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Impact of industrialization on heavy metals contamination in agricultural soils of Sonepat, a satellite township of New Delhi, India.

Impacto de la industrialización en la contaminación por metales pesados en los suelos agrícolas de Sonepat, un municipio satélite de Nueva Delhi, India.

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ABSTRACT

Present study was conducted to assess the impact of industrialization on heavy metals contamination in agricultural soils of Sonepat in the state of Haryana and a satellite township of New Delhi. A total of 23 agricultural soil samples, collected from different locations in the study area were analyzed for pH, total organic carbon (TOC), and heavy metals (Al, Cd, Cu, Cr, Pb, Ni, Zn, Mn, Co, and Fe). Soil samples had an average pH of 7.81±0.25 with TOC values of 0.59±0.12 percent. Average metal concentrations followed the order as Fe > Mn > Zn > Ni > Cr > Cu >Pb > Co > Cd with concentration values (mg/kg) as 17977 > 325 > 91> 52 > 44 > 34 > 32 > 2 > 1. The contamination factor (CF) and geo-accumulation index analysis revealed that the agricultural soils were contaminated with Cd, Pb, Mn, Ni, and Zn. A moderate potential ecological risk was found in most of the soil samples due to the presence of Cd. Interpretation of enrichment factors (EFs) showed that Cd, Mn, and Zn were mainly anthropogenic in origin while Ni and Pb were having both anthropogenic and crustal origin. The health risk index on inhabitants due to exposure to heavy metals in agricultural soils was calculated for oral, dermal, and inhalation pathways and the values obtained were below 1, showing no significant health effects due to direct exposure.

Keywords: Heavy metals, contamination factor (CF), enrichment factor (EF), health risk index (HRI), national capital region (NCR).

INTRODUCTION

Soil is the outermost layer of the earth's crust and provides primary requirements for plant growth. The main components of the soil are soil air, soil moisture, minerals, and organic matter. The quality of soil mainly depends upon the parental rock material, but it is getting degraded due to waste addition from industrial activities.In absence of specific disposal techniques and sites for industrial waste, industries are dumping their solid and liquid waste directly on the soil without treatment, which is deteriorating the soil quality (Lente et al., 2012).Industries like thermal power plants, integrated iron and steel industries, waste sludge, etc. are adding heavy metals to the environment (Wuana and Okieimen, 2011). The use of untreated wastewater for irrigation and the application of sewage sludge as fertilizer is responsible for increasing the heavy metals concentrations in agricultural soils (Awasthi et al., 2013; Chopra and Pathak, 2015). Industries are also discharging heavy metals containing wastewater into natural water bodies, hence the use of river water for irrigation is also not good for agricultural soil health (Chaudhary and Banerjee, 2007). The use of pesticides and fertilizers further enhances the heavy metals pollution in agricultural soils (Gupta et al., 2013). Vegetable cultivation in heavy metals contaminated soils may lead to the accumulation of these metals in the edible and non-edible parts of plants. Some heavy metals (Fe, Zn, Ni, Co, Mn, and Cu) are required for plant growth, while some are non-essential (Al, Cd, Pb, and Cr) for the proper growth of plants (Poonam et al., 2017). Heavy metals are non-biodegradable, carcinogenic and, show bioaccumulation through the food chain (Rani and Kaushik, 2014). The factors like pH, organic matter, cation exchange capacity regulates the mobility and availability of metals for plants in soil (Rieuwerts et al. 1998). Accumulation of heavy metals in food crops can have adverse effects on plants and animals (Rajindiran et al., 2015). Limited literature has been found regarding the evaluation of heavy metals in agricultural soils of the Sonepat district in the state of Haryana which shares its geographical boundary with New Delhi and also falls in the National Capital Region of New Delhi. Therefore, the present study was designed to evaluate heavy metals contamination in the agricultural soil of the Sonepat district of Haryana. The city of Sonepat is located at latitude and longitude of 28.92^0 N and77.02^o E, respectively, and to the north of the National Capital Territory of New Delhi. It is a semi-metropolitan city and is connected to Delhi by road and railways. The Yamuna River flows through the eastern part of the city, and its soil is suitable for agriculture.The district has fine loamy soil in most of the parts with some areas having sandy soil. The city is a major supplier of agricultural products, particularly to the national capital. This district is an industrial hub of a large number of small and large industries. In Sonepat, a total of

2125 industrial units are present, out of which 1527 are micro scale, 582 small scale, and 16 medium scale. These industries are manufacturing different types of products like food, medicine, cycles, polymers, printing, alloys, fabrication of communication towers, electrical lightening, manufacturing of brake parts, CFL, PVC, laminated papers, transformers, craft papers, leather footwear, surgical knives & scissors, leather tanning, yarns etc (MSME, 2011& 2016).

Heavy metals emitted from these industries can accumulate in agricultural soils. Therefore, soil samples were collected from agricultural fields in the study area for the assessment of heavy metals.

MATERIALS AND METHODS

Sample collection and preparation: A total of 23 soil samples (0-15 cm in depth) were collected from five different locations in the agricultural fields of Sonepat NCR in January 2018 (Figure 1). The soil samples weighing approximately 1 kg were collected in polyethylene bags and brought to the laboratory. The samples were air-dried, crushed, and passed through a 2-mm-mess sieve for further analysis. The pH of the soil was determined by the electrometric method using a digital pH meter. Soil organic carbon (SOC) content was determined by following Walkley Black wet oxidation method (Bhatti et al., 2016).

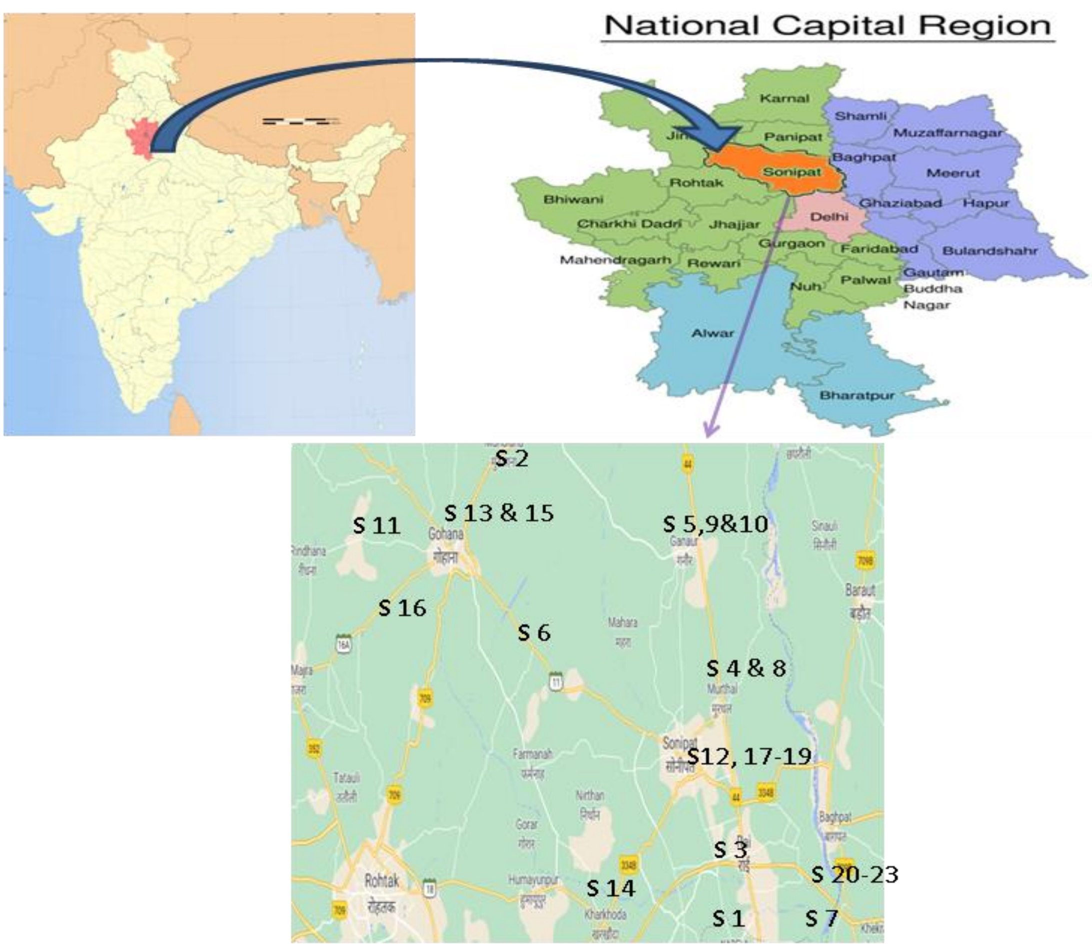

Figure 1. Map of sampling location (https://images.app.goo.gl)

