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Case Study

Seasonal statistical analysis of studied metals in soil profiles in the vicinity of coal based thermal power plant: a case study

Meena Bharat Singh[1], Meena Manju[1*], Chandrawat Uttra [1] and Ashu Rani[2]
[1]Deptt. of Chemistry, Govt. College, Kota-324001, Rajasthan, India
[2]Deptt. of Pure & Applied Chemistry, Uni. of Kota, Kota-324005, Rajasthan, India
meenamanju87@gmail.com

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Abstract

A case study was performed by assessing metal pollution within alkaline soil to evaluate their potential sources in Kota city, India. A total of 900 samples in requisite amount of soil are collected depth wise at various sampling sites in the study area during winter, rainy and summer seasons of 2011-12. Seasonal variation, in the deposition patterns of selected metals down soil profiles, controlled by meteorological parameters has been observed. Anthropogenic metal concentrations are observed to be greater in winter and less in summer. Due to washout phenomenon of upper layer of soil, the concentrations level of crustal and anthropogenic metals deposited on top soil decreases drastically in rainy season. The elevated level of metals at top soil characterized with lower pH is explained by their increased mobility which decreases on going down the soil profile due to complexation at higher pH found in clay rich bottom layer. Source apportionment by principal component analysis and positive correlations among Cu, Cd, Zn and Pb indicate their similar anthropogenic origin which is point source coal based thermal power plant mainly along with other industrial processes and traffic exhaust. However, Ca, Mg and Fe are found to have mostly crustal origin.

Keywords: Heavy metals, soil Profiles, seasonal variation, principal component analysis, coal based thermal power plant.

Introduction

Soil, a complex heterogeneous system, possessing distinct morphological, mineralogical, physical, chemical and biological characteristics, consists of minerals, organic matter, water and air. Soil particles are formed due to weathering of rocks into small fragments. Among these structural ingredients, different minerals are active structures that can bind to heavy metals. Many of these elements are essential for living beings which are released into aquatic atmosphere caused by human activities some of them being mining, smelting besides coal and vehicular exhaust, industrial and anthropogenic activities.

Aerosol particles get bound to these heavy metals and move in the atmosphere. After reaching the surface of the soil through dry out (gravitational settlement) and wet out (precipitation) they get deep into the soil. Generally, contaminants in the soil are chemically attached to or physically trapped into soil structure particles[1]. If pH, humus and clay mineral content of soil are high, the most of heavy metals get bound to soil and become biologically inaccessible. Easily available metals (soil or in the soil solution), after reaching the ground water, enter into the human nutrition chain. At low pH, acidic soils with low humus and clay mineral content do not bind heavy metals. Hence, the solubility, mobilization and deposition of toxic metals is controlled by soil components and its properties, which can be observed is observed in different soil profiles[2-4].

Though heavy metals in small amounts are essential for living beings, concentrations significantly higher than natural levels are toxic for them. Besides natural and anthropogenic emission sources, the climate and the meteorological factors, owing to their effect on erosion and weathering, influence the intensity and distribution of heavy metals in different soils in relation to their certain physico-chemical properties determining their mobility and bioavailability in soil[5, 6]. In soil, heavy metals can be affected by processes of sorption/desorption, precipitation, dissolution, redox reaction and incorporation in the solid components of soil[7]. High CEC values i.e. clay minerals with a high density of negative surface charges, high surface areas (small sizes) and also weak vander Waals forces between the structural layers favour absorption and migration of metal compounds in soil environments[8,9]. Kota district has deep, medium and black shallow alluvium soils with clayey texture ranging from shallow to very deep with lime concretion or lime encrusted gravels at varying depths.

Owing to the existence of a major coal based thermal power plant (KSTPS), generating and releasing large amount of fly ash in the atmosphere and presence of many other industries, further escalating the metal load, the present research work of assessing heavy metal toxicity in soils of Kota city has been carried out.

Keeping this view in mind, this work has been carried to assess the concentration and distribution of studied metals (readily extractable content) in the soil samples collected depth wise in all zones of study area of Kota city during study period.

Materials and methods

Study Area: Kota, one of the major industrial city of Rajasthan state in India, situated on the eastern bank of river Chambal in the southern part of Rajasthan with an elevation of 271 meters (889 feet) above sea level on the south- east of Aravali ranges.

Sampling Sites: Selection criteria of sampling sites have been described in our earlier research paper[10]. Figure-1 shows the selected five zones whose location in relation to the point source i. e. KSTPS, the possible source of heavy metal emission are presented in Table-1.

Table-1: Situatedness and features of different zones of Kota city.

