Research article **Available online www.ijsrr.org** **ISSN: 2279–0543**

International Journal of Scientific Research and Reviews

Heavy metal Contamination and Pollution Indices in Roadside soils of Ahmedabad, Gujarat

Snigdha Singh* and R. Hiranmai Yadav

School of Environment and Sustainable Development, Central University of Gujarat, Gandhinagar 382030, Email.: sngdhasingh@gmail.com

ABSTRACT:

In the present era, the concentration of heavy metals in the environment is increasing. Due to the deleterious effects of these metals on human health as well as their dangerous consequences on ecosystem it becomes a necessity to evaluate the concentration in the soil environment. Therefore, the contamination of HMs in soils is of increasing concern in urban environmental management. Based on the above background, the objectives of this study are to (a) evaluate the concentration and distribution of heavy metals in soils of Ahmedabad city, (b) and to determine the degree of soil contamination. The collected soil samples were processed as per standard procedures and analysed for the physicochemical properties and metals concentration. The soil pH indicates that the soil is alkaline in nature. The Zn and Mn content in the soil was more in the post monsoon season than in the pre monsoon at all the sampling sites. Cu and Fe content was found to be higher during the post monsoon than in the pre monsoon at S-2 and S-3 whereas it was low at the S-1 site. The results concluded that the soil samples have elevated concentration of the heavy metals in the wet season than the dry season which might be due to the mobilisation effect that tends metals to accumulate in the adjacent soils.

KEYWORDS: Heavy metals; Seasonal Variations; Soil; Soil contamination; Traffic emission

***Corresponding author:**

Snigdha Singh

School of Environment and Sustainable Development,

Central University of Gujarat,

Gandhinagar 382030,

Email.: sngdhasingh@gmail.com

INTRODUCTION

Urban soil contamination is a mounting concern for the potential health impact on the ever-increasing number of people living in these areas. Soils could be considered as the source and sink of a range of pollutants that can be accumulated over extensive periods of time[1]the adsorbed contaminants can be liberated to the environment due to the changes in soil physic-chemical properties.Heavy metals are the predominantly perilous ones amongst different types of environmental pollutants[2]and their contamination is of huge concern due to their tendency for bioaccumulation and noxious effects on plants, animals and human beings [3.]

With the rapid advancement of human civilization there has been a radical increase in the number of automobiles. The automobile emission turns out to be the primary source of heavy metals in the urban environment with the relocation of industrial areas from cities to sites where there is low density of population[4]. A range of detrimental pollutants like hydrocarbons and heavy metals are produced by the traffic sources into the urban atmosphere[5].

As urban traffic is incessantlygrowing, traffic generated atmospheric pollutant loads will impose an even greater impact on human and ecosystem health. Environmental pollution of heavy metals from road traffic emissions has attained much consideration in recent past due to their long term accumulation. These urban pollutants may be captured and attenuated in the soils[6]. Roadside environments are contaminated by heavy metals such as Pb, Cd, Cu and Zn released into the atmosphere during various operations of the road transport has been proved by a number of studies[7, 8, 9, 10]. A portion of the traffic generated pollutants is directly deposited on ground surfaces, whilst the remainder will initially accumulate in the atmosphere. Accumulation of heavy metals in roadside soil is of huge ecological apprehension since it can alter biological activities in the soil. The excessive accumulation of HMs in urban soils may lead to the deterioration of the soil ecosystem, threaten human health, and create other environmental problems. Therefore, the contamination of HMs in soils is of increasing concern in urban environmental management. Based on the above background, the objectives of this study are to (a) evaluate the concentration and distribution of heavy metals in soils of Ahmedabad city, (b) and to determine the degree of soil contamination.

MATERIALS AND METHODS

Description of the Study area

Ahmedabad lies at 23.03°N 72.58°E in western India at 53 metres (174 ft) above sea level on the banks of the Sabarmati River, in north-central Gujarat. It is the largest city of Gujarat. The estimated population of Ahmedabad in 2016 is over 7 million people in the city and approximately 8 million in the urban agglomeration[11]. This makes Ahmedabad the fifth largest city in India and the seventh largest metropolitan area. Ahmedabad has a hot, semi-arid climate.There are three main seasons: summer, monsoon and winter. Aside from the monsoon season, the climate is extremely dry.