Digestion of Samples: 1 gram of air-dried soil sample was digested on a hot plate in the fume hood at 80^0C by adding 15 ml of a tri-acid mixture (HNO_3, H_2SO_4, and $HClO_4$ in 5:1:1 ratio) until a transparent solution was obtained (Kumar et al., 2007). The final volume of the digested sample was made up to 50 ml with double distilled water and, it was filtered using the Whatman No. 42 filter paper for analysis of heavy metals. The concentrations of heavy metals (Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in the digested soil samples were estimated by atomic absorption spectrophotometer (Lab India AAS 8000). The instrument was calibrated with a blank and reference standard (Make- Merck, India) of Al and Fe concentrations (0.02-10 ppm) and for Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn concentration (0.02-5 ppm) with R^2 value as 0.99.Blank and standard were run after every 10 readings of the sample on the instrument. For data quality assurance, triplicate readings were used to interpret the results.

Assessment of soil pollution and ecological risk: Heavy metals contamination in the study area was calculated by comparing the analyzed concentration of heavy metals in the collected soil samples to their background values of Indian agricultural soils. The background concentrations of Fe, Cu, Co, Mn, Zn, Ni, Pb, Cr, Al and Cd in soils were taken as 32015 mg/kg, 56.5 mg/kg, 15.2 mg/kg, 209 mg/kg, 22.1 mg/kg, 27.7 mg/kg, 13.1 mg/kg, 114 mg/kg, 71000 mg/kg and 0.35 mg/kg, respectively (Giri and Singh, 2017; Kumar et al., 2019)(US Environmental Protection Agency 2014). Geo-accumulation index (Igeo), contamination factor (CF), and enrichment factor (EF) were used to assess the heavy metal pollution in the collected agricultural soils and their possible sources. The Igeo value for heavy metals in agricultural soil samples was calculated using equation 1. The soils can be classified into the following categories depending upon I geo value, (≤0) uncontaminated, (0<Igeo≤1), uncontaminated to moderately contaminated, (1<Igeo≤ 2) moderately contaminated, (2<Igeo≤3) Moderately to heavily contaminated, (3<Igeo≤4) heavily contaminated, (4<Igeo≤5) heavily to extremely contaminated, (Igeo>5) extremely contaminated (Niu et al., 2019).

$$I_{geo} = log_2(\frac{C_n}{1.5\ B_n}) \qquad (1)$$

C_n=Concentration of metal in the soil (mg kg^{-1}), B_n denotes the background concentration of metal in the soil (mg kg^{-1}) and,1.5 is a constant used as a factor to minimize possible variations in the background values due to lithogenic effects.

The Contamination factor is defined as the ratio of the specific metal content (C_i) in the soil to the background value (C_b) of the same metal in the soil. CF represents the anthropogenic input of heavy metals(Dogra et al., 2020).

$$CF = (C_i/C_b) \qquad (2)$$

CF was divided into six classes as (≤0) uncontaminated, (0<CF≤1) slight, (1<CF≤3) moderate, (3<CF≤5) considerable, (5<CF≤6) Strong, (CF>6) very strong (Li et al., 2017).

EF was used to elucidate potential pollution sources of heavy metals in agricultural soil samples. The EF values of metals in soil samples were calculated as follows:

$$EF = \frac{(C_i/C_{Fe})sample}{(C_i/C_{Fe})crust} \qquad (3)$$

Where C_i is the metal concentration and,C_{Fe} is the concentration of the reference element (Fe) in the sample and continental crust, respectively. An EF value of 0.5–1.5 indicates that the metal is derived primarily from crustal materials, while EF> 1.5 indicates that metal arises from non-crustal or anthropogenic processes(Chen et al., 2019).

The Potential Ecological Risk Index (Ei) was used to identify environmental impacts to organisms due to the presence of metals in soil and is calculated using Equations (4 and 5). RI is the ecological risk index defined as the sum of the potential ecological risk index (E_i) of various metals present in the soil(Chen et al., 2019).

$$RI = \sum_{i=1}^{n}(E_i) \quad (4)$$

$$E_i = T_i(C_i/C_0) \quad (5)$$

$E_i$is the potential ecological risk index of an individual metal, T_i is the toxic response factor (i.e., Cd =30, Pb=Cu=Ni = 5; Cr =2; and Zn = 1), C_i is the concentration of metal i in soil, C_0 is the background concentration.

Health risk assessment (HRA):Daily dose assessment of metal intake was calculated using equations (6), (7), and (8) for ingestion, dermal contact, and inhalation pathways of exposure. The total potential non-carcinogenic risk posed by different metals through different exposure pathways was calculated as the sum of HQs, which is calculated by using equation (9)(Giri and Singh, 2017)(Li et al., 2017).

$$ADD_{ing} = \frac{C_{soil} \times IngR \times EF \times ED}{BW \times AT} \times [CF] \quad (6)$$

$$ADD_{derm} = \frac{C_{soil} \times SA \times AF_{soil} \times ABS \times EF \times ED}{BW \times AT} \times [CF] \quad (7)$$

$$ADD_{inh} = \frac{C_{soil} \times EF \times ED}{PEF \times AT} \quad (8)$$

Where C_{soil} – Concentration of the contaminant in soil (mg/kg), IngR – Ingestion rate of soil (mg/day) (100 for adult and 200 for child), EF – Exposure frequency (350days/year), ED – Exposure duration [(Years) (24 for adult and 6 for child) (0-6 years as a child and 7-30 years as an adult)], BW – Body weight (57.5kg for adult and 15kg for child), AT – Averaging time (74845440 days for adult and 4677840 days for child), SA—Surface area of the skin that contacts the soil (5700 cm^2 for adult and 2800 cm^2 for child), AF_{soil}—Skin adherence factor for soil (0.07 mg/cm^2 for adult and 0.2 mg/cm^2 for child), ABS—Dermal absorption factor (0.001), PEF – Particle emission factor ($1.36 \times 10^9 m^3/kg$).

$$HQ = \frac{ADD}{R_f D} \quad (9)$$

Where HQ is hazard quotient, and ADD is an average daily dose (mg/kg), RfDs for three exposure pathways are R_fD_o (mg/kg/day) for ingestion, R_fD_{derm} (mg/kg/day) for dermal contact, and R_fC_i(mg/m^3) for inhalation(Giri and Singh, 2017).

Statistical analysis: Standard statistical analysis like bivariate correlation analysis with the Pearson's correlation coefficient (r) at two-tailed significance level (P), principal component analysis (PCA), and hierarchical cluster analysis (CA) using complete linkage method were applied using SPSS software package (22.0).

RESULTS AND DISCUSSION

In the present study, the pH of agricultural soils was found to be slightly alkaline with an average value of 7.81±0.25. The alkaline pH may affect the availability of heavy metals in soil. In alkaline soils, Cd from soil particles gets desorbed in the presence of Ca and Zn, and become bio-available (Khaledian et al., 2016). The values of pH reported here were in good agreement with the values reported in the agricultural soil samples collected from Panipatand other districts of Haryana, India (Daulta et al., 2014:Verma et al., 2015).