Zone No.	Situatedness with reference to point source (KSTPS)	Features
Zone-1 (n=10)	Within 2 Km. radii surrounding point source	Coal dust (as raw material for coal based KSTPS); Fly ash (emitted from KSTPS); Soil dust; High population density; High traffic load
Zone-2 (n=10)	2-10 Km. towards North-east direction from point source	Fly ash (emitted from KSTPS favoured by north-east wind blow mainly during the study period); Soil dust; Traffic dust owing to location of several public transport centres
Zone-3 (n=10)	2-7 Km. towards East direction from point source	Fly ash (emitted from KSTPS); Soil dust; High traffic dust; Commercial activities (Multimetals Limited, Samtel Glass Limited); High population density
Zone-4 (n=10)	2-12 Km. towards East-south direction from point source	Fly ash (emitted from KSTPS); Soil dust; High traffic dust; Establishment of industrial complex (DCM Shriram Consolidated Limited, Shriram Fertilizers and Metal India, Shriram Rayons); High population density
Zone-5 (n=10)	2-8 Km. towards South direction from point source	Fly ash (emitted from KSTPS); Soil dust; Residential area; Stone mining activities

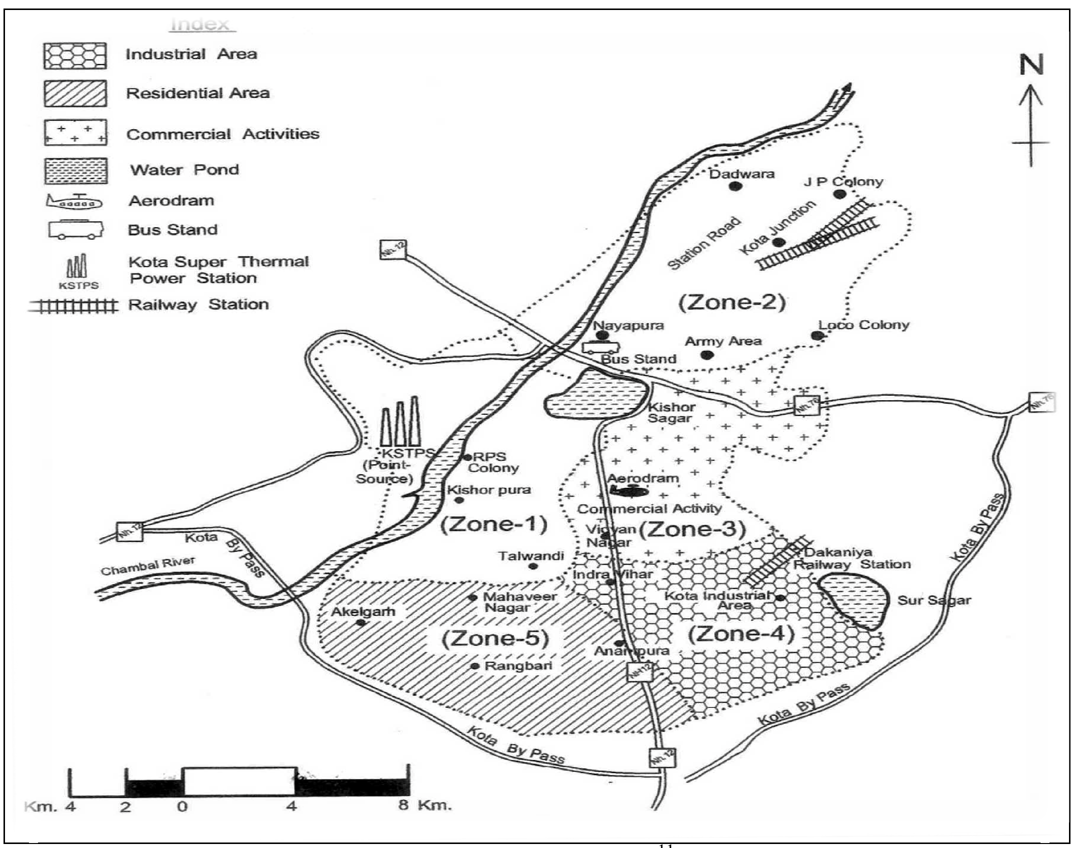


Figure-1: Kota city map[11].

Soil Analysis: soil samples (n=900) in requisite amount are collected from three horizons (300 samples each) i.e. topsoil (0-10 cm), mid soil (10-20cm) and bottom soil (20-30cm) at various selected sampling sites of all the five zones during winter (January, February, November and December), rainy (June, July, August and September) and summer (March, April, May & October) seasons of 2011-12. All samples of soil are air dried first, thereafter gently crushed in the ceramic mortar and sieved for collecting fraction smaller than 2mm. The dried samples, thus obtained, are passed through the sieves with 300 BSS openings (< 53µm) followed by appropriate digestion to extract water soluble heavy metal content[11].