Sample collection

The sampling locations were selected based on the traffic related activities. No industrial activities are conducted around the sampling sites. Land uses include business areas and residential areas. Thus, traffic emissions are almost the only pollution source of heavy metals in the area. Urban roads (UR) which are located within the urban area are selected for the study on the basis of traffic volume and congestion.

Roadside soil samples were collected from three sites (Heavy traffic area), medical centre, educational centre and roadways bus stand with high traffic congestions across the Ahmedabad city during March 2017 and September 2017. 15 Soil samples (three replicates) were collected at surface level (0–10 cm in depth) from various locations. Samples were collected using auger, transferred to zip lock bags and brought to the laboratory.

Sample preparation and analysis

In the laboratory, samples were air dried, homogenized and sieved through a 2 mm sieve to remove debris, gravel and other materials prior to analysis. Soil pH and electrical conductivity (EC) were measured in aqueous suspensions (1:2.5 weight/volume) through EC and pH meters, organic carbon was determined using standard procedures by Walkey& Black (1934)[12].Organic matter content in the soils was determined by multiplying the organic carbon content by 1.742. Heavy metals (Cu, Fe, Mn, Zn) were determined using Inductively Coupled Plasma Mass Spectroscopy (ICP-MS). To determine the total heavy metal content in the soil, 0.5 gm of the air dried sample was groundedand digested in the aqua-regia solution ($1HNO_3$:3HCL) on a hot plate for about 1 hour at 90 ^{0}C and then filtered through Whatman filter paper no. 42 maintaining 20 ml of the solution with distilled water.

Methods of assessment of contamination in soils

In this study, geoaccumulation index (I_{geo}), degree of contamination (C_d) and pollution load index (PLI) were calculatedto assess the heavy metal contamination levels in soils from the study area.

Geoaccumulation index (I_{geo})

The index of geoaccumulation (I_{geo}) is widely used in the assessment of contamination by comparingthe levels of heavy metals obtained to background levels originally used with bottom sediments[13,14].It is calculated using the equation:

$$Igeo = log2\left(\frac{Cn}{1.5Bn}\right)$$

Where

*C*n represents the measured concentration of the elements studied and *B*n is the geochemicalbackground value of the element in fossil argillaceous sediment (average shale)[15].The following classification is given for geoaccumulation index: <0 = practically unpolluted, 0–1 = unpolluted to moderately polluted, 1–2 = moderately polluted, 2–3 = moderately to stronglypolluted, 3–4 = strongly polluted, 4–5 = strongly to extremely polluted and > 5 = extremely polluted[16].

Degree of Contamination (C_d)

The Degree of contamination is defined as the sum of all the contamination factors(CF) of the various metals for a given sample. The value of contamination factors is calculated using the equation given by Hakanson (1980)[17].

$$CF = C^i_{measure} / C^i_{background}$$

Where $C^i_{measure}$= the measured concentration (mg/kg) of heavy metal i,

$C^i_{background}$= the background concentration (mg/kg) of heavy metal i.

A CF value of heavy metals > 1 indicates the accumulation and potential pollution of heavy metals in topsoil.

Pollution load index

The pollution index (PI) is defined as the ratio of element concentration in the study to the backgroundcontent of the abundance of chemical elements in the continental crust. PI and integratedPI are also commonly used to assess environments quality. PLI for the soilsamples was determined by the equation below, as proposed by Thomilson, et. al., 1980[18].

$$PLI = \sqrt{CF_1 \times CF_2 \times CF_3 \times CF_4 \times \ldots \ldots . \times CF_n}$$

The PI of each element is classified as either low (PI ≤ 1), middle (1 < PI ≤ 3) or high (PI > 3)[19].

Corelation analysis

Pearson correlation coefficients were calculated to quantify the relationship among the physic chemical properties and heavy metal concentrations.