The TOC (%) was found to be 0.59±0.12 percent, which was much less than the TOC of agricultural fields of Sonepat situated near Yamuna river (Chaudhary et al., 2016). The main source of organic matter in the agricultural soil located near Yamuna may be sewage and industrial effluent disoposal in the river Yamuna alon with dead plants (Mazhar, et al., 2021). Thus the agricultural soil smaples were having medium level of organic carbon content. Similar results were reported by other researchers in Haryana (Kumar et al., 2014 and Gyawali et al., 2016). Soil organic matter affects the cation exchange capacity and hence controls the availability of heavy metals to the plants (Krull et al., 2009).

Variation of non-essential heavy metals (Al, Cd, Cr, and Pb): The concentration of Al, Cr, Pb, and Cd in the collected agricultural soil samples ranged between 7659.8-27210 mg/kg, 11.7-127.22 mg/kg 2.1-80.1 mg/kg, and 0.4-1.96 mg/kg, respectively (Figure 2a). Al concentrations reported here were below the world's average concentration of metals in the soils. Cd concentration in the agricultural soils of the present study was found to be higher than the average values of Cd in shale, showing that they were anthropogenic in origin (Giri and Singh, 2017). Pb concentration in most of the agricultural soil samples was exceeded the Indian natural soils background concentration of Pb.The Cd and Pb concentrations in this study were higher than the concentration reported in the agricultural fields of China (Xu et al., 2016; Hu et al., 2017; Tian et al., 2017), and Nigeria (Yaradua et al. 2020). Cd and Pbare the trace metals found in phosphate and superphosphate rocks; hence application of fertilizers derived from these rocks could add the concentration of these metals into the agricultural soils (Krishna and Govil, 2004). The chromium concentration of this study was higher as compared to several other studies conducted elsewhere in the world (Chen et al., 2019; Proshad et al., 2019). Although these metals are non-essential for plant growth, if present in high concentration, then they may enter into the food chain (Jaishankar et al., 2014).

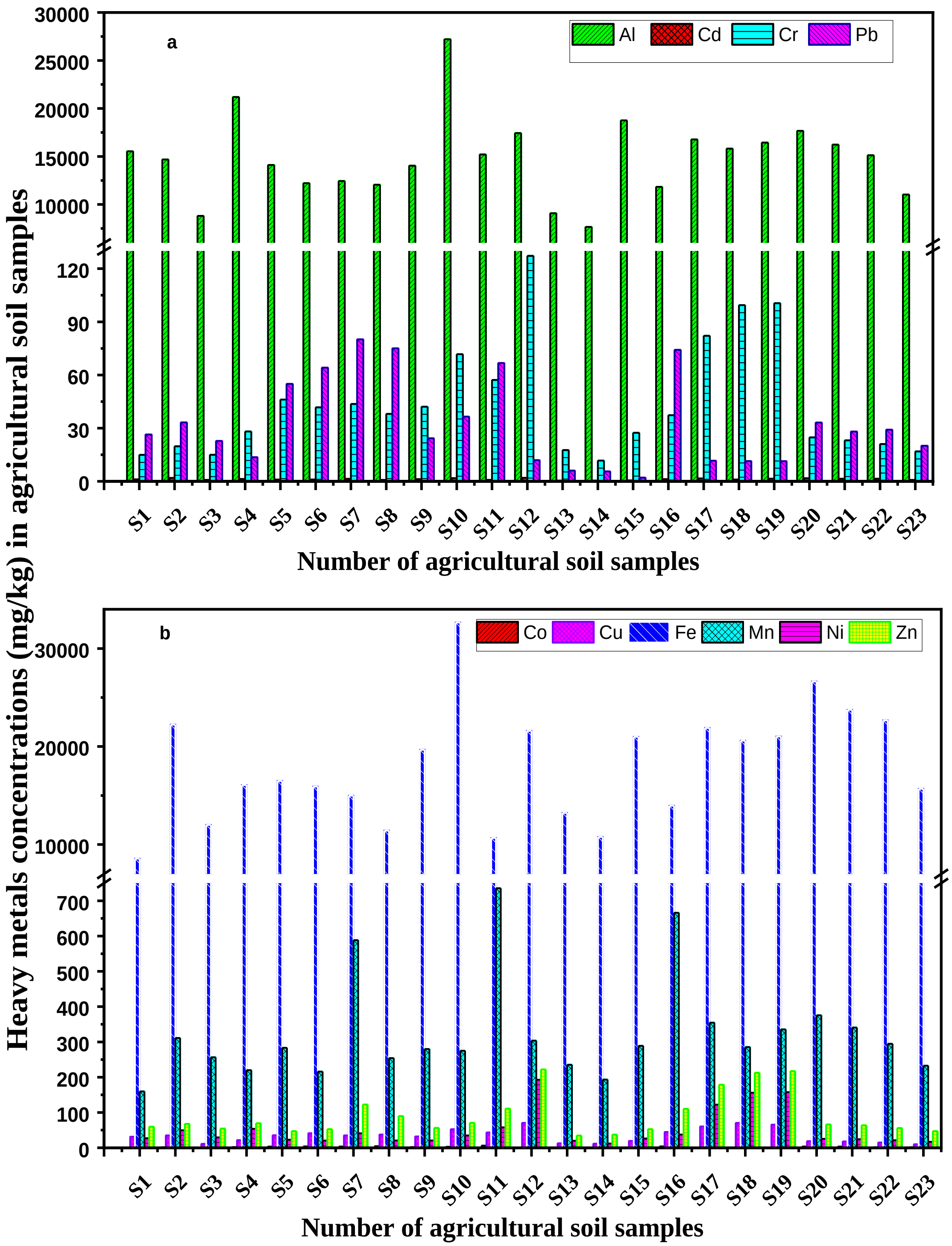

Figure 2. Concentrations of heavy metals in agricultural soils of NCR, India.

Variation of essential heavy metals (Co, Cu, Fe, Mn, Ni, and Zn):The concentrations of Co, Cu, Ni, Zn, Mn, and Fe, in the collected agricultural soil samples, ranged between

0.61-6.21 mg/kg, 9.9-70.43 mg/kg, 11.9-192.63 mg/kg, 34-221.88 mg/kg, 159.74-735.72 mg/kg, and, 8650-32650 mg/kg, respectively (Figure 2b). These metals are essential for the proper growth of plants (Urmila et al., 2016). The concentrations of Co were below the background values of agricultural soil, which indicates that the agricultural soils of Sonepat are deficient in Co. All of the soil samples except for sites S12, S17, and S19 were also deficient in Cu as per Indian agricultural soil values of Cu. A low concentration of Cu has also been reported in Yamuna floodplain agricultural soils (Chaudhary et al., 2016). The value of copper reported here was comparable with other studies conducted on soils in the state of Haryana (Urmila et al., 2016; Krishan et al., 2018) and other areas (Islam et al., 2016). Fe concentrations were below the background value except for the sample collected from site S10. This may be attributed to various steel fabrication industries located around site S 10. Although the concentration of Fe in our samples was higher than the concentration of the metal in agricultural soils of Kermanshah province and the Northeastern region of Iran (Doabi et al., 2019; Keshavarzi and Kumar, 2019). The average concentration of Mn (325 mg/kg) was higher than the background value of Mn in Indian agricultural soils. The potential source of input of the metal may be the use of Mn-containing fungicides in the agricultural fields, vehicles and industries (NIPHM, 2018). The dumping of waste from steel industries may also contribute to Mn in the soils as Mn acts as a deoxidizing and decarburizing agent in steel industries (https://www.britannica.com/technology/steel/Removing-oxygen). The Mn concentrations reported here were higher than the concentrations observed in the agricultural soil of Bangalore (Puttaih, 2012) and Panipat (Bharti et al., 2013). The average concentration of Ni (51.62mg/kg) was almost twice the background value of Ni in Indian agricultural soils. The high concentration of Ni may be attributed to the different types of chemical industries that are dumping their waste in the city sewage drain. Farmers were using drain water for irrigation in the fields situated adjacent to the drain. Nickel concentration in the soil samples was higher than the concentration reported in agricultural soils in the Jhajjar district of Haryana (Urmila et al., 2016). The mean concentration of Zn (91.31 mg/kg) was four times the background value of Zn in Indian agricultural soils. The high concentration of Zn may be due to the application of Zn fertilizers along with the different industrial emissions in the study area (NIPHM, 2018). The Zn concentration reported here was higher than the concentrations of previous studies (Krishan et al., 2018; Keshavarzi and Kumar, 2019; Chasapis et al., 2020).