The soluble heavy metals are extracted in beakers by 6 hours agitation of 1 gm sieved soil with 25mL milli-Q water on a magnetic stirrer. The extract is centrifuged, filtered through Whatman filter paper no. 42 and filtrates are acidified and made up with 1% HNO_3 in a 50mL polyethylene bottle.

Following digestion, Direct Air – Acetylene Flame method (Atomic Absorption Spectrophotometer - Shimadzu-6300) was used to determine the concentrations of 6 metals (Fe, Zn, Cu, Cd, Mg and Pb). Flame Photometer (Systronics -128) method was used to measure Ca metal concentration[10].

Results and discussion

The analysis of metals of both crustal and anthropogenic origin i.e. results of their distribution in top, middle and bottom layer while going down the vertical profile in soil along with soil pH has been carried out in winter, rainy and summer season of 2011-12 and the results have been evaluated with respect to meteorological observations and discussions based on general evidence related with this research. Statistical analysis (Pearson's correlation coefficient and factor analysis) has been performed.

Physico-Chemical Properties of Soil: Results of physico-chemical analysis of surface layer of soil from a selected sampling site of zone 1 (being closest to the point source) are shown in Table-2.

Table-2: Some physico-chemical characteristics of soil.

Soil properties	Values
pH	7.5
ECe (dSm^{-1})	0.67
Bulk density (mg mg^{-3})	1.35
Colour	Brownish-black
Sp-gravity	2.57
Type	Clay-clay loam
Sand (%)	25
Silt (%)	26.2
Clay (%)	48
CEC	46.01
O. C. (g/kg)	6.5

*The physico-chemical analysis of soil is performed by soil and water laboratory, Chambal Krishi Kendra, CAD, Nanta Farm, Kota (Raj.).

pH and Metal Analysis of Crustal and Anthropogenic Origin: Depth wise concentrations of studied metals in soil are presented in Tables-3 to 5.

Table-3: pH & concentration of crustal and anthropogenic metals (mg/L) in soil at five zones in Kota city collected during winter season.

Zone	Depth	pH	Ca	Mg	Fe	Pb	Zn	Cu	Cd
Zone 1 (n=60)	0-10 cm	6.78	89.24	3.9988	3.9665	0.5133	0.2866	0.2895	0.0149
	10-20 cm	7.09	87.76	3.9714	3.6625	0.5065	0.2932	0.2256	0.0101
	20-30 cm	7.14	80.12	3.9678	3.1125	0.4985	0.2843	0.2172	0.0099
Zone 2 (n=60)	0-10 cm	6.82	93.95	4.6872	4.5113	0.4881	0.1835	0.1216	0.0091
	10-20 cm	7.01	91.14	4.1511	4.2665	0.4369	0.1763	0.1176	0.0089
	20-30 cm	7.05	86.12	3.7892	4.1296	0.4412	0.1615	0.1014	0.0078
Zone 3 (n=60)	0-10 cm	6.80	98.76	4.7615	3.8926	0.1432	0.2866	0.2116	0.0096
	10-20 cm	7.07	94.56	4.2259	3.2132	0.1229	0.2983	0.2212	0.0092
	20-30 cm	7.12	82.39	4.1221	3.5299	0.1236	0.2777	0.1932	0.0089
Zone 4 (n=60)	0-10 cm	7.47	112.25	4.9256	4.7736	0.1663	0.1687	0.0273	0.0066
	10-20 cm	7.51	108.34	5.0921	4.6685	0.1516	0.1911	0.0211	0.0053
	20-30 cm	7.58	96.17	4.8113	4.1629	0.1425	0.1554	0.0232	0.0051
Zone 5 (n=60)	0-10 cm	8.27	144.99	5.2113	5.4336	0.0811	0.0998	0.0166	0.0046
	10-20 cm	8.32	131.68	5.2669	5.2325	0.0735	0.0992	0.0159	0.0039
	20-30 cm	8.38	100.14	5.1218	5.2191	0.0725	0.0993	0.0143	0.0035

*n = Number of samples.

Table-4: pH and concentrations of crustal and anthropogenic metals (mg/L) in soil at five zones in Kota city collected during rainy season.