RESULTS AND DISCUSSION

The physicochemical properties of the soil samples of various sites in Ahmedabad are shown in table.1. The soil pH and EC rangedfrom 7.72 to 8.37 and 0.35 to 0.45(μS/cm^3) respectively in different seasons at various sampling sites. There is a slight variation in the values of Organic carbon and organic matter as it ranges from 0.36 to 0.76 (%) and 0.61 to 1.30 (%) in the soil samples of both the seasons.

As shown in the table, the soil pH of the sites ranged from 7.72 to 8.34 i.e., alkaline in nature. pH were not significantly variable from one season to another. Organic content of the soil samples was greater in the wet season than the dry season. Organic content has an important role in the soil structure, cation exchange and in the formation of complexes

Figure 2 shows the amount of potentially toxic contentin the soil samples of various sampling sites in Ahmedabad city. Zn, Fe, Mn and Cu content in the soil in both the seasons ranges from 79.32 ppm to 226.32 ppm for Zn in pre monsoon whereas 44.12 ppm to180 ppm in post monsoon,138.16 ppm to 4776 ppmfor Fe in pre monsoon whereas 36.04 ppm in post monsoon, 399 ppmto 509.6 ppmfor Mn in pre monsoon whereas 419.2 ppm to585.2 ppm in post monsoonand 5.32 ppm to 36.04 ppmfor Cu in pre monsoon whereas 5.64 ppm to18.64 ppm in post monsoon respectively.

Fig. 2 shows the heavy metal contents in the soils samples collected from various sites during both the seasons. The Zn and Mn content in the soil was more in the monsoon season than in the pre monsoon at all the sampling sites. Cu and Fe content was found to be higher during the monsoon season than in the pre monsoon at Geeta Mandir area and L D college area of Ahmedabad whereas it was low at the civil hospital site.

The heavy metal content at various sampling sites was shown in table 1. The higher concentration of the metals in the wet season might be due to the run off effect which may facilitate the deposition of the metals in the roadside soil. Roadside soils consistently had greater metal content for all metals than those farther away[20].Copper is also one of the major heavy metal considered as an environmental pollutant. Copper is a micronutrient but toxic when it is in excess concentration. The source of copper being due to corrosion of metallic parts of cars derived from engine wear, brushing and bearing metals[21].

The concentration of Zn and Cu are significantly higher in relation to other elements among the sampling sites. The main source of Zn on the roadside is because of automobile traffic i.e., break lining loses of oil and cooling liquid[22].Relatively higher values of cadmium and zinc concentrations in the analyzed soil samples reflect a possible anthropogenic effect that may be due to agricultural activities and fossil fuel burning. The soil lying at the vicinity of highways may have a cadmium content ranging from 1 to 10 ppm[23]. This may explain the relatively high concentrations of Cd and

Zn in the soils of the study area. Since no major industry exists in the study areas such as smelting operations, we may assume that the primary sources of Zn are probably the attrition of motor vehicle tire rubber exacerbated by poor road surfaces, and the lubricating oils in which Zn is found as part of many additives such as zinc dithiophosphates[24].Cu and Zn are essential plant micronutrients. They can also bind to soil organic matter and become unavailable to plants.

High content of Fe is usually found in the tire linings and in the dust coming from brakes and engines[25]. The main processes through which vehicles spread heavy metals (Pb, Zn, Cu, Cd, Ni) into the environment are combustion processes, the wear of automobiles (tires, brakes, engine), leaking of oil and corrosion.

A strong correlation between Cu and Zn ($r = 0.87$) was observed, which suggested that Cu and Zn derived from the same sources such as brake linings. The significant level of automotive Pb and Fe is evident despite the introduction of unleaded petrol since 2000 in China. Some studies have shown that Cu, Zn and Pb were associated in soils of urban highways[26].Zn may result from tire abrasion and lubricating oils. Brake linings are one of the main sources of Cu. The average value of Zn/Cu ratio was 3.01, which has been reported for other highways[27].

Table 3 shows the degree of contamination and the PLI of the potentially toxic elements in the soil samples. From the results, as the degree of contamination lies in the range of 1.18 to 3.10 in the pre-monsoon as well as post-monsoon, it can be concluded that the soil is low to moderately contaminated.

