

## GEO- SPATIAL APPLICATION TO ASSESS THE IMPACT OF LAND USE/LAND COVER ON HEAVY METAL CONTAMINATION IN THE SURFACE SOIL OF WESTERN ASSAM, INDIA

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**Abstract:** *Remote sensing techniques along with Geographic Information System (GIS) are an important tool to assess the health, monitoring and management of soil resources by providing a synoptic view of the area. The integrated study of geospatial technology and conventional lab analysis of soil samples provide a holistic view of the existing health of the surface soil. Any type of change in land use pattern directly or indirectly affects the natural resources of the area. To assess the change in soil health in term of the chemical contamination of heavy metals in surface soil, a integrated study of geospatial technology and chemical analysis of soil sample have been conducted in this study. A Land use Land cover (LULC) layer have been generated through 23.5 meter resolution LISS III dataset and 28 soil samples have been collected from different land use features from the selected area and chemical analysis were performed. The result obtained through this study indicated that chemical properties of soil are largely affected by landuse pattern. Some of the soil samples are affected by Pb, Cr, and Zn contamination due to vehicular pollution, agricultural fertilisers, agricultural pesticides and change in land use pattern.*

**Key words:** GIS, LULC, Heavy metal

### Introduction

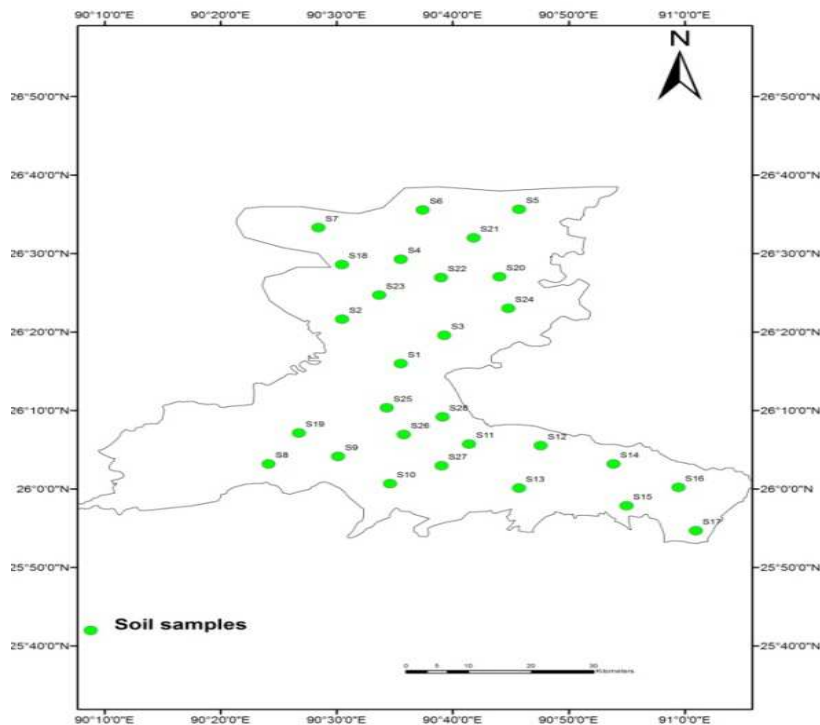
The characteristics of soil depend upon the parent material, regional climate, topography, biotic potential, and the passage of time. The soil is the cumulative results of lithology, weathering experienced by the source area and subsequent changes during transportation and deposition of soil. From the past few decades, much attention has been drawn towards the heavy metal contamination (Kanmani and Gandhimathi, 2013). The Heavy metals like iron, zinc, manganese, and copper are essential at low levels and are beneficial to plants, but if present above certain level they may be toxic to them, while metals like cadmium, chromium, lead and arsenic are toxic and may cause a great harm to plants, animals and humans through the food chain (Costa, 2000). Heavy metals in soil may be present in dissolved or exchangeable forms as structural components of the lattices or insolubly precipitated (Zalidis et al., 1999, Aydinalp and Marinova, 2003) but only dissolved and exchangeable forms of metals can be utilized by plants (Peijnenburg and Jager, 2003), if heavy metal present in inert form, are not harmful even though they are present in high concentration, but they can become mobile as a result of change in land use, agricultural input or climate change and it may affect the soil quality (Stigliani, 1993). Soil may be subjected to number of pollutants and simultaneously they can also be a source of pollution to surface and ground water because of anthropogenic activities such as mining or industrial activities, chemical fertilizers, pesticides industrial effluents, sewage sludge and wastewater irrigation is a matter of concern in agricultural production (Ramadan and Alashkar, 2007; Kuo et al., 2006). The mobility and availability of heavy metals are controlled by adsorption and desorption characteristics of soil (Krishnamurti et al., 1999) which in turn are controlled by many factors like pH, organic matter content, cation exchange capacity, contents of clay minerals and soil texture (Usman et al., 2008). The speciation and solubility of metal in the soil is depending upon the soil pH (Zhao et al., 2010). Organic matter content affects the heavy metal availability by retaining them in an exchangeable form. The dissolved organic matter in soil can increase the mobility and uptake of heavy metals to plant roots (Du Laing et al., 2009). Soil