Zone	Depth	pH	Ca	Mg	Fe	Pb	Zn	Cu	Cd
Zone 1 (n=60)	0-10 cm	6.69	74.12	3.8649	3.0056	0.4135	0.2956	0.2668	0.0101
	10-20 cm	6.99	96.15	5.4335	3.6638	0.5003	0.3115	0.2632	0.0102
	20-30 cm	7.06	98.27	5.4873	3.9925	0.4966	0.3005	0.2539	0.0112
Zone 2 (n=60)	0-10 cm	6.74	85.78	4.2652	3.4329	0.3876	0.1972	0.1176	0.0083
	10-20 cm	7.08	96.12	5.5538	3.9858	0.3938	0.2005	0.1258	0.0086
	20-30 cm	7.16	110.14	5.6218	4.4261	0.4226	0.2003	0.1429	0.0088
Zone 3 (n=60)	0-10 cm	6.76	98.22	4.0076	3.1132	0.1125	0.2563	0.2678	0.0092
	10-20 cm	7.07	119.14	4.5392	3.3394	0.1172	0.2596	0.2816	0.0093
	20-30 cm	7.14	125.46	4.8853	3.5625	0.1412	0.2638	0.3072	0.0095
Zone 4 (n=60)	0-10 cm	7.33	107.79	5.0662	4.3252	0.1296	0.2414	0.0213	0.0059
	10-20 cm	7.55	124.12	5.1925	4.6673	0.1336	0.2312	0.0261	0.0061
	20-30 cm	7.67	129.66	5.3378	4.7625	0.1557	0.2423	0.0288	0.0065
Zone 5 (n=60)	0-10 cm	7.97	109.28	5.4995	5.3392	0.0748	0.1023	0.0148	0.0039
	10-20 cm	7.99	146.11	5.7783	5.6652	0.0771	0.1128	0.0161	0.0041
	20-30 cm	8.11	151.85	5.9884	5.7728	0.0802	0.1216	0.0175	0.0046

*n = Number of samples.

Table-5: pH and concentrations of crustal and anthropogenic metals (mg/L) in soil at five zones in Kota city collected during summer season.

Zone	Depth	pH	Ca	Mg	Fe	Pb	Zn	Cu	Cd
Zone 1 (n=60)	0-10 cm	6.85	93.92	4.9835	4.0064	0.4335	0.3008	0.3125	0.0189
	10-20 cm	7.10	92.16	4.1326	3.8933	0.4229	0.2998	0.2863	0.0181
	20-30 cm	7.12	79.14	4.0063	3.5392	0.4431	0.2965	0.2688	0.0178
Zone 2 (n=60)	0-10 cm	6.91	96.65	5.1139	4.5629	0.4226	0.1935	0.1014	0.0089
	10-20 cm	7.16	92.56	4.8852	4.3885	0.4065	0.1866	0.1005	0.0079
	20-30 cm	7.15	89.32	4.5262	4.1335	0.3995	0.1625	0.0957	0.0082
Zone 3 (n=60)	0-10 cm	6.85	91.16	4.8826	3.8859	0.1416	0.2213	0.1298	0.0093
	10-20 cm	7.26	90.78	4.4253	3.8211	0.1148	0.2585	0.1178	0.0093
	20-30 cm	7.34	84.99	4.6626	3.5593	0.1003	0.2539	0.1109	0.0090
Zone 4 (n=60)	0-10 cm	7.43	109.59	5.2255	4.4225	0.1632	0.1946	0.0288	0.0063
	10-20 cm	7.66	105.68	5.3394	4.6652	0.1598	0.1632	0.0199	0.0048
	20-30 cm	7.68	98.66	4.8859	4.1186	0.1378	0.1284	0.0198	0.0045
Zone 5 (n=60)	0-10 cm	8.00	115.52	5.3665	5.4428	0.0614	0.1012	0.0148	0.0038
	10-20 cm	8.19	109.73	5.4326	5.1395	0.0621	0.1009	0.0157	0.0035
	20-30 cm	8.22	106.87	5.4293	5.1134	0.0619	0.0956	0.0142	0.0029

*n = Number of samples.

Down the soil profile, heavy metal concentrations vary depending on different soil properties and individual metal species. Deposition of heavy metals in vertical soil profile show a decrease with the depth owing to formation of some metal complexes with increase in pH. Average concentration of both crustal and anthropogenic metals during the winter & summer months (dry season) on the top soil is greater in comparison to rainy season. Metals from the top soil are washed out to some extent due to seasonal rains, dilution and other run-off during the wet season therefore their concentrations are found to be lowered in this season than that in dry season.

On comparing the concentration levels, crustal metals are found in higher concentrations than those of anthropogenic metals as they are abundant in nature being main structural ingredients of soil. The average concentration levels of crustal metals (Ca, Mg and Fe) are observed highest in Z_5 and lowest in Z_1 in winter, rainy and summer seasons. The activities in the residential areas of zone 5 might be responsible for the erosion and disturbance of upper layer of earth crust leading to higher concentrations of crustal elements while these activities are lower in Z_1 resulting in their reduced levels. A reverse trend of distribution is observed for anthropogenic metals (Cu, Cd, Zn and Pb) i.e. zone 1 is found to have highest average concentrations due to presence of coal based Thermal Power Plant over there, while zone 5, which is a residential area with lesser number of anthropogenic sources, is found to have the lowest concentrations.