Corelation analysis

Information about the metal sources and their pathways are generally inferred from the inter-element relationships[28]. Pearson correlation coefficient matrixes data (with significant r values $\geq \pm 0.40$ at $p < 0.05$) for the present study is presented in Table 2.

It has been reported that pH of the soil controls the availability of metals as pH decreases solubility of metal complexes increases[29]. We found a negative correlation between Zn, Fe and Mn with pH as shown in Table 2.

It is inferred from the table that highly significant positive correlation between the pairs of heavy metals in the soils along the roadside samples occurred as follows- Mn with Fe ($r=0.97$), Zn with EC ($r=0.66$) and Cu with pH ($r = 0.62$).

CONCLUSION

The present study was carried out to assess the concentration level of various heavy metals in the roadside soil at various sites in Ahmedabad city. From this work it can be concluded that the soil samples have elevated concentration of the heavy metals in the wet season than in the dry season which might be due to the run off effect that tends metals to accumulate in the adjacent soils. Results from the study showed that Zn, Cu, Mn and Fe were the most abundant elements especially in the topsoil. Generally the concentration of these metals in the roadside environment increases with increasing traffic volumes and also in urban areas. The pattern of total metal concentrations in the roadside soils followed Zn>Mn>Cu>Fe.

The study would therefore provide significant information for readdressing environmental pollution due to anthropogenic activities.

REFERENCES

1. Mohammed LB, Abdelaziz B, Youcef H, &Mohd. Hadjel. Human Health Risks Associated with Metals from Urban Soil and Road Dust in an Oilfield Area of South eastern Algeria. Arch Environ ContamToxicol., 2015;70(3): 556-571.
2. Yong Y, Yang HL,Liu H, &Xu Q. Exogenous glycinebetaine alleviates the detrimental effect of Cd stress on perennial ryegrass.Ecotoxicology. 2015;24(6): 1330-1340.
3. Cai, L, Xu Z, Ren M, Guo Q, Hu X, Hu G,Wan H,&Peng P.Source identification of eight hazardous heavy metals in agricultural soils of Huizhou, Guangdong Province, China.Ecotox Environ Safe,2012; 78: 2–8.
4. Peng, C, Wang M, Chen W, Chang A, &Crittenden CJ. Mass balance-based regression modeling of Cd and Zn accumulation in urban soils of Beijing. J. Environ. Sci.,2017; 53: 99–106.
5. Mahbub P., Goonetilleke A., Godwin A. Ayoko P, Egodawatta & Yigitcanlar T. Analysis of build-up of heavy metals and volatile organics on urban roads in Gold Coast, Australia.Wat. Sci. and Tech.,2011;63(9): 2077-2085.
6. Wang M, Chen W, Markert B, Peng C,& Ouyang Z. A GIS technology based potential eco-risk assessment of metals in urban soils in Beijing, China. Environ. Pollut.;2012;161:235–242.
7. Zhang F, XuedongY, Chen Z, Zhang M, Shrestha S, Devkota LP, & YaoT. Influence of Traffic Activity on Heavy Metal Concentrations of Roadside Farmland Soil in Mountainous Areas. Int. J. Environ. Res. Public Health.2012; 9: 1715-1731.
8. Sharma S, &PrasadeFM. Accumulation of Lead and Cadmium in Soil and Vegetable Crops along Major Highways in Agra (India). J. Chem.2010; 7(4):1174-1183.
9. Atayese MO, Eigbadon AI, Oluwa KA, & Adesodun JK. Heavy metal contamination of Amaranthus grown along major highways in Lagos. African Crop Science Journal,2009; 16:225-235.