textural composition controls the soil water availability and the activity of soil organisms by affecting the pore size distribution and pore continuity (Hassink et al., 1993 a). Soil organic matter comprises of partly disintegrated and decomposed plant and animal residues which helps in maintaining the soil structure, retaining water and act as an nutrient reserve and chemical buffer (Ling at et al., 2005). The assessment of metal content in an area is of vital importance and it can be assessed using geo-accumulation index, enrichment factor. This indicator reflects the type and level of chemical contamination in the soil. The objectives of this study are to assess the impact of land use land cover on the surface soil physical and chemical properties.

### Study area

The selected study area covers Goalpara and Bongaigaoun district of Assam (Fig.1). The district Goalpara is situated on the Southern bank of river Brahmaputra and covers an area of 1,842 sq. km. and is located between 25°53' N & 90°07' E and 26°15'N & 91°05' E. The district Bongaigaoun is situated on the northern bank of river Brahmaputra, adjacent to Goalpara district covering an area about 1725 sq. km. and is located between 26°30' N and 90°23' E and 26°10' N and 90° 52' E. The geological formation in the area is the Archean group of rock comprising Biotite Hornblend gneiss, granulites, and schists. The major part of the area is lying under younger alluvial plain which consists of gravel, pebbles, sand, silt and clay while older alluvium is compact and contains limonitic clay, unsorted boulders, pebbles, gravel and sand. (GSI report 2009). The annual average rainfall of the state varies between 160 cm and 430 cm from place to place. The average temperature varies from 4° C to 19° C during winter and 26° C to 37° C during the summer. Rain makes its first appearance in the month of April with occasional and irregular light showers. Southwest tropical monsoon has dominant influence on the Assam from April to October with occasional winter showers.

**Figure 01 : Soil Sampling points**



### Materials and Method

#### (a) Sampling and Chemical analysis

Soil samples (n= 28) were collected from different types of landuse / landcover, features using hand auger from a depth ranging up to 20 cm and were stored in polypropylene bags in December 2014. All these soil samples, after being brought to the laboratory, were kept at 4°C. The moisture content of the soil was calculated in the lab. In an oven dried and pre weighed petridish (W1), 10.01 g of fresh soil (W2) was added and dried in an oven at 120°C until a

constant weight was attained (W3). The moisture content was then calculated by using below formula

$$\text{Moisture Content (\%)} = [(W2 - W3) / (W2 - W1)] \times 100$$

For measurement of the soil pH and electric conductivity, soil solution was prepared by adding 50 ml of water in 20 g of soil. The mixture was stirred for 10 min and after 30 min it was again stirred for 2 min. pH of the supernatant was measured immediately with the help of pH probe. The mixture was then left for one hour to settle. Then, the conductivity of the supernatant was measured with the help of conductivity meter. Preparation of the samples for textural analysis involved the following steps: (1) Taking 50-100 gm of the uniformly powdered sample, removing carbonates by adding 1N HCl with stirring and rim washing, followed by decanting the HCl. (2) Removing organic matter by adding 6% to 30% H<sub>2</sub>O<sub>2</sub>, stirring and rim washing. (3) Adding distilled water and heating on the oven for 12 hrs at 40°C. (4) Removing Iron oxide by adding distilled water, aluminium foil and 15gm oxalic acid with stirrer and heating in an oven for 25-30 minutes followed by decanting excess clear water. (5) Drying and Weighing. The particle size analysis of soil helps in the estimation of sand, silt and clay percentage in soil content. Based on the proportions of different particle sizes, a soil textural category may be assigned to the sample. The particles having diameter of (2.00-0.05mm) comes under sand, (0.05-0.002 mm) under silt and (< 0.002 mm) under clay. X-ray diffraction study of soil was done for mineral identification. Slides were subjected to XRD in which a monochromatic beam of X-ray is passed through a mineral grain. The beam is scattered by the atoms which compose the minerals and at specific angles of incidence, the scattered X-ray is in phase producing an intensified secondary beam. The general relationship is expressed by the Bragg equation