In addition to these anthropogenic factors, meteorological parameters also seem to affect toxic metals concentration levels in soil of different zones. Wind blow in North and North-east direction carrying these metals through fly ash emission from KSTPS mainly towards Z_1, Z_2 and $Z_{3,}$ result in their higher atmospheric depositions on soil.

On looking at the seasonal difference of distribution pattern of anthropogenic metals in all the zones, heavy metal concentrations viz. Cu, Cd, Zn and Pb are greater in winter and less in summer. Meteorological factors are responsible for this different concentrations observed during two different seasons. During the sampling period in winter, Kota faces low average temperature, high relative humidity and low wind speed causing increased levels of anthropogenic metal species in ambient air while summers had high average temperature, low relative humidity and high average wind speed causing erosion and disturbance of upper layer of soil resulting in decreased concentration of these metal species as given in Table- 6.

Depth wise metal concentration in soil at zone 1, owing to its location (being closest to the point source hence facing highest pollution load), in different seasons have been shown in Figure 2 and 3 for crustal and anthropogenic metal species respectively. It is evident from Figure 2 (i and iii) and 3 (i and iii) that these metal species decrease down the soil profile in both winter and summer seasons. It is to be noted that, in rainy season, due to washout phenomenon of upper layer of soil, the concentrations level of crustal and toxic metals decreases drastically and we found a rise in these levels while going down vertically in soil profile depth of soil layers i.e. maximum in bottom layer as shown in Figure 2 (ii) and 3(ii).

Table-6: Meteorological conditions of Kota city.

Meteorological parameter	Winter	Summer
Temperature (^{0}C)	19.7 ± 3.7	30.7 ± 4.1
Humidity (RH) (%)	42.2 ± 5.4	20.0 ± 8.6
Wind speed (km/h)	2.0 ± 0.8	5.5 ± 3.1
Rain fall (mm)	10.0	10.0

Heavy metals toxicity in soil is also considered to be in relation with pH and chemical composition of soil. Clay minerals and oxides (inorganic colloidal fractions) have a significant role in metal remobilization in soil[8]. It is to be noted that the highest concentration level of toxic metals are found in upper most layer of soil followed by middle and bottom layer, respectively. Soil pH influences metal movement and distribution strongly with more mobile metals at lower pH (pH<7). Top soil of the investigated area has low average pH while it is observed high at lower horizon of soil, therefore, resulting in higher concentration at surface in comparison to bottom layer of soil where they are bound to soil possibly owing to hydroxides, carbonates and insoluble organic compounds formation, thereby decreasing their concentration levels. Our findings are supported by earlier studies where same trend of metal distribution is observed down the soil profile[12].