10. Akbar KF, HaleWHG, HeadleyAD,& AtharM. Heavy metal contamination of roadside soils of northern England. Soil Water Res.2006; 4: 158–163
11. http://worldpopulationreview.com/world-cities/ahmedabad/
12. Walkley A,&Black IA. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 1934; 37: 29-37.
13. Sampson AtiemoM, Francis Ofosu G, Kuranchie-Mensah H, Tutu AO, Linda Palm NDM, & Blankson SA. Contamination Assessment of Heavy Metals in Road Dust from Selected Roads in Accra, Ghana.Res. J. of Environ. and Earth Sci. 2011; 3(5): 473-480,
14. Muller G. Index of geoaccumulation in sediments of the Rhine River. Geo Journal1969; 2: 108–118.
15. Taylor SR, &McLennanSM. The Continental Crust:Its composition and evolution, Blackwell, Malden, Mass.1985.
16. Lu X, WangL, LeiK, Huang J, & Zhai Y. Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China. J. Hazardous Mat.,2009;161: 1058-1062.
17. Hakanson L. An ecological risk index for aquatic pollution control: A sediment-ecological approach. Water Research1980;14: 975–1001.
18. Thomilson DC, Wilson DJ, Harris CR, & JeffreyDW. Problem in heavy metals in estuaries and the formation of pollution index. HelgolWissMeeresunlter.1980;33(1–4):566–575
19. Chen TB, Zheng YM, Lei M, Huang ZC, Wu HT, Chen H, Fan KK, Yu K, Wu X, &Tian QZ. Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China. Chemosphere. 2005;60: 542–551
20. Amjadian K, Sacchi E, & Mehr MR. Heavy metals (HMs) and polycyclic aromatic hydrocarbons (PAHs) in soils of different land uses in Erbil metropolis, Kurdistan Region, Iraq. Environ Monit Assess 2016; 188:605
21. Guagliardi I, Cicchella D, &Rosa RD. A geostatistical Approach to assess Concentration and Spatial distribution of heavy metals in urban soil .Water Air Soil Pollut.,2012; 223:5983–5998
22. Plyaskina OV, & Ladonin DV. Heavy Metal Pollution of Urban Soils. Eurasian Soil Sci.,2009; 42(7):816–823
23. Li X,&Feng L. Multivariate and geostatistical analyzes of metals in urban soil of Weinan industrial areas, Northwest of China. Atmos. Environ. 2012; 47: 58–65.

24. Yang Z, Lu W, Long Y, Bao X, &Yang Q. Assessment of heavy metals contamination in urban topsoil from Changchun City, China. J. Geochem. Explor.,2011; 108: 27–38.
25. Joshi SR, Kumar R, Bhagobaty RK, & Thokchom S. Impact of pollution on microbial activities in sub-tropical forest soil of north east India. Res J. Environ Sci. 2010; 4(3): 280–287.
26. Al-Khashman OA. Determination of metal accumulation in deposited street dusts in Amman, Jordan. Environ Geochem Health. 2007; 29:1–10
27. Saeedi M, Hosseinzadeh M, Jamshidi A, & Pajooheshfar S. Assessment of heavy metals contamination and leaching characteristics in highway side soils, Iran. Environ. Monit. Assess.2009; 151(1-4), 231-241.
28. Kabata-Pendias A, & Pendias H, Biogeochemistry of Trace Elements (in Polish). PWN Warszawa, 1984; 397.
29. Bai J, Cui B, Wang Q, Gao H, &Ding Q. Assessment of heavy metal contamination of roadside soils in Southwest China. Stoch. Environ. Res. Risk Ass.2008; 23(3):341-347.
30. Trujillo-González JM, Torres-Mora MA, Keesstra S, Brevik EC,& Jiménez-Ballesta R. Heavy metal accumulation related to population density in road dust samples taken from urban sites under different land uses. Sci Total Environ. 2016; 553:636–642.
31. Horstmeyer N, Huber M, Drewes JE, & Helmreich B. Evaluation of site-specific factors influencing heavy metal contents in the topsoil of vegetated infiltration swales. Sci Total Environ. 2016; 560-561, 19-28.
32. Huber M, Welker A, & Helmreich B.Critical review of heavy metal pollution of traffic area runoff: Occurrence, influencing factors, and partitioning. Sci Total Environ,2016; 541:895-919.
33. Turekian KK, & Wedepohl KH. Distribution of the Elements in Some Major Units of the Earth's Crust. Geol. Soc. Am. Bull.,1961;72(2): 175-192.
34. Zhang XY, Lin FF, Wong MTF, Feng XL,&Wang K. Identification of soil heavy metal sources from anthropogenic activities and pollution assessment of Fuyang County, China. Environ. Monit. Assess.,2009; 154:439–449.
35. Ebrahimpour M, & Mushrifah I. Heavy metal concentrations in water and sediments in Tasik Chini, a freshwater lake, Malaysia. Environ. Monit. Assess.,2008;141(1):297□307.