$$n \lambda = 2 d \sin \theta$$

Data was stored in the .xrdml, .dat and .udf format. The results were analyzed using X'Pert PRO software. Soil samples were analyzed using Wavelength Dispersive X-Ray fluorescence (WDXRF) (Pan Analytical) to identify their multi-element chemical composition. X-Ray Fluorescence (XRF) spectrometry is an analytical technique to do a qualitative and quantitative analysis of elemental composition by excitation of atoms and detection of their characteristic X-rays. The elemental range for WD-XRF goes from Beryllium to Uranium (Be to U). For XRF analysis, in 2 gm of dried soil (size < 63µ) 0.2 gm of boric acid powder was mixed in mortar and pestle. Then pellets were prepared by pressing the samples for one minute at 12 tons of pressure in a semi-autonomous press (In smart system). After making the pellets samples were analyzed in WD-XRF.

### **LULC map generation**

The landuse land cover (LULC) map of the area was prepared at GIS platform through visual interpretation of satellite data (LISS-III) having a 23.5meter spatial resolution. The features have been identified on the basis of the tone, shape, size pattern on the satellite data.

## **RESULTS AND DISCUSSION**

### **pH and EC**

The heavy metals equilibrium, solubility and their adsorption to colloids are affected by soil pH (Sommers and Lindsay, 1979; Brady, 2002). All the soil samples are acidic in nature (Table 1) and range from 4.5 to 6.1. The acidity of soil may be due to its geographical locations which receive the major part of the Indian monsoon from the month of April to end of September. The rapid weathering and intense leaching under high rainfall condition augmented the development of soil acidity (Brady, 2002). The study area covered with healthy vegetation and open forest due to rich vegetation, soils richer in organic matter which forms complexes with non-nutrient cation such as Ca and Mg and facilitates the loss of these cations by leaching. Soil acidity creates the agricultural problem leading to toxicity of iron and aluminium and also affects the microbial activities in soil (Reza et al., 2012). The electrical conductivity of soil samples ranges between 500 to 3500 µs/cm which are under the permissible limit.