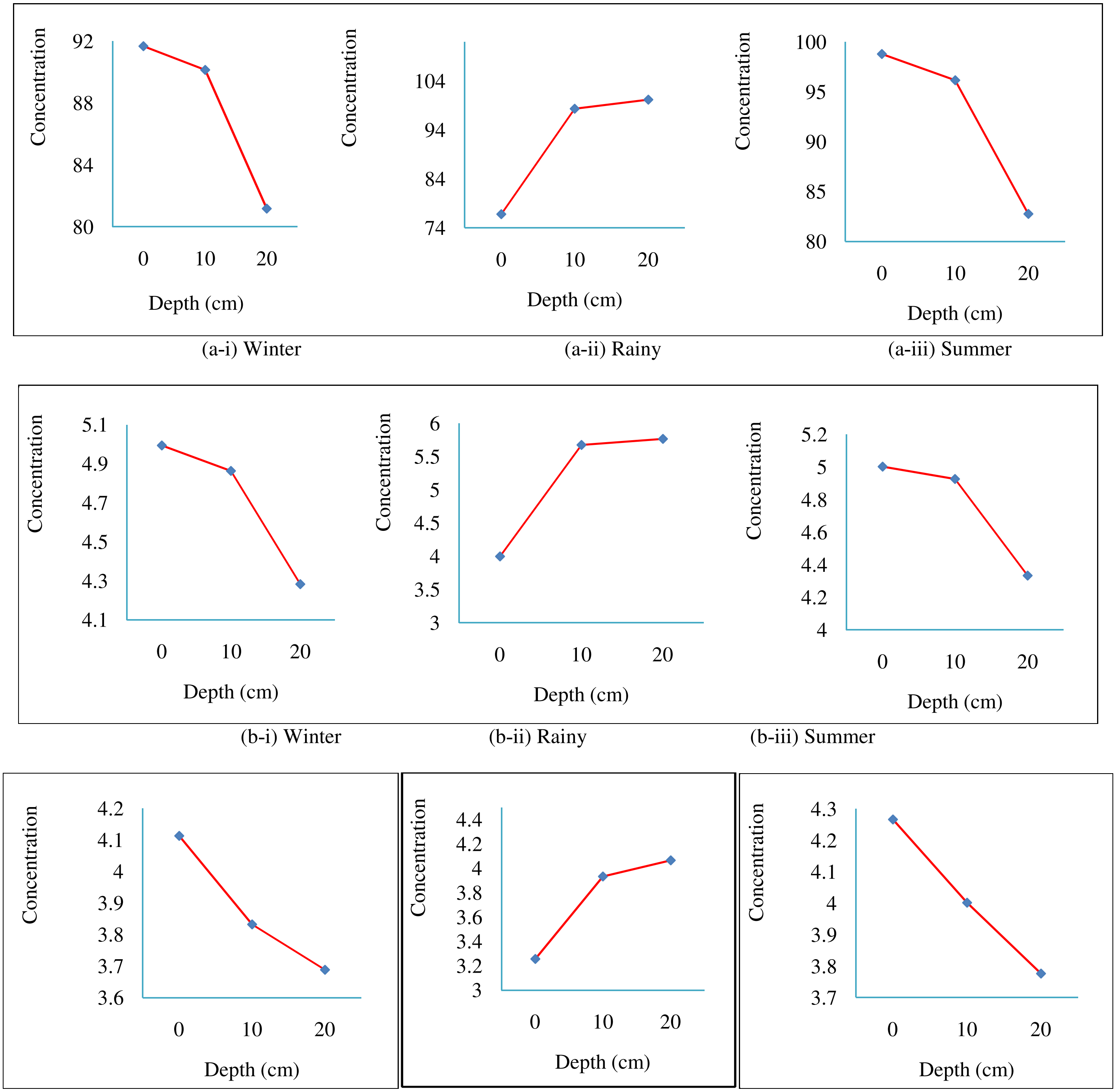
Thus, anthropogenic activities mainly fly ash emission from KSTPS along with vehicular emissions and other industrial activities, have a significant role in the increased pollution burden besides soil pH and meteorological factors.

Data Analysis: Correlation Analysis: In winter, rainy and summer seasons of study period, the extent of binding of elements to soil is evaluated using Pearson's correlation coefficient to find out any common source (Tables-7 to 9).

Significant positive correlations are found between Mg and Ca (r= 0.779); Mg and Fe (r= 0.767); Ca and Fe (r= 0.845) in winter season, respectively. For the rainy season following values are reported: for Mg and Ca (r= 0.601); Mg and Fe (r= 0.721); Ca and Fe (r= 0.697) respectively. Summer season witnessed following values: Mg and Ca (r= 0.850); Mg and Fe (r=0.804); Ca and Fe (r= 0.788) respectively. These significant positive correlations indicate that these metals have a common source, possibly natural soil.

Similarly, significant positive correlation are found between Cu and Cd (r= 0.819); Cu and Zn (r= 0.813); Cu and Pb (r= 0.626);

Cd and Zn (r= 0.783); Cd and Pb (r= 0.649); Zn and Pb (r= 0.526) in winter season, respectively. For the rainy season, following values are reported: for Cu and Cd (r= 0.814); Cu and Zn (r= 0.623); Cu and Pb (r= 0.526); Cd and Zn (r= 0.610); Cd and Pb (r= 0.531); Zn and Pb (r= 0.443) respectively. Summer season witnessed following values: Cu and Cd (r= 0.893); Cu and Zn (r= 0.774); Cu and Pb (r= 0.658); Cd and Zn (r= 0.786); Cd and Pb (r= 0.675); Zn and Pb (r= 0.495) respectively. These significant positive correlations indicate that these metals have a common origin i.e. point source KSTPS along with earlier vehicular emission dust beside other industrial activities.



(c-i) Winter (c-ii) Rainy (c-iii) Summer

Figure-2: Depth wise (cm) metal concentrations (mg/L) of soil in winter, rainy and summer season at a selected sampling site in zone 1 [(a = Ca metal); (b =Mg metal); (c = Fe metal)].