3.0 Tables and figures

Table 1: Description of sampling sites

Site No	Sampling sites	Site code	Description of the sampling sites
1	Civil hospital	S-1	Government hospital area
2	Geeta mandir	S-2	City Bus stand, heavy and congested traffic
3	L D college	S-3	Educational institutions, local market area, heavy traffic

Table 2: Physico-chemical properties and potentially toxic element content of the soil samples from different sampling sites in Ahmedabad

Parameters	Pre Monsoon			Post Monsoon		
	S-1	**S-2**	**S-3**	**S-1**	**S-2**	**S-3**
pH	8.37	8.22	7.72	8.34	8.20	7.98
EC (μS/cm^3)	0.45	0.35	0.42	0.38	0.41	0.43
Organic Carbon (%)	0.41	0.36	0.59	0.76	0.52	0.73
Organic Matter	0.70	0.61	1.01	1.30	0.89	1.25
Zn (ppm)	90.32	79.32	226.32	150.12	44.12	180
Fe (ppm)	4776	361.48	138.16	405.2	1728	3.52
Mn (ppm)	509.6	399	468.4	513.2	419.2	585.2
Cu (ppm)	36.04	5.32	7.8	18.64	8.36	5.64

Table 3: Selected potentially toxic metals Concentration in Ahmedabad soil compared with Selected Cities in the world

City	Contents	As	Cd	Cr	Cu	Fe	Pb	Zn	Reference
Ahmedabad (India)	mean	ND	-	-	13.63	1235.39	-	128.37	Present study
Erbil (Iraq)	mean	5.68	1.03	39.61	113.59	2.32	140.67	262.8	Amjadian et. al., (2016)
Cosenza-Rende (Italy)	mean	7.48	0.4	90.54	44.36	5.47	63.67	166.73	Guagliardi et. al., (2012)
Moscow (Russia)	mean	ND	2	79	59	ND	37	208	Plyaskina & Ladonin (2009)
Weinan (China)	mean	8.49	ND	96.99	20.88	ND	46.71	71.56	Li and Feng (2012)
Changchun (China)	mean	12.5	0.132	66	29.4	ND	35.4	90	Yang et. al., (2011)

Table 4: Contamination factor and PLI of the potentially toxic metals

Sites	Pre monsoon						Post monsoon					
	Zn	Fe	Mn	Cu	C_d	PLI	Zn	Fe	Mn	Cu	C_d	PLI
S-1	0.95	0.10	0.60	0.80	2.45	0.21	1.58	0.01	0.60	0.41	2.60	0.06
S-2	0.83	0.01	0.47	0.12	1.43	0.04	0.46	0.04	0.49	0.19	1.18	0.04
S-3	2.38	0.00	0.55	0.17	3.10	0.47	1.89	0.00	0.69	0.13	2.71	0.41

***Background values of Zn=95,Fe=47200,Mn=850 and Cu=45 (**Turekian, and Wedepohl, 1961)

Table 5: Correlation coefficient between concentrations of metals and physicochemical properties at the 3 sampling sites

	pH	EC	OC	OM	Zn	Fe	Mn	Cu
pH	1.00							
EC	-0.20	1.00						
OC	-0.26	0.13	1.00					
OM	-0.26	0.13	1.00	1.00				
Zn	-0.45	**0.66**	0.30	0.30	1.00			
Fe	-0.69	-0.15	-0.06	-0.06	0.38	1.00		
Mn	-0.73	-0.20	-0.09	-0.09	0.21	**0.97**	1.00	
Cu	**0.62**	0.40	-0.37	-0.37	0.25	-0.21	-0.34	1.00