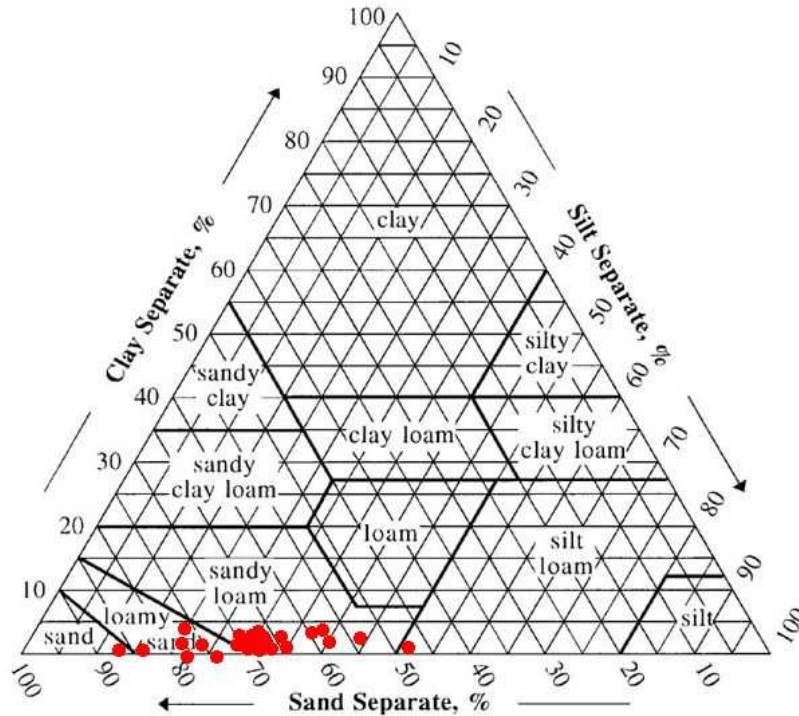
## Soil Texture

Particle size alters the soil moisture and metal holding capacity of soil. The soil moisture in the area is generally higher and its maximum value is 25.8% and a minimum value of 12.1 %. (Table1). The higher soil moisture in the area is due to high rainfall and several small and large rivers draining the area. Out of 28 soil samples, 32 % samples are loamy coarse sand, 46.4% coarse sandy loam, 10.7% sandy loam, and sample (S23) was sandy loam, (S13) was silt loam, (S21) was loamy sand (Fig 2). As compared to loam, sand particles have the lower water holding capacity and higher free drainage of water (Brady, 2002). The size of particles also determines the chemistry of soil; the clay silt fraction (<63  $\mu\text{m}$ ) are mostly involved in physicochemical sorption reaction in soil due to the high specific area (Hart, 1982; Maher et al., 1999; Haque and Subramanian, 1982).The mineralogical composition of the sediment and soil samples of the area is reflected by the geological and mineralogical formation of the study area. The mineralogical study of soil samples of the area reveals that the samples are constituted of quartz, calcite, haematite, fluorite minerals (Fig 3). Hematite acts as the source of Iron in the samples while calcite and fluorite act as the source of calcium and fluoride in the samples respectively.

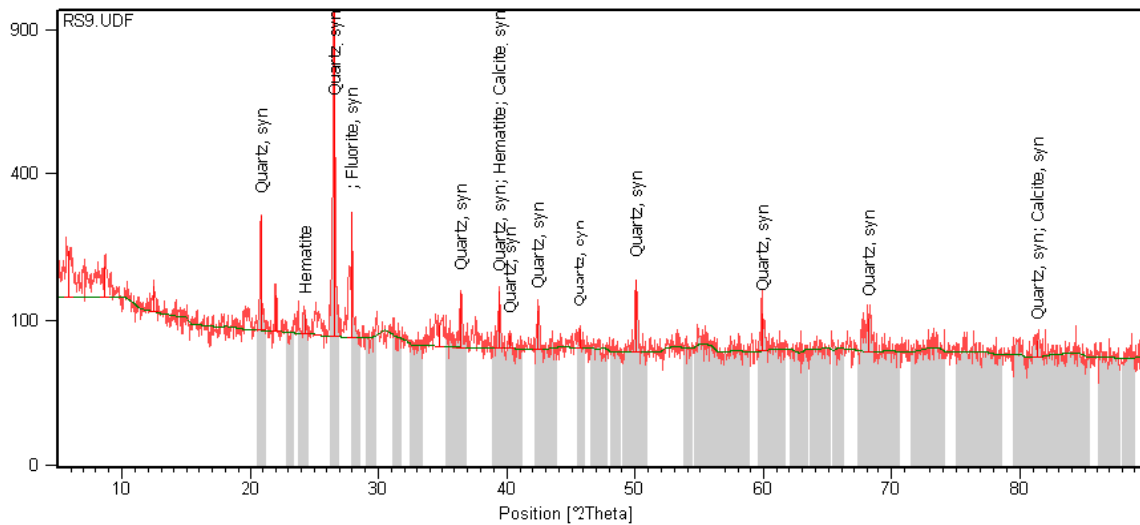
**Table 01: Physical Parameters of Soil Samples**

