E-03
5C	*Raphanus sativus*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6A	*Artemisia vulgaris*	2.31E-03	2.36E-02	2.27E-03	1.31E-03	3.58E-03
6B	*Solanum lycopersicum*	2.77E-03	0.00E+00	2.72E-03	0.00E+00	2.72E-03
6C	*Brassica nigra*	2.37E-03	0.00E+00	2.32E-03	0.00E+00	2.32E-03
CA	*Oryza sativa*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CB	*Solanum tuberosum*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CC	*Vigna mungo*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Threshhold risk limit	4.60E-02[a]	2.10E-01[a]		1.00E-04[b]	
		1.00E-03[b]	3.50E-04[b]		1.00E-05[c]	

Note: [a] JECFA (2003); [b] US EPA (2002); [c] Polish Regulation of the Minister of the Environment (2016).

(Table 2) The calculated incremental lifetime cancer risk (ILCR) for Cd and Pb and cumulative cancer risks (ΣILCR) of the studied plants are shown in Table 2. ILCR was higher than the risk level in all the edible parts of the studied plants where Cd and Pb were detected. Cd tends to accumulate more at the toxic level in edible parts of plants than Pb. A high ILCR level of Cd was detected in *Artemisia vulgaris* in site 5B and *Solanum tuberosum* in site 1A. No Pb contamination at the carcinogenic level was detected in rice. Cd has crossed the threshold risk limit in 72% of food crops and for Pb, the value was 28% of the studied crops. In the study area, cadmium was the dominant carcinogen. The trend of the risk of acquiring cancer due to exposure to Cd and Pb from consuming the studied edible plant parts was in the order: fruit crop > root crop > paddy.

Plants detected with the carcinogenic threat having the highest ΣILCR was *Artemisia vulgaris* in site 5B and the lowest was *Oryza sativa* in site 2B (Table 2). According to US EPA recommendation, the risk values show that ingestion of beans from *Artemisia vulgaris* (5B) would produce an overabundance of 78 cancer cases per 10,000 people exposed while ingestion of rice (2B) would produce an overabundance of 42 cancer case per 100,000 people exposure (Sultana *et al*., 2017). *Ipomoea batatas* (1C), *Oryza sativa* (3A, 4A), *Capsicum species* (4C) and*Raphanus sativus* (5C), did not accumulate Pb or Cd to impact human health. The recommended threshold risk limit ($>10^{-4}$) of ΣILCR of the studied edible plant parts exceeded 60%, 38% and 2% respectively for fruit crops, root crops and rice (Fig. 4). The potential health risks due to exposure to Cd must therefore be apprehended.

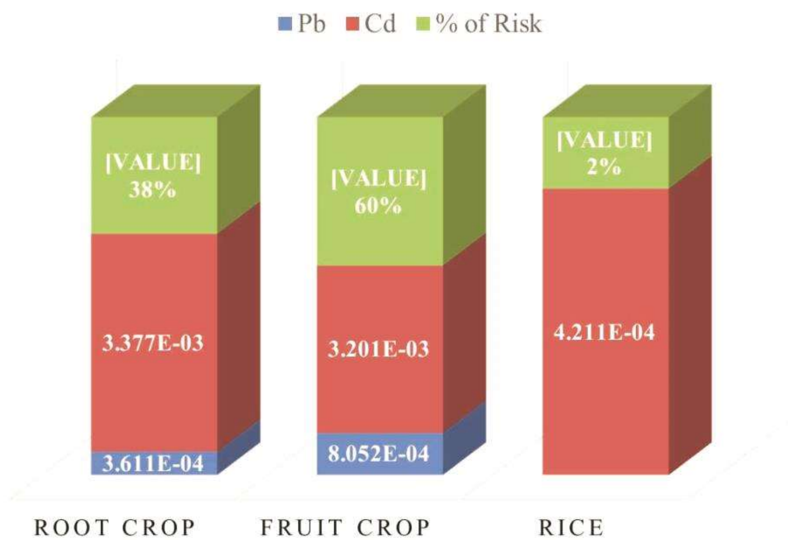

Fig. 4. Cumulative cancer risks (ΣILCR,**%**) associated with carcinogenic heavy metals in the studied crops.