Figures

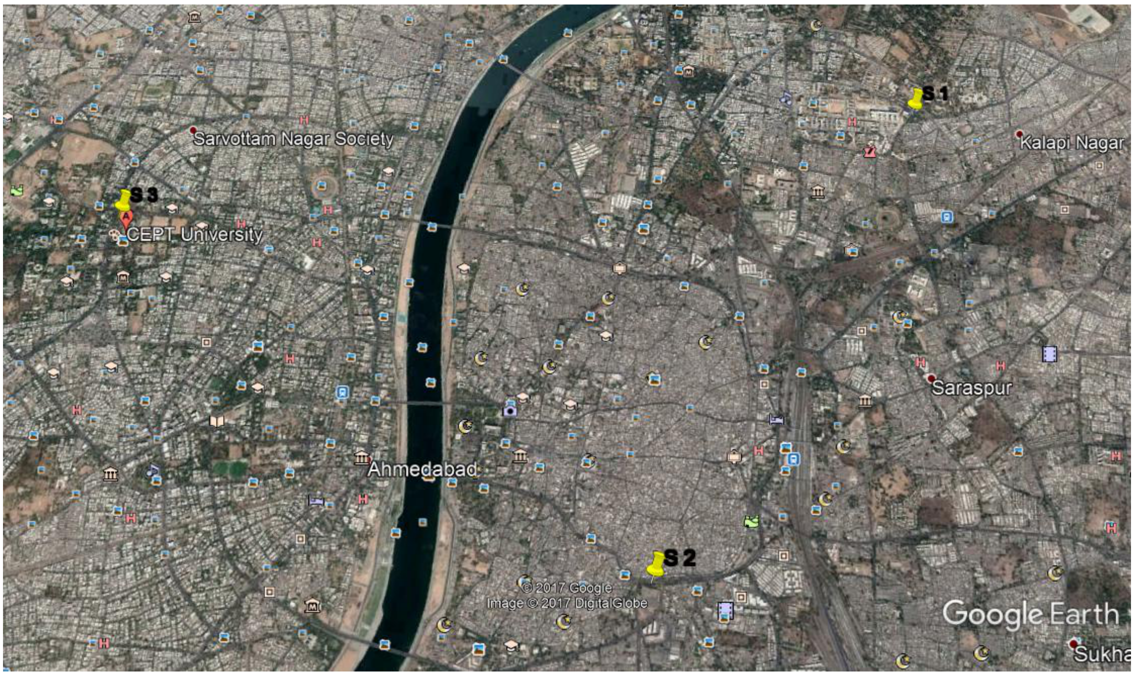

Fig 1: Map showing the different sampling sites in Ahmedabad City

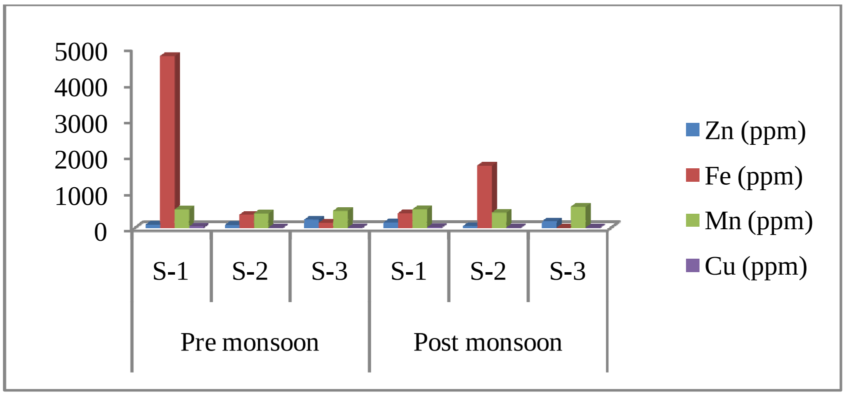

Fig 2: Potentially toxic element content of the soil samples from different sampling sites in Ahmedabad