Assessment of soil pollution and ecological risk: The analysis of I_{geo}, CF, and EF values showed that the agricultural soils in the study area were moderately to considerably contaminatedfor Cd, Ni, Pb, and Zn (Figure 3-5). The calculated Igeo value for Zn were found >1 for all of the agricultural soils collected during the present study that indicted towards contamination of agricultural soils with Zn in the study area. The I geo value for Cd was greater than 1 for the soil samples S3, S5-6, S11, S13-15, and S23, for Cd in the soil samples S5-8, S11, and, S16, for Mn in the soil samples S16 and for Ni in the soil sample S12, S17-19. Dixit et al., 2020 have studied the soil samples from Gurugram district and were found Igeo values greater than 1 for Pb and Zn, which are consistent with the results of the present study.

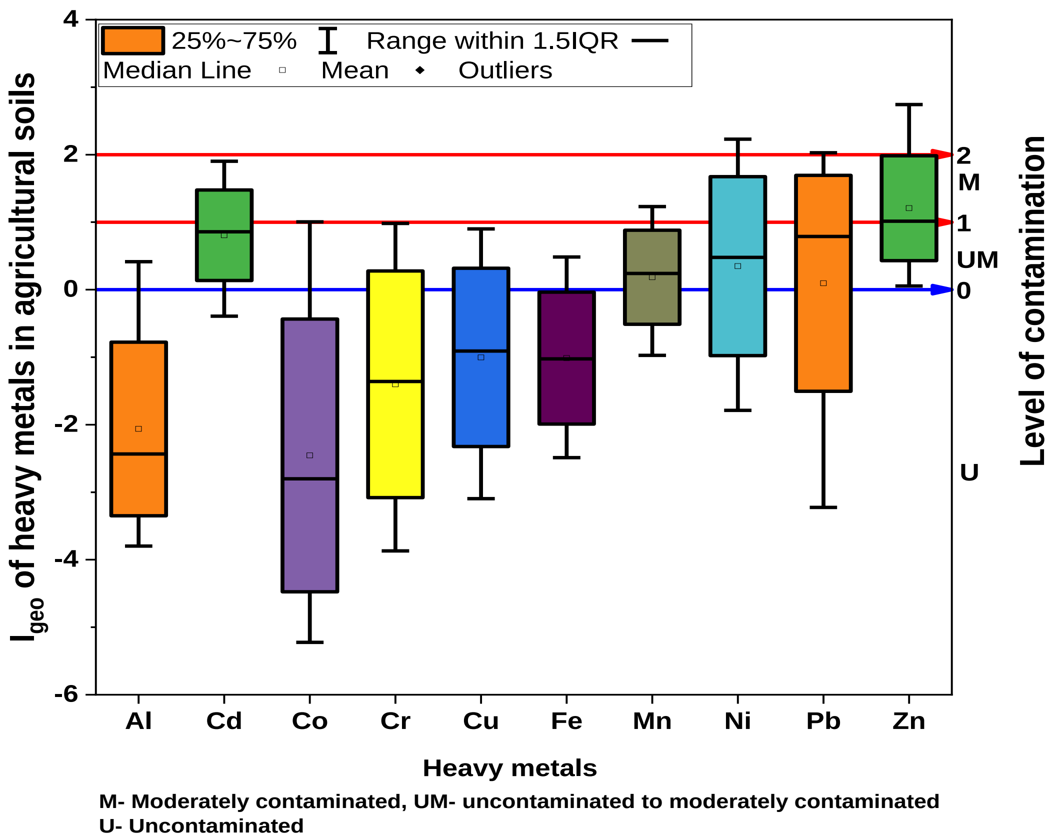

Figure 3. Geo-accumulation index of agricultural soils of NCR, India

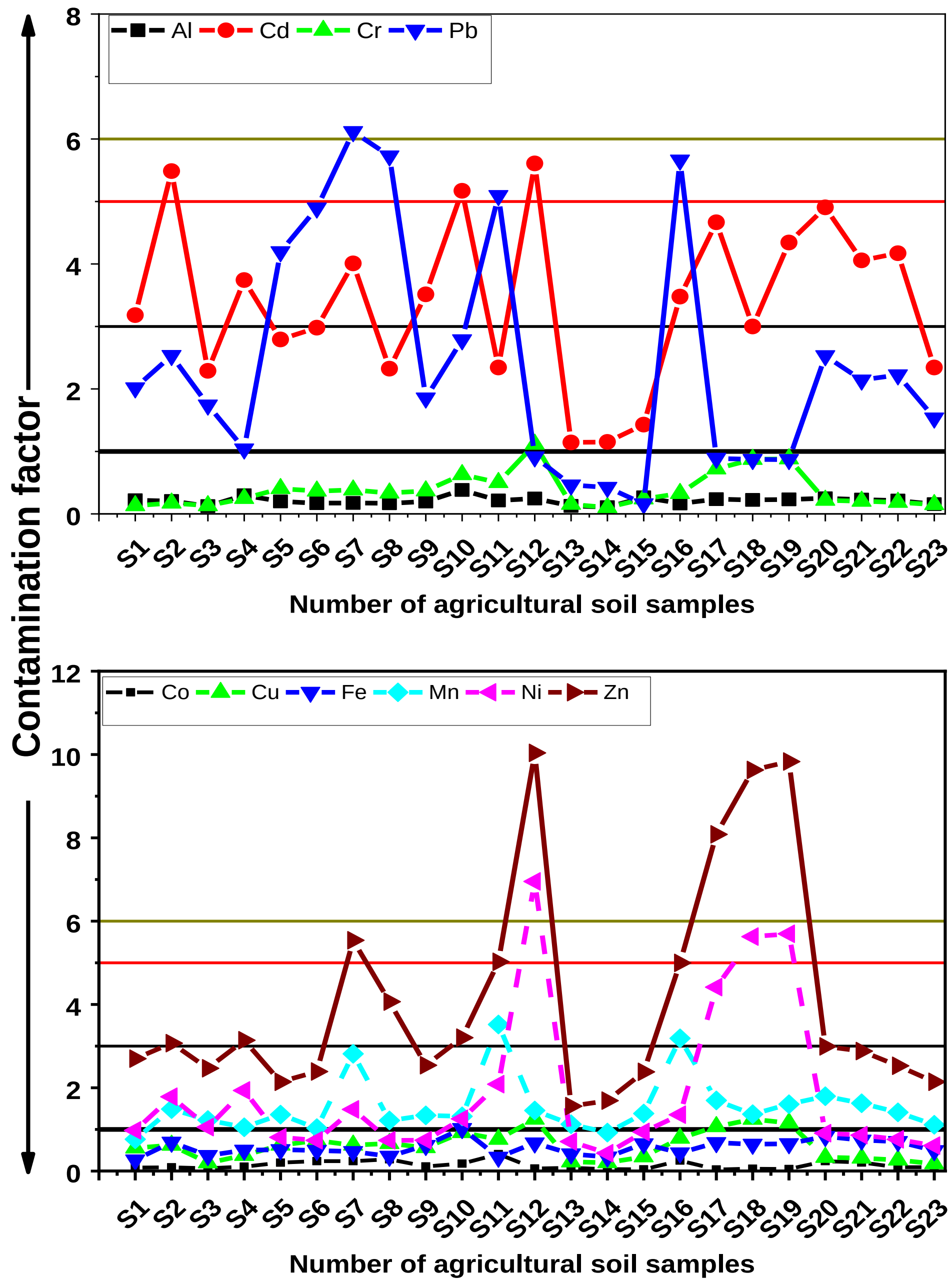

Figure 4. Contamination factor of agricultural soils of NCR, India.