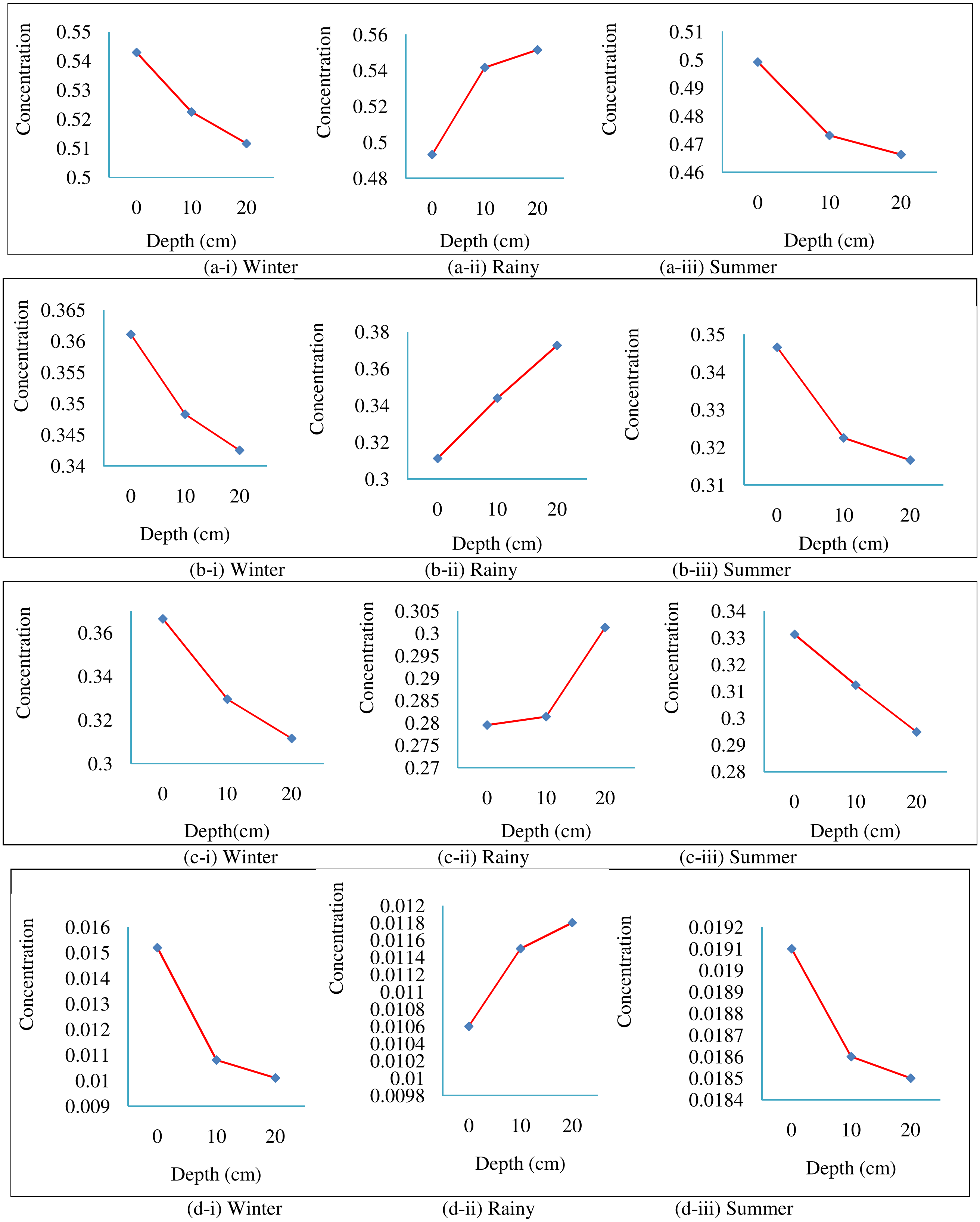


Figure-3: Depth wise (cm) metal concentrations (mg/L) of soil in winter, rainy and summer season at a selected sampling site in zone 1 [(a = Pb metal); (b =Zn metal); (c = Cu metal); (d = Cd metal)].

Table-7: Correlation coefficients between concentrations of assessed metals in surface soil in study area during winter season (*significant at 5% level).

Metal	Mg	Ca	Fe	Cu	Cd	Zn	Pb
Mg	1.000						
Ca	0.779*	1.000					
Fe	0.767*	0.845*	1.000				
Cu	-0.592	-0.533	-0.679	1.000			
Cd	-0.517	-0.626	-0.701	0.819*	1.000		
Zn	-0.586	-0.590	-0.659	0.813*	0.783*	1.000	
Pb	-0.445	-0.392	-0.371	0.626*	0.649*	0.526*	1.000

n=100

Table-8: Correlation coefficients between concentrations of assessed metals in surface soil in study area during rainy season (*significant at 5% level).