Characterization of heavy metals in soils and crops:Dendrogram grouping of contaminated soils by carcinogenic heavy metals Cd and Pb, were characterized by similar responses of crop plants by their heavy metal concentration, toxicity index (*TF*, *EDI* and *ILCR*) to soil heavy metal concentration along with soil physicochemical properties were performed (Fig. 5). Hierarchical cluster analysis has shown that 75% of

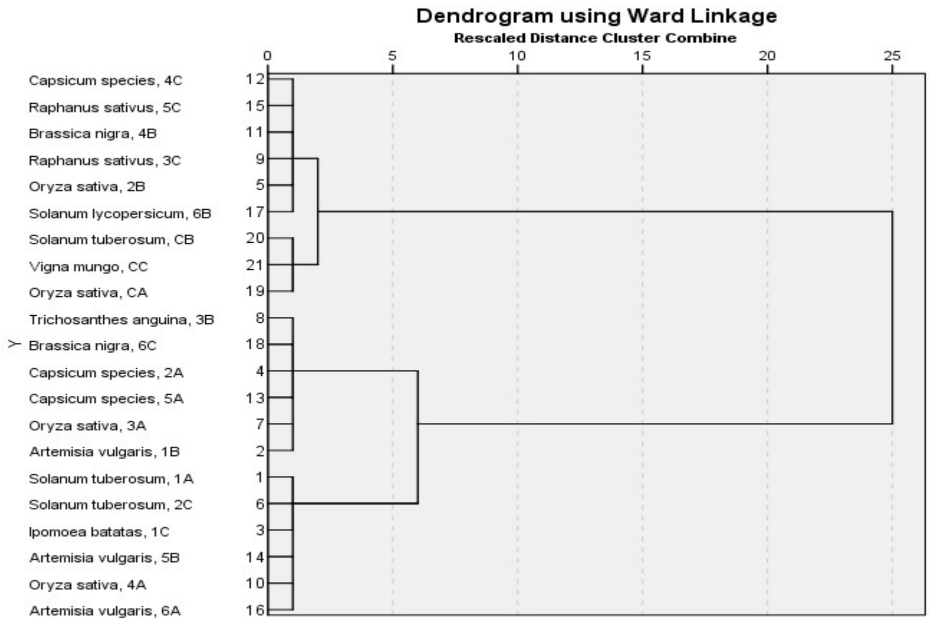

Fig. 5. Hierarchical cluster analysis of the Cd and Pb concentrations at sample sites and their effects on related crop species are displayed in a dendrogram.

agricultural soils of the brick kiln area were contaminated with carcinogenic heavy metals Cd and Pb. Two major clusters of similarities in the soils contaminated with heavy metals were identified in the dendrogram. In the sites (4C, 5C, 4B, 3C, 2B and 6B) that are clustered together with reference sites (CA, CB and CC), the average plant ecology in these soils was not under any stressed condition. Among the contaminated sites, the cluster difference shows that Cd and Pb stress on plants were in the sequence as

1A=2C=1C=5B=4A=6A>3B=6C=2A=5A=3A=1B>4C=5C=4B=3C=2B=6B.

The present study manifested that extensive, uncontrolled brick kiln operation is a possible source of carcinogenic trace metals (Pb and Cd) in the surrounding environment. Cd was the dominant carcinogen in the study area. Some of the crops in the area were at the carcinogenic risk level. Small accumulations of Cd in agricultural soils should be taken into consideration. Although the Cd concentrations were in the acceptable range provided by the standard agency, the computed carcinogenic data however, showed potential carcinogenic effects on human consumption. It is recommended from the study that growing specific metal-excluding crop species can help lower the possible health concerns related to metal toxicity.

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