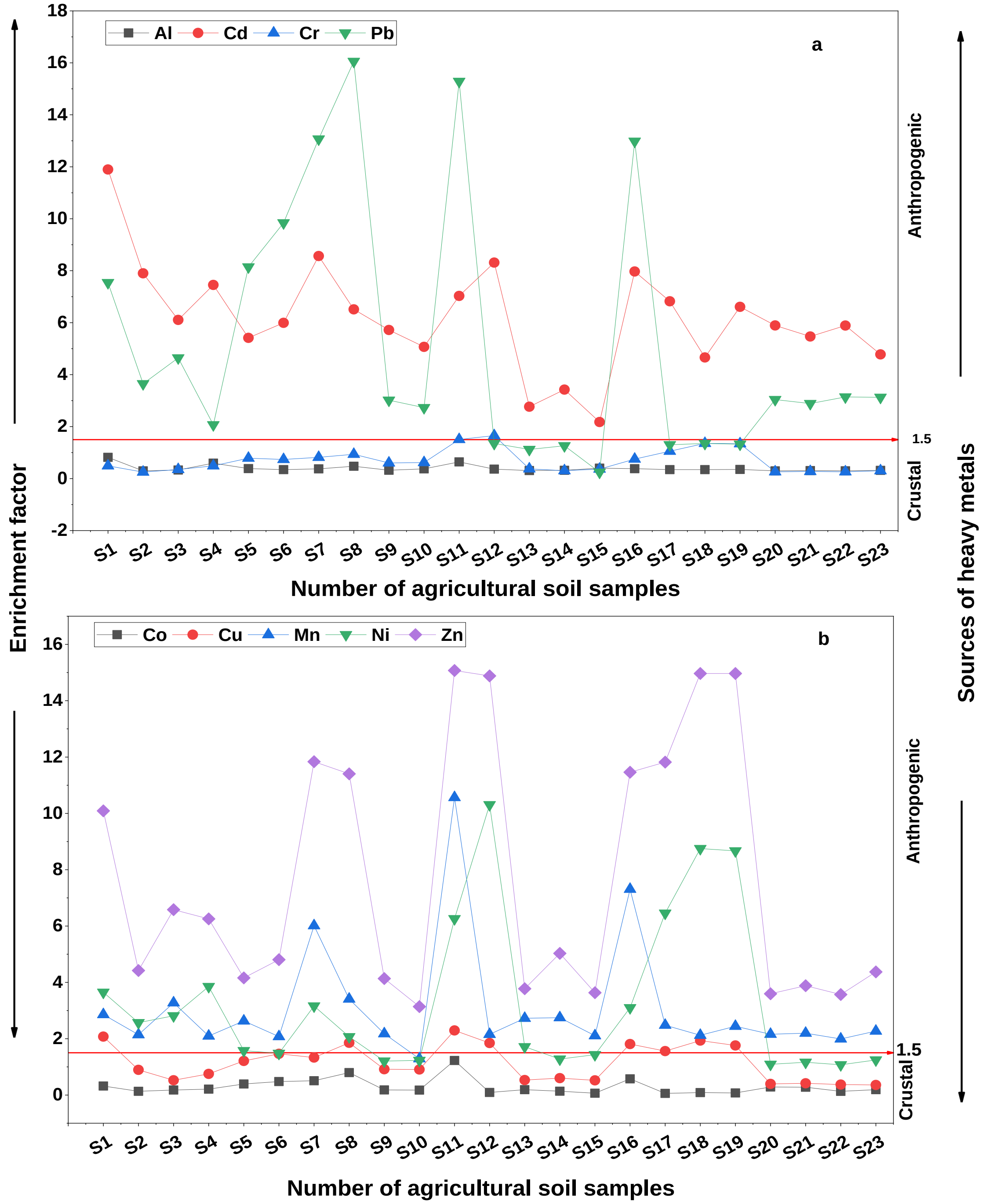

Figure 5. Enrichment factors of agricultural soils of NCR, India.

Contamination factor values suggested that 100 % of the soil samples had a moderate to strong level of contamination of agricultural soils with Cd and Zn. A moderate level of contamination due to Cr, Cu, Fe, Mn and Ni was observed at some specific sites (Cr (S12), Cu (S12, S17-19), Fe (S10), Mn (S1 and S14), Ni (S2-4), S7, S10-12, S16-19). Contamination factor was > 1 for Pb in all of the soil samples except for S12-15 and S17-19. A moderate level of CF was also reported in the soils of Gurugram district for Pb, and Zn and low level of CF for Ni (Dixit et al., 2020).

The values of EF at different sampling locations have been shown in figure 5.The mean EF values follow the trend Zn (7.73) > Cd (6.19) >Pb (5.18) > Ni (3.31) >Mn (3.10) > Cu (1.15). The value of EF was > 1.5 for 100 % of the agricultural soil samples for Cd and Zn that indicted the enrichment of these metals in the agricultural soils. Approximately 96 %, 70 % and 57 % of the soil samples were had EF >1 for Mn, Pb and Ni, respectively that is pointing towards the beginning of enrichment of these metals in the agricultural soils of the study area. Zn, Cd, and Pb show relatively high EFs, suggesting the contributions from anthropogenic sources whereas Ni and Mn were derived from the weathering of parental material along with some level of anthropogenic input. Enrichment of Pb and Zn has also been reported ealrlier in the national capital region (Dixit et al., 2020).

Ei and RI were calculated for seven metals (Cd, Cr, Cu, Ni, Pb, Mn, and Zn) using equations 4 &5, and the values obtained are shown in Figures 6 a & b. Mean potential ecological risk Ei was 102 for Cd, indicating considerable potential ecological risk due to Cd in all agricultural soils. A total of 61 %, 22 % and 6 % of the collected soil samples were showed considerable, moderate and high level of ecological risk due to Cd. The agricultural soils of sample no. S2, S7, S10, S12, S16, S17, S19, and S20 were contributed to low potential ecological risk due to the presence of different heavy metals as they showed the mean RI value >150.

Health Risk Assessment: Health risk assessment calculations were done based on mean concentrations of heavy metals in the agricultural soils. HQ values of metals due to the ingestion, dermal, and inhalation were <1 in both adults and children. Oral exposure to the agricultural soils may be the primary route of exposure to heavy metals inchildren (Table 1). The cumulative effect (HI) of all the pathways was found to be below unity for all the metals in adults and children showing that there was no significant health risk to the people living in the study area due to heavy metals present in the agricultural soils.