Metal	Mg	Ca	Fe	Cu	Cd	Zn	Pb
Mg	1.000						
Ca	0.601*	1.000					
Fe	0.721*	0.697*	1.000				
Cu	-0.439	-0.334	-0.581	1.000			
Cd	-0.404	-0.460	-0.603	0.814*	1.000		
Zn	-0.294	-0.309	-0.490	0.623*	0.610*	1.000	
Pb	-0.107	-0.532	-0.360	0.526*	0.531*	0.443*	1.000

n=100

Table-9: Correlation coefficients between concentrations of assessed metals in surface soil in study area during summer season (*significant at 5% level).

Metal	Mg	Ca	Fe	Cu	Cd	Zn	Pb
Mg	1.000						
Ca	0.850*	1.000					
Fe	0.804*	0.788*	1.000				
Cu	-0.591	-0.518	-0.561	1.000			
Cd	-0.576	-0.502	-0.570	0.893*	1.000		
Zn	-0.649	-0.560	-0.650	0.774*	0.786*	1.000	
Pb	-0.463	-0.448	-0.454	0.658*	0.675*	0.495*	1.000

n=100

Principal Component Analysis: Factor analysis (FA) derives a smaller number of new, synthetic variables called factors from numerous variables[13] which is performed on variables standardized to zero mean and unit of standard deviation[14]. The product-moment correlation coefficient (r) is applied as a measure of similarity between variables.

Principal component analysis (PCA) indicates that only two Eigen values are >1 explaining over 59.89%, 61.65% and 59.84% of variance in all winter, rainy and summer season respectively. PCA can effectively be used in understanding soil composition data[15,16]. The rotated component matrix displayed in Table 10 show that all the seven metals can be explained by two factors (varimax factors 1, 2).
The first factor (VF 1), explaining over 30.75%, 31.46% and 30.02% of variance in winter, rainy and summer, show high burden of Pb, Zn, Cu and Cd suggesting the impact of anthropogenic processes mainly coal combustion. VF 2 accounting for 29.14%, 30.19% and 29.82% of the layout variance in winter, rainy and summer indicate higher levels of Ca, Fe and Mg suggesting the influence of crust contribution.

The crustal metals are seldomely influenced by anthropogenic processes. Their sources are rock weathering and chemical processes mainly in soil and their distribution in all the three layers of soil is determined by lithology.

Conclusion

The distribution of heavy metals in topsoil in all the studied zones indicate their anthropogenic input through fly ash emission from KSTPS under the influence of prevalent wind direction and soil characteristics. It is evident that the average levels of all anthropogenic metals (Cu, Cd, Zn and Pb) are greatest in the zone situted in closer vicinity of point source KSTPS while distant zones lying in opposite direction of wind blow, having comparatively low traffic load faced less metal burden in both winter and summer seasons.

Seasonal difference in the deposition patterns of analysed metals in soil controlled by meteorological parameters can be seen. Anthropogenic metals are observed to be greater in winter and reduced in summer. It is to be noted that in rainy season, due to washout phenomenon of upper layer of soil, the concentrations level of crustal and toxic metals deposited on top soil decreases drastically.

The higher level of metals at top soil characterized with lower pH can be understood by their increased mobility which decreases on going down the soil profile due to complexation at higher pH found in clay rich bottom layer.
Source apportionment by PCA and positive correlations indicated a common origin for Cu, Cd, Zn and Pb and which is related to point source KSTPS along with other industrial processes and traffic burden. However, Ca, Mg and Fe have mostly crustal origin.

Thus, the analysis of heavy metals within soil profiles represents a significant environmental hazard. This contamination is an important concern for food safety and human health and shows a dire need for maintaining soil quality to check man induced soil contamination.

Table-10: Varimax rotation of PCA indicating seven variables with two independent varimax factors (VF) of soil in winter, rainy and summer season.

Variables	Component					
	Winter season		Rainy season		Summer season	
	VF 1	VF 2	VF 1	VF 2	VF 1	VF 2
Ca	-0.246	0.832	-0.218	0.802	-0.311	0.828
Mg	-0.232	0.841	-0.241	0.852	-0.265	0.865
Fe	-0.193	0.802	-0.258	0.815	-0.202	0.832
Pb	0.612	-0.212	0.623	-0.331	0.638	-0.248
Zn	0.689	-0.241	0.599	-0.297	0.676	-0.214
Cu	0.698	-0.207	0.655	-0.254	0.682	-0.229
Cd	0.741	-0.278	0.698	-0.278	0.705	-0.268
% of variance	30.75	29.14	31.46	30.19	30.02	29.82
Cumulative (%)	30.75	59.89	31.46	61.65	30.02	59.84

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