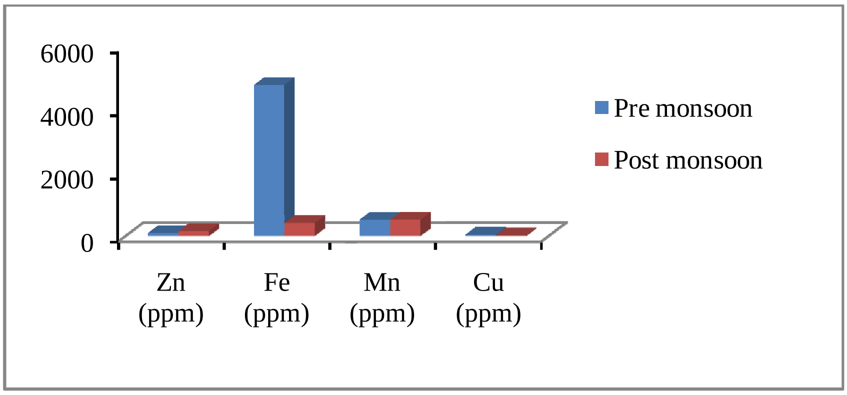

Fig 3: Potentially toxic element contentin Civil hospital area of Ahmedabad during two different seasons

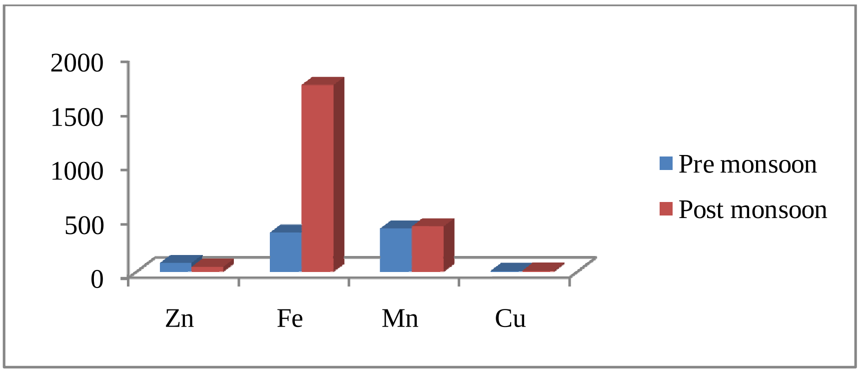

Fig 4: Potentially toxic element contentin Geeta Mandir area of Ahmedabad during two different seasons

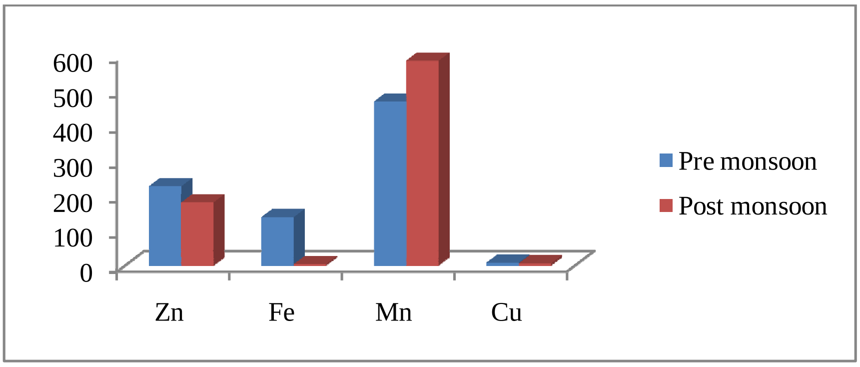

Fig 5: Potentially toxic element contentin L D college area of Ahmedabad during two different seasons

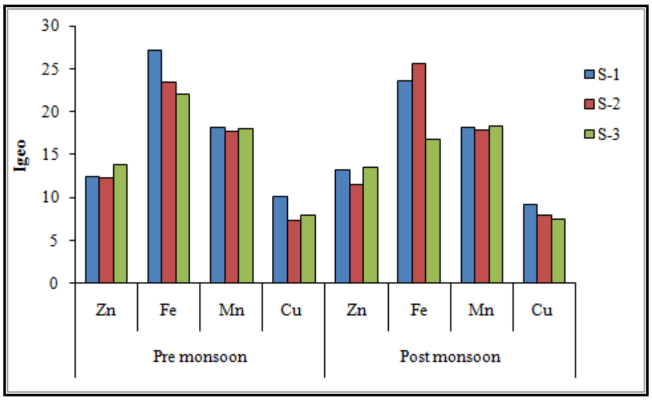

Fig 6: Igeo content of soil samples from different sampling sites in Ahmedabad in two different seasons