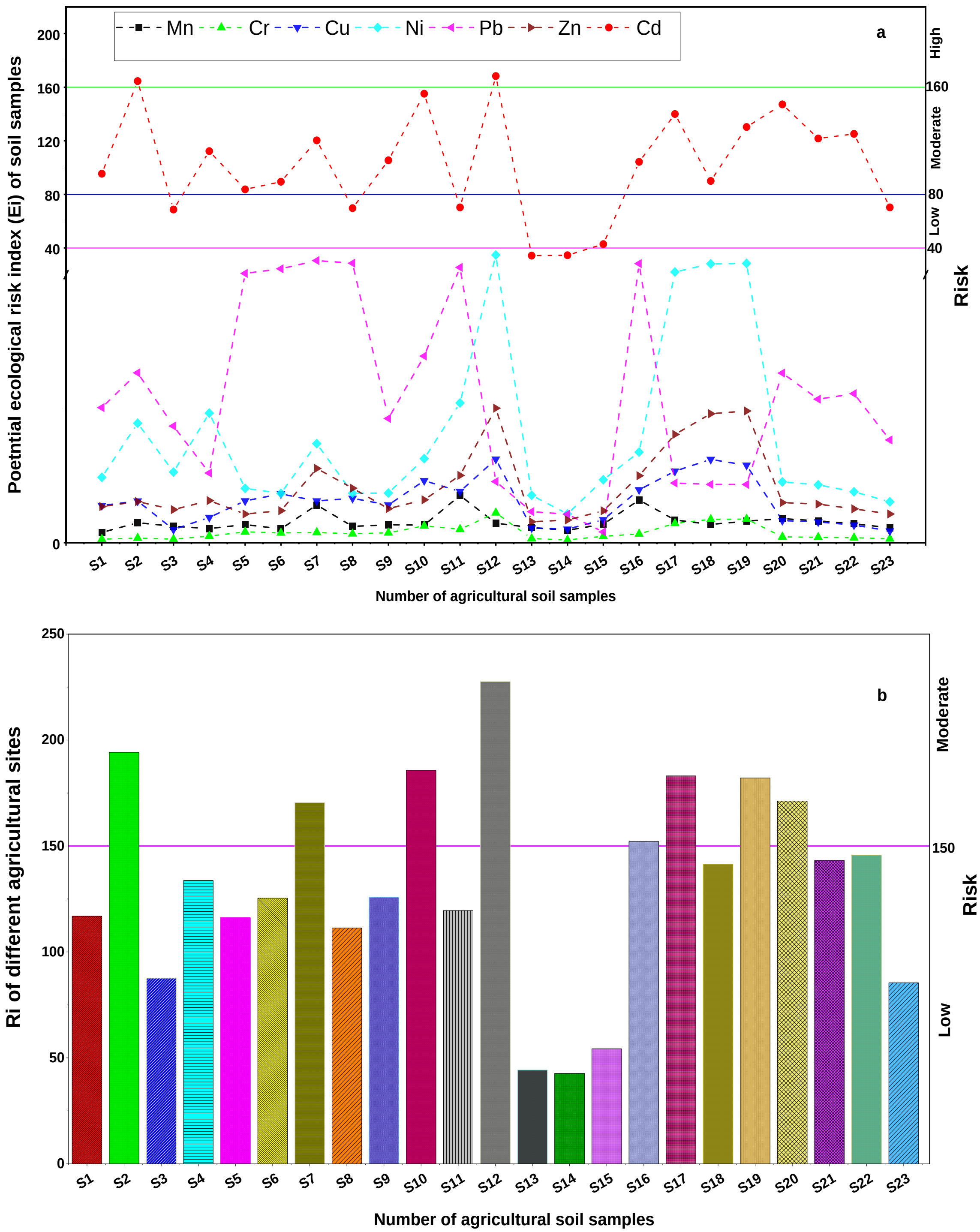

Figure 6. Ei and Ri values of heavy metals in agricultural soils of NCR, India

Table1. Health risk assessment to adults and children due to heavy metals exposure form soil

Heavy metals	HQ ing		HQ derm		HQ Inh	
	Adult	child	Adult	child	Adult	child
Cd	2.32E-07	7.12E-06	3.7E-08	7.97E-07	9.81E-09	3.92E-08
Co	1.41E-06	4.31E-05	2.81E-08	6.04E-07	2.97E-08	1.19E-07
Cr	2.14E-07	6.56E-06	4.27E-09	9.18E-08	3.62E-08	1.45E-07
Cu	2.24E-06	6.86E-05	3.57E-07	7.68E-06	--	--
Fe	5.01E-06	0.000154	1E-07	2.15E-06	--	--
Mn	2.65E-06	8.12E-05	2.64E-07	5.68E-06	5.37E-07	2.15E-06
Ni	5.04E-07	1.55E-05	5.03E-08	1.08E-06	4.73E-08	1.89E-07
Pb	1.80 E-06	0.002195	4.79E-08	4.1E-05	1.78E-08	2.82E-06
Zn	5.94E-08	1.82E-06	1.19E-09	2.55E-08	--	--

Statistical analysis: Pearson correlation technique and PCA multivariate technique was applied to explore the association between the heavy metals (Table 2). Pearson correlation analysis showed that all of the heavy metals were significantly and positively correlated but to a different extent. PCA and dendrogram analysis suggested the formation of three primary clusters of Cu-Cr-Zn-Ni, Co-Pb-Mn, Al-Fe-Cd (Figure 7 & 8). The three factors were having a cumulative variance of 86.58% were obtained (Table 3). Factor 1 contributed 44.88% to the total variance with the high loading of Cu, Cr, Ni, and Zn, indicating their industrial source of origin. Factor 2 contributed 25.08% to the total variance with the high loading on Co, Pb, and Mn, pointing towards their vehicular origin. Break wear and the loss of Pb wheel weight contribute Pb in the environment (Taylor and Kruger, 2020). In India at least 36,250 tonnes of lead are used as balancing weights (https://www.downtoearth.org.in/coverage/wheels-of-pollution-44952). Factor 3 contributed 16.62 % to the total variance with high loading on Al, Fe, and Cd, suggesting that these metals may be of crustal origin.

Table 2. Inter-metal Pearson's correlation for agricultural soils

Heavy	Al	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Al	1									
Cd	0.590**	1								
Co	0.007	-0.003	1							
Cr	0.407	0.455*	-0.091	1						
Cu	0.387	0.490*	0.023	0.924**	1					
Fe	0.721**	0.685**	-0.157	0.364	0.275	1				
Mn	-0.010	0.143	0.642**	0.177	0.247	-.069	1			
Ni	0.279	0.445*	-0.325	0.903**	0.822**	0.254	0.102	1		
Pb	-0.145	0.059	0.864**	-0.090	0.106	-0.250	0.584**	-0.313	1	
Zn	0.231	0.438*	-0.143	0.902**	0.867**	0.203	0.292	0.953**	-	1

**. Correlation is significant at the 0.01 level and * at 0.05 level.

Table3. PCA and factor analysis

	Factor 1	Factor 2	Factor 3
Al	0.577	-0.084	0.669
Cd	0.686	0.081	0.518
Co	-0.175	0.911	0.213
Cr	0.934	0.085	-0.221
Cu	0.893	0.237	-0.205
Fe	0.556	-0.226	0.712
Mn	0.166	0.826	-0.044
Ni	0.906	-0.108	-0.372
Pb	-0.170	0.917	0.098
Zn	0.893	0.116	-0.391
Eigen Value	4.489	2.508	1.662
% of Variance	44.888	25.076	16.618
Cumulative %	44.888	69.965	86.583