Samples	Ph	EC ( $\mu\text{s}/\text{cm}$ )	% Moisture	Soil Texture
S1	5.4	1600	16.5	Loamy Course Sand
S2	5.1	1200	13.1	Sand
S3	6.1	700	17.9	Sandy Loam
S4	5.3	1000	15.0	Course Sandy Loam
S5	5.0	600	18.0	Loamy Course Sand
S6	4.6	3700	14.0	Loamy Course Sand
S7	5.1	400	13.5	Loamy Course Sand
S8	4.6	2700	15.8	Course Sandy Loam
S9	4.6	3500	13.6	Loamy Course Sand
S10	4.5	600	18.9	Course Sandy Loam
S11	4.7	500	16.7	Loamy Course Sand
S12	5.8	1280	23.2	Course Sandy Loam
S13	5.2	2500	12.1	Silt Loam
S14	4.9	1500	18.2	Course Sandy Loam
S15	5.5	1100	16.8	Course Sandy Loam
S16	4.9	700	15.2	Loamy Course Sand
S17	5.2	2200	21.0	Course Sandy Loam
S18	5.5	1300	19.0	Course Sandy Loam
S19	4.9	900	22.0	Loamy Course Sand
S20	5.6	3200	18.3	Sandy Loam
S21	5.3	2700	22.2	Loamy Sand
S22	5.2	3200	16.7	Loamy Course Sand
S23	4.9	2700	18.8	Sandy Loam
S24	5.1	1400	13.0	Course Sandy Loam
S25	5.3	1800	24.8	Course Sandy Loam
S26	5.6	1300	13.6	Course Sandy Loam
S27	5.2	1200	14.9	Course Sandy Loam
S28	5.1	800	23.0	Course Sandy Loam

**Figure 02: Soil Texture of the Study Area**



**Figure 03: XRD Spectra showing peaks of Minerals in Soil Sample (S 9)**



**Heavy Metals and Land use/Land cover (LULC)**

A comprehensive analysis of land use/ land over and the influence of land use on the soil behaviour are important for soil management. Land cover of an area is based on the topography, climate and edaphic factors while land use represents the anthropogenic activities operating in the area. The LULC map of the study area has been classified in following 6 features (Fig 4) (a) Agricultural field (b) Forest area (c) River (d) Settlement (e) Tree-clad area (f) Wetlands-inland. The study area is mostly covered by agricultural field (38%) and tree clad area (25%). Along with Brahmaputra River, several annual and perennial rivers pass through study area and they cover about 24% of the study area. The concentration of heavy metal in soil samples are summarise in table-3. The geochemical index and enrichment factors have been calculated to assess the level of heavy metal contamination.

### Geo-accumulation Index

Heavy metal contamination in soil was evaluated by calculating geoaccumulation index (Muller, 1981). The index of soil in the study area was calculated on background of world average concentration of these elements reported for shale (Turkian and Wedephol, 1961) and it was determined by the following equation:

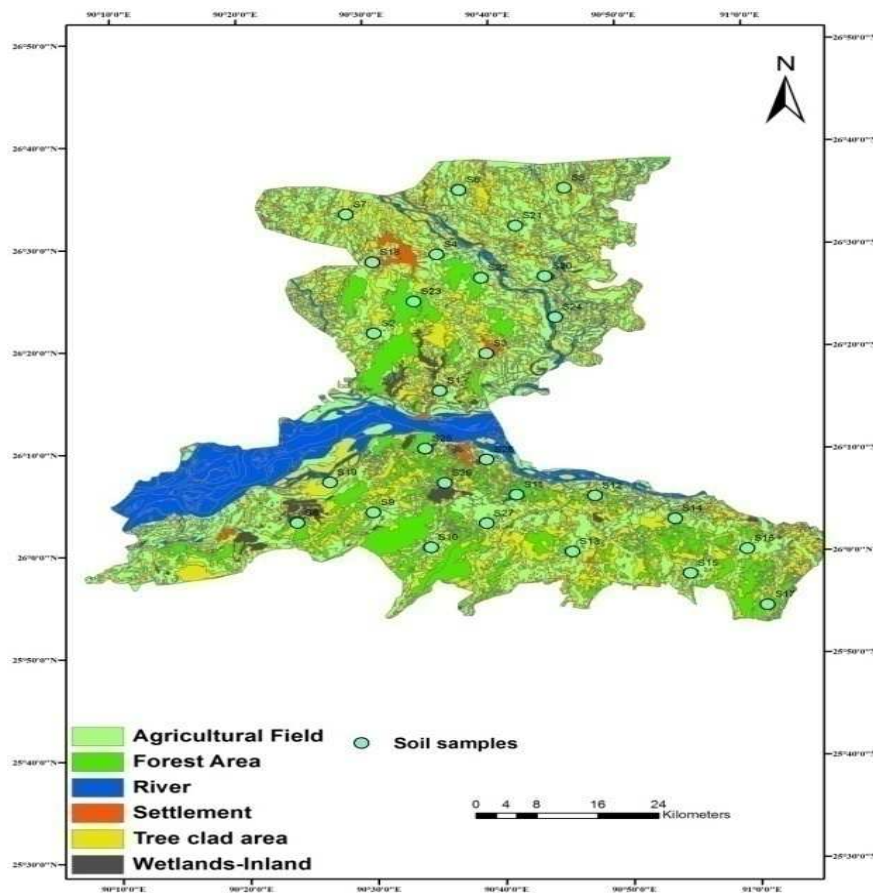
$$I_{geo} = \log_2 C_n / 1.5 B_n$$

Where,  $C_n$  is the measured concentration of element  $n$  (mg/kg) in the sediment sample ( $<2 \mu\text{m}$ ) while  $B_n$  is the element content in average shale (Turkian and Wedephol, 1961). On this basis, Muller (1981) has distinguished 6 classes of the geoaccumulation index (Table 2). The geoaccumulation index of heavy metal in soil samples were measured as shown in graph Fig.5.

**Table 02: Geo-accumulation Index Classification**

Igeo Class	Igeo Value	Contamination level
0	$I_{geo} < 0$	Uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated/ moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately / strongly contaminated
4	$3 < I_{geo} < 4$	Strongly contaminated
5	$4 < I_{geo} < 5$	Strongly/extremely contaminated
6	$5 < I_{geo}$	Extremely contaminated

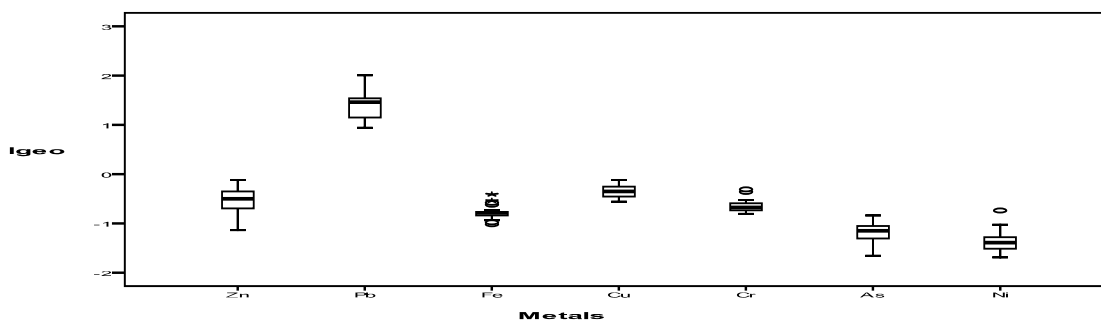
**Figure 04: LULC map of the study area and soil samples**



**Table 03: Concentration of Metal (mg/ kg) in Soil Samples**

Samples	Zn	Pb	Fe	As	Cu	Cr	Ni
S1	64.5	20.8	37107.6	10.9	48.0	109.2	49.8
S2	106.5	24.1	35854.4	9.0	52.9	77.2	33.4
S3	82.3	22.4	41215.2	6.8	49.5	80.9	35.6
S4	88.4	22.8	34879.7	9.0	46.0	77.2	31.5
S5	105.9	30.1	36968.4	9.4	55.1	84.6	36.0
S6	116.7	33.6	47202.5	8.2	57.3	91.6	38.8
S7	120.3	29.3	40449.4	8.6	57.6	77.2	36.4
S8	110.5	42.4	48803.8	6.7	61.9	93.1	47.6
S9	110.8	32.7	42816.5	7.0	59.0	105.2	61.1
S10	123.8	29.6	40936.7	8.5	54.3	83.7	35.9
S11	130.7	36.7	53189.9	6.2	56.1	91.0	41.5
S12	97.0	25.1	46088.6	6.6	51.9	88.2	39.8
S13	78.5	21.3	38012.7	7.8	49.0	82.9	32.1
S14	99.9	24.6	41006.3	9.4	56.8	87.8	45.9
S15	104.0	23.8	39544.3	9.1	52.8	83.9	38.8
S16	87.9	21.1	41145.6	8.1	46.9	81.1	42.7
S17	97.6	20.1	37734.2	10.0	52.1	84.3	34.6
S18	113.4	29.9	41632.9	9.0	59.9	80.0	33.1
S19	101.7	30.9	40170.9	6.8	56.3	86.0	49.0
S20	119.0	27.4	41632.9	8.7	46.3	86.7	40.3
S21	112.8	28.8	41841.8	9.6	48.6	83.2	39.0
S22	78.7	36.8	40936.7	8.9	58.1	79.9	41.1
S23	72.8	31.2	41145.6	10.6	56.0	80.9	36.5
S24	97.9	29.8	39613.9	10.0	53.2	85.7	37.9
S25	91.9	30.2	41563.3	8.0	50.2	84.6	35.7
S26	108.5	29.0	41006.3	8.5	53.1	93.3	43.2
S27	78.9	21.0	40588.6	9.9	51.2	84.2	37.3
S28	91.2	26.6	39474.7	9.1	45.9	91.1	39.9
Max	<b>130.7</b>	<b>42.4</b>	<b>53189.8</b>	<b>10.9</b>	<b>61.9</b>	<b>109.1</b>	<b>61.1</b>
Min	<b>64.5</b>	<b>20.0</b>	<b>34879.7</b>	<b>6.1</b>	<b>45.8</b>	<b>77.1</b>	<b>31.5</b>
Mean	<b>100.7</b>	<b>28.4</b>	<b>41577.7</b>	<b>8.6</b>	<b>53.3</b>	<b>87.0</b>	<b>40.5</b>
Stdv	<b>16.5</b>	<b>5.5</b>	<b>3852.81</b>	<b>1.2</b>	<b>4.5</b>	<b>7.4</b>	<b>6.3</b>