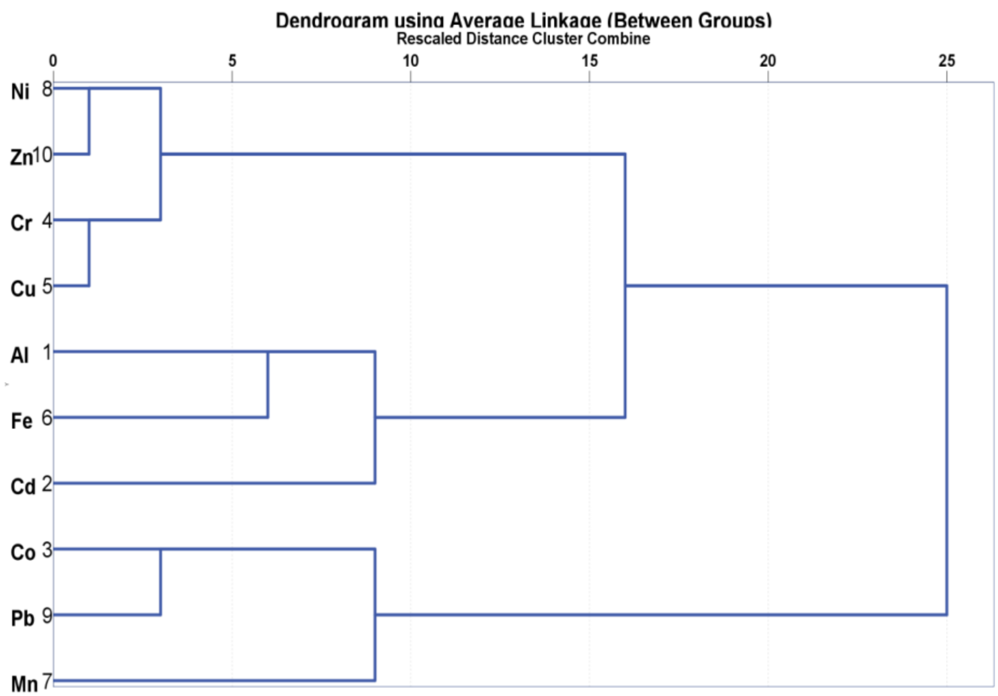

Figure 7. Dendrogram showing clustering of heavy metals

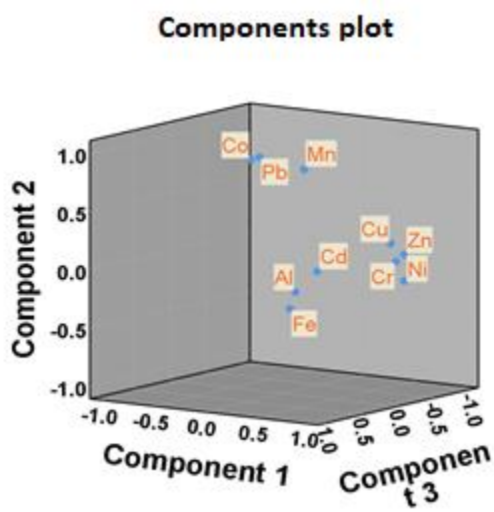

Figure 8. Principal component analysis of heavy metals in agricultural soils

As conclusion, agricultural soils in the Sonepat were alkaline in nature and having moderate level of organic carbon content. The study revealed high concentrations of Pb, Cr, Mn, Ni, and Zn in the agricultural soils compared to the background values of the respective metals in the Indian agricultural soils. The mean concentration of Cd in the soil samples was approximately three times higher than the world's average concentration of Cd in soil. Statistical analysis has shown that Cr, Ni, and Zn were released mainly from industrial sources while Pb and Mn were released from vehicular emissions. Based on the Igeo values it was interpreted that the soils were having a low level of contaminated with Mn, Pb and Ni and moderate contamination with Cd. On the basis of contamination factor, a high level of contamination due to Cd and Zn was observed in all soil samples collected during the study while some sites were contaminated with some specific metals (Cr, Cu, Fe, Mn, and Ni). Enrichment factor was high for Zn (7.73) and Cd (6.19), indicating the high level of anthropogenic input of these metals in the study area. Different levels of ecological risk were reported in different soil samples due to Cd, and 35% sampling sites were showed a low potential ecological risk due to presence of multi-metals. Although health risk assessment showed no direct health effects to the inhabitants in the study area due to exposure to the contaminated soils. However, a high concentration of heavy metals in agricultural soil may be taken up by vegetables grown in these contaminated soil, and hence may have health effects on the consumers. On the basis of present study it can be concluded that a baseline level of heavy metals pollution has occurred in the agricultural soils of the Sonepat district, therefore, it is recommended to carry out a further study to assess the heavy metal concentrations in the vegetables grown in this area.

REFERENCES

Awasthi, A.K., Pandey, A., Pandey, A.K., and Jamaluddin. 2013. Comparative Study on Heavy Metal Characteristics of Leachate from Municipal Solid Waste in Central India. International Journal of Science Inventions Today. 2(5): 390–396.

Bharti, P.K., Kumar, P., and V. Singh. 2013. Impact of industrial effluents on ground water and soil quality in the vicinity of industrial area of Panipat city. Journal of Applied and Natural Science. 5(1): 132–136.

Bhatti, S.S., Kumar, V., Singh, N., Sambyal, V., Singh, J., Katnoria, J.K., and A. K. Nagpal, 2016. Physico-chemical Properties and Heavy Metal Contents of Soils and Kharif Crops of Punjab, India.Procedia Environmental Sciences. 35: 801–808.

Chasapis, C.T., Ntoupa, P.S.A., Spiliopoulou, C.A., and M.E. Stefanidou. 2020. Recent aspects of the effects of zinc on human health. Archives of Toxicology. 94(5): 1443–1460.

Chaudhary, S., and D.K. Banerjee. 2007. Speciation of some heavy metals in coal fly ash. Chemical Speciation and Bioavailability. 19(3): 95–102.

Chaudhary, S., Banerjee, D.K., Kumar, N., and S. Yadav. 2016. Assessment of bioavailable metals in the sediments of Yamuna flood plain using two different single extraction procedures. Sustainable Environment Research. 26(1): 28–32.

Chen, L., Wang, G., Wu, S., Xia, Z., Cui, Z., Wang, C., and S. Zhou. 2019. Heavy Metals in Agricultural Soils of the Lihe River Watershed, East China: Spatial Distribution, Ecological Risk, and Pollution Source. International Journal of Environmental Research and Public Health.16 (2094).

Chopra, A.K., and C. Pathak. 2015. Accumulation of heavy metals in the vegetables grown in wastewater irrigated areas of Dehradun, India with reference to human health risk. Env.Monit Assess 187(445): 1–8.

Daulta, R., Rani, J., and A. Yadav .2014.Effect of sugar mill effluent on physico-chemical properties of soil at Panipat City, India.International Archive of Applied Sciences and Technology. 5(2): 6–12.

Doabi, S. A., Karami, M., and M. Afyuni. 2019. Heavy metal pollution assessment in agricultural soils of Kermanshah province, Iran. Environmental Earth Sciences.78(70).

Dogra, N., Sharma, M., Sharma, A., Keshavarzi, A., Minakshi, Bhardwaj, R., Thukral, A.K., and V. Kumar. 2020. Pollution assessment and spatial distribution of roadside agricultural soils: a case study from India. International Journal of Environmental Health Research. 30(2): 146–159.

Puttaih, J.E.T. 2012.Heavy metal contamination in soil under the application of polluted sewage water across Vrishabhavathi River.Internnational Journal of Engineering Research and Applications. 2(6): 1666–1671.

Giri, S., and A.K. Singh. 2017. Ecological and human health risk assessment of agricultural soils based on heavy metals in mining areas of Singhbhum copper belt, India. Hum. Ecol. Risk Assess. 23(5): 1008–1027.

Gupta, D.K., Corpas, F.J. and J.M. Palma. 2013. Heavy Metal Stress in Plants. New York.

Gyawali, C., Dahiya, D. S., Devraj, Bhat, M. A., Bhandari, R. R. 2016. Spatial distribution of physico-chemical properties and macronutrients in rice growing soils of Haryana, The Ecoscan, 10(3&4): 365-370.

https://www.britannica.com/technology/steel/Removing-oxygen Accessed on 8 Feb 2021

https://images.app.goo.gl/VCdoJv6smBqrLF6x6 Accessed on 24 Jan 2020

https://images.app.goo.gl/gPB25PQin2BApuoHA Accessed on 24 Jan 2020

https://goo.gl/maps/Xhg2NVSrNxm2tbd17 Accessed on 24 Jan 2020

https://www.downtoearth.org.in/coverage/wheels-of-pollution-44952 Accessed on 19 Nov 2021

Hu, W., Huang, B., Tian, K., Holm, P. E., and Y. Zhang. 2017. Heavy metals in intensive greenhouse vegetable production systems along Yellow Sea of China : Levels, transfer and health risk. Chemosphere 167: 82–90.

Islam, M.S., Ahmed, M.K., and M. Habibullah-Al-Mamun. 2016. Apportionment of heavy metals in soil and vegetables and associated health risks assessment. Stochastic Environmental Research and Risk Assessment. 30(1): 365–377.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., and K.N. Beeregowda. 2014. Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary Toxicology. 7(2): 60–72.

Keshavarzi, A., and V. Kumar. 2019. Ecological risk assessment and source apportionment of heavy metal contamination in agricultural soils of Northeastern Iran. International Journal of Environmental Health Research. 29(5): 544–560.

Khaledian, Y., Pereira, P., Brevik, E.C., Pundyte, N., and D. Paliulis. 2016. The Influence of Organic Carbon and pH on Heavy Metals, Potassium, and Magnesium Levels in Lithuanian Podzols. Land Degradation and Development. 28(1): 345–354.

Krishan, G., Chandniha, S.K., Lohani, A.K., Yadav, B.K., Arora, N.K., Singh, S., Kumar, C.P., Sharma, L.M., and A.K. Bhardwaj. 2018. Assessment of Heavy Metals in Relation to Soil Pollution at Mewat, Haryana, India. Curr.Current World Environment. 13(3): 299–306.

Krishna, A.K., and P.K. Govil. 2004. Heavy metal contamination of soil around Pali Industrial Area, Rajasthan, India. Environmental Geology. 47(1): 38–44.

Krull, E.S., Skjemstad, J.O., and J.A. Baldock. 2009. Functions of Soil Organic Matter and the Effect on Soil Properties. GRDC Final Report CSO00029.

Kumar, R., Agrawal, M., Marshall, F., Kumar Sharma, R., Agrawal, M., and F. Marshall. 2007. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi , India. Ecotoxicology and Environmental Safety. 66(2): 258–266.

Kumar, R., Aggarwal, P., Singh, R., Chakraborty, D., Bhattacharya, R., Garg, R. N., Kamble, K. H., and Yadav, B. 2014. Assessment of soil physical health and productivity of Kharkhoda and Gohana blocks of Sonipat district (Haryana), India. Journal of Applied and Natural Science 6 (1): 6-11.JANS

Kumar, V., Sharma, A., Kaur, P., Sidhu, G.P.S., Bali, A.S., Bhardwaj, R., Thukral, A.K., and A. Cerda. 2019. Pollution assessment of heavy metals in soils of India and ecological risk assessment: A state-of-the-art. Chemosphere 216: 449–462.

Kumari, S., and J. Rani. 2014. Assessment of water quality index of ground water in Smalkhan, Haryana. International Journal of Latest Research in Science and Technology. 3(6): 169–172.

Lente, I., Keraita, B., Drechsel, P., Ofosu-Anim, J., and A.K. Brimah. 2012. Risk assessment of heavy-metal contamination on vegetables grown in long-term wastewater irrigated urban farming sites in Accra, Ghana. Water Quality, Exposure and Health. 4: 179–186.

Li, H., Ji, H., Shi, C., Gao, Y., Zhang, Y., Xu, X., Huaijian, D., Tang, L. and Y. Xing. 2017. Distribution of heavy metals and metalloids in bulk and particle size fractions of soils from coal-mine brownfield and implications on human health. Chemosphere.172: 505-515.

Mazhar, M. A., Ahmed, S., Husain, A., Uddin, R., and Khan, N. A. 2021. Trends in Organic Contamination in River Yamuna: A Case Study of Delhi Stretch (2007-2016). A case report. Research Square, p. 1-17. DOI: https://doi.org/10.21203/rs.3.rs-254013/v1

MSME. 2011. Brief Industrial Profile of Sonepat District. Ministry of micro, small and medium enterprises development institute of Karnal, Goveronment of India. p. 1-19.

MSME. 2016. State Industrial Profile of Haryan. Ministry of micro, small and medium enterprises development institute of Karnal, Goveronment of India. p. 1-63.

NIPHM. 2018. Pesticide classification on Use, Chemical nature, Formulation, Toxicity and Mode of Action etc. Pesticide management devision, Hydrabad.11 pp.

Poonam, Y., Balvinder, S., Garg, V.K., Suman, M., and P. Vandana. 2017. Bioaccumulation and health risks of heavy metals associated with consumption of rice grains from croplands in Northern India. Human and Ecological Risk Assessment. 23(1): 14–27.

Proshad, R., Islam, M., Kormoker, T., Bhuyan, M., Hanif, M., Hossain, N., Roy, R. and A. Sharma. 2019. Contamination of Heavy Metals in Agricultural Soils : Ecological and Health Risk Assessment. SF Journal of Nanochemistry and Nanotechnology. 2(1): 1012.

Rajindiran, S., Dotaniya, M.L., Coumar, M.V., Panwar, N.R., and J.K. Saha. 2015. Heavy metal polluted Soils in India : status and countermeasures. JNKVV Research Journal. 49(3): 320–337.

Rani, J., and C.P. Kaushik. 2014. Potential of Various Immobilization Matrices in Heavy Metal Ions Removal Using Nostoclinckia beads: A Comparative Study. IOSR Journal of Environmental Science, Toxicology and Food Technology. 8(12): 31–40.

Rieuwerts, J.S., Thornton, I., Farago, M.E., and M.R. Ashmore. 1998. Factors influencing metal bioavailability in soils: Preliminary investigations for the development of a critical loads approach for metals. Chemical Speciation and Bioavailability. 10(2): 61–75.

Sharma, R., Agrawal, M. and F. Marshall. 2007. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicology and Environmental Safety. 66(2): 258–266.

Taylor, M. and N. Kruger. 2020. Tyre weights an overlooked diffuse source of Lead and Antimony to road runoff. Sustainability 2020 (12): 6790. doi:10.3390/su12176790.

Tian, K., Huang, B., Xing, Z., and W. Hu. 2017. Geochemical baseline establishment and ecological risk evaluation of heavy metals in greenhouse soils from Dongtai, China. Ecological Indicators. 72: 510–520.

Urmila, Garg, A., and Annu. 2016. Assessment of heavy metal pollution in soil of Jhajjar , Haryana-India. Journal of Chemical and Pharmaceutical Research. 8(5): 629–634.

United States Environmental Protection Agency. 2014. A Ecological Soil Screening Level for Aluminium. Office of solid waste and emergency response 1200 Pennsylvania Avenue, N.W. Washington, DC 20460.pp.1-1.

Verma, A., and S. Bhatia. 2014. Analysis of some physicochemical parameters and trace metal concentration present in the soil around the area of Pariccha Thermal Power Station in Jhansi ,India . International Journal of Innovative Research in Science, Engineering and Technology. 3(3): 10482–10488.

Verma, S., Yadav, S., Yadav, S. K., Kadyan, P. S., Singh, I., and D. Singh. 2015. Heavy metals in wheat grains of Haryana (India) and their health implications. Journal of Chemical and Pharmaceutical Research, 7(10): 342–351.

Wuana, R., and F.E. Okieimen. 2011. Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. ISRN Ecology.1–20.

Xu, L., Lu, A., Wang, J., Ma, Z., Pan, L., and X. Feng. 2016. Effect of land use type on metals accumulation and risk assessment in soil in the peri-urban area of Beijing , China. Human and Ecological Risk Assessment. 22(1): 265–278.

Yaradua, A.I., Alhassan, A.J., Nasir, A., Matazu, K.I., Usman, A., Idi, A., Abdulahi, I., Nasiru, A., Ibrahim, M.U., and A.M. Kanadi. 2020. Evaluation of heavy metals in agricultural soils from Katsina state Nigeria. Sustainability, Agri, Food and Environmental Research. 8: 212–229.

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