**Figure 05: Geo-accumulation Index of Metals**



**Enrichment Factors**

Enrichment factors of the metal in soil are used to assess the level of contamination and influence of human activities on sediment/soil. The Enrichment factor calculation is based upon the standardisation of tested element against conservative element (low occurrence variability) as reference element (Al, Fe, Ti) (Sutherland, 2000; Reimann and De Caritat, 2000). In this study, Al has been used as a conservative element for geochemical normalisation by using following formula:

$$EF = \frac{Cn(sample) / Cref(sample)}{Bn(background) / Bref(background)}$$

The Contamination categories on the basis of the enrichment factor described in table (Buat-Menard et al., 1979) in table 4 and the enrichment factors of metals summarised in table 5

**Table 04: Contamination Categories**

EF < 2	Deficiency to minimal enrichment
EF = 2-5	Moderate enrichment
EF = 5- 20	Significant enrichment
EF = 20-40	Very high enrichment
EF > 40	Extremely high enrichment

**Table 05: Enrichment factors of the Metals**

	Zn	Pb	Fe	As	Cu	Cr	Ni
EF max	7.92	34.65	9.18	0.84	12.45	14.16	0.90
EF min	0.91	3.41	0.77	0.48	1.05	0.80	0.46
EF mean	1.86	7.47	1.75	0.65	2.36	2.22	0.61

### Zinc (Zn)

Availability of zinc in soil is essential for growth of plant but at the levated level, it has adverse effect on flora. The concentration of zinc in samples varies between 64.5 to 130.7 mg/kg with a mean concentration of  $100.7 \pm 16.5$ . Igeo value for Zn ranged from -0.12 to -1.14 (Fig 5.5) which shows no soil contamination in the area. Although all the soil samples of the area have enrichment value lower with a mean value of 0.91 but sample S1 have enrichment value 7.9 which shows the anthropogenic influence over the soil. This soil sample belongs to an agricultural field near the settlement (Fig 5.4). The enrichment of Zn in the field may be due to the excessive use of agrochemical pesticide in the field (Huai-yang et al., 2004).

### Lead (Pb)

Lead species are mainly associated with clay minerals in soil samples and their average concentration in samples of the study area was  $28.4 \pm 5.5$  mg/kg. The maximum concentration of lead in soil was 42.4 mg/kg while minimum concentration was 20.0 mg/kg. The acidic pH of soil enhances the solubility of Pb in water (Kumar, 2005). The geo accumulation index of lead is higher among all the heavy metals of soil samples of the area and ranges between low contaminated to moderately contaminated. The enrichment factor (EF) of the lead in all the soil samples are in the range of moderate enrichment but three samples S1, S4, and S25 show severe enrichment. All these three samples were taken from an agricultural field which is lying near the highway from where several trucks pass so the probability of vehicular exhaust which gets deposited through air fall may be considered for the lead enrichment in soil samples (Binggan Wei, 2010).

### Iron (Fe)

The concentration of iron in soil samples of the study area is higher in comparison to other heavy metals and its mean concentration is  $41577.7 \pm 3852$  mg/kg, while the average concentration of iron in an uncontaminated sediment and soil are 26000 mg/kg (Bown, 1979, Ghrefat et al., 2010). The geoaccumulation index value (Igeo) and enrichment value are lower for most of the samples (EF mean < 3) except for two soil samples S1 (EF > 9) and S4 (EF 3.04). It shows that most of the samples are an uncontaminated and major source of iron is parent rock materials in the study area and there is no any anthropogenic enrichment of iron in the soil. Magnetite, haematite and quartzite are reported to be associated with the gneiss in the study area which may act as a natural source of iron (GSI reports, 2009). Sample S1 and S4 are collected from the agricultural field which is near the settlement (Fig 5) and there was the activity of vehicle repairing and rod cutting so there may be chances of iron contamination of samples through human activities.

### Copper (Cu)

The organic and inorganic compound of copper is extensively used in agricultural pesticide. The concentration of copper in soil ranges between 45.8 to 61.9 mg/kg with a mean value of



53.5±4.5mg/kg. Most of the collected soils samples belong to an agricultural field. The mean value of Igeo for copper was -0.35 which shows no contamination of soil with respect to copper. Although the mean value of enrichment factor (EF) for Cu is 2.36 but most of the soil samples have EF > 2. The enrichment factor is higher for two samples S1 (EF= 12.4) and S4 (EF=4.2) which means that except these two points, all the soil samples are less enriched and there is no role of human activities to alter copper concentration in soil samples of the area. In contrast to others soil sample, S1 (Extremely contaminated) and S4 (Moderately contaminated) shows the enrichment of the most metals which may be due to anthropogenic activity.

### **Chromium (Cr)**

Chromium is low mobile element and adsorption of their species varies according to soil acidity and soil alkalinity. The Cr<sup>6+</sup> is toxic for the biological system and the normal range of chromium in soil is 100 mg/kg (Wedephol, 1995). In the study area, out of 28 soil samples, only two samples (S9 & S10) have slightly higher concentration of chromium in soil (Table 5.2). Geo accumulation index value of chromium is very low which shows that there is no contamination in soil. The enrichment of the chromium is also low for most of the samples except two samples S1 and S4 which belong to the agricultural field but near the market area painting works was being done in vehicle repair house which may be one of the reasons for chromium enrichment in these samples. Chromium is primarily used in tannery industry and pigment production (Govil et al., 2001).

### **Nickel (Ni)**

Nickel content in soil samples ranged from 31.5 to 61.1 mg/kg with a mean value of 40.5 ± 6.3 mg/kg. In soil, Ni is normally present in the organically bound form whose mobility and bioavailability under acidic and neutral environment gets increased (Amundsun et al., 1992). The Igeo value for Ni ranges from maximum - 0.74 to a minimum -1.69 with a mean value of -1.39 and all the samples belong to uncontaminated category (Muller, 1981). The enrichment of Ni in all the soil samples is not significant and maximum enrichment was 0.91 which shows that there is no contribution of anthropogenic activities in the concentration of nickel.

### **Arsenic (As)**

The mean arsenic content in soil was 8.6 ± 1.2 mg/kg with a maximum concentration of 10.9 mg/kg at location S10. The concentration of arsenic in the surface soil of all points is higher than mean content in the soil of 2mg/kg (Chen et al., 2001). Mean geoaccumulation (Igeo) for arsenic was - 1.20 and mean enrichment factor (EF) was 0.65 which shows that the arsenic content in soil sample of the area is not under influence of anthropogenic activity and the main source of arsenic in the area is geogenic in nature (Zhang and Liu, 2002).

### **Conclusions**

An integrated approach to geospatial technology and lab analysis of soil samples provides a holistic approach to identifying the probable source of surface soil contamination. The land use pattern has significant impact on physical and chemical properties of surface soil. The agricultural soil samples near to national highway contain higher enrichment of lead and soil samples near to paint application industries having greater concentration of chromium. The anthropogenic activities identified as an agent for the enrichment of heavy metal in soil samples which directly or indirectly affecting the flora and fauna of the area.

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