

## Assessment of Soil Contamination in Patancheru Industrial Area, Hyderabad, Andhra Pradesh, India

<sup>1</sup>B. Dasaram, <sup>1</sup>M. Satyanarayanan, <sup>2</sup>V. Sudarshan and <sup>1</sup>A. Keshav Krishna

<sup>1</sup>National Geophysical Research Institute (Council of Scientific and Industrial Research)

Uppal Road, Hyderabad-500007, India

<sup>2</sup>Department of Applied Geochemistry, Osmania University, Hyderabad-500007, India

**Abstract:** Toxic trace metals concentrations in soil exert a decisive impact on soil quality and its use in food production particularly in an industrial area. An attempt is made here to study toxic metals such as Cr, Cu, Ni, Pb, Zn, including Ba, Co and V in representative soil samples from Patancheru industrial area near Hyderabad, Andhra Pradesh. It is a known polluted area and is one of the most contaminated regions where about 260 small and large-scale manufacturers of pharmaceuticals, paints, pesticides, chemicals, steel and metallic products have been functioning for over several decades. Toxic trace metal geochemical studies were carried out in fifteen representative soil samples collected from residential and agricultural area, to understand the spatial distribution and to assess the level of contamination on the basis of index of geoaccumulation, enrichment factor, contamination factor and degree of contamination. The various indices show that residential soils are contaminated with Cr, Ni and Pb (Cu to some extent). The agricultural area, although were invariably enriched in these toxic metals, showed comparatively less contamination possibly due to uptake by plants.

**Key words:** Contamination, industrial area, patancheru, toxic trace metal

### INTRODUCTION

The unchecked industrial and human activities have contributed toxic trace metals from anthropogenic sources into surface and subsurface soils when compared to those contributed from geogenic processes (Ferguson, 1990). Higher economic growth, rapid industrialization and indiscriminate disposal of waste materials without adequate knowledge of toxic pollutants and their control, are responsible for increasing soil environmental hazards at an alarming rate. Hyderabad is the fifth largest city in India with its population touching five millions and covering an area of 1574 km<sup>2</sup>. Many industrial zones like Patancheru, Nacharam, Cherlapalli, Jeedimetla, Balanagar and Saroornagar, which were once located at the outskirts, have now become integral parts of the city threatening the environment. Patancheru industrial development area is one such industrial zone, which has been identified as one of the most contaminated areas by the various Pollution Control Boards (PCBs) and frequently referred to as an area of ecological disaster (Govil *et al.*, 2001; Subrahmanyam and Yadaiah, 2001).

Earlier studies were carried out to decipher concentration of several toxic trace metals in soil/water in Patancheru (Govil *et al.*, 2001; Gurunadha Rao *et al.*, 2001; Govil *et al.*, 1997; Chandra *et al.*, 2003). In order to assess the level of contamination an attempt is made to study the impact of toxic trace metals in soil on

the basis of (i) Index of geoaccumulation (assessment by comparing current and crustal concentration) (ii) Enrichment factor (standardization of trace metals against a reference element) (iii) Contamination factor (assessment of soil contamination through a reference element in comparison with crustal level) and (iv) Degree of contamination (sum of all elements examined).

### MATERIALS AND METHODS

**Study area:** The study area in Patancheru (17°13'N - 17°35'N; 78°12.5'E - 78°17.5'E), located north of Hyderabad, covers an area of about 124 km<sup>2</sup>, and forms part of the catchments of Nakkavagu stream, a tributary of the Manjira River, which is one of the main sources of drinking water for Hyderabad city. It can be seen from the drainage map (Fig. 1) that many of the rivulets tend to flow towards Nakkavagu stream thereby contributing the load of toxic trace metals into the stream (NEERI, 1989). About 260 industries are situated in this area, producing chemicals, pharmaceuticals, paints, pesticides, steel products and different types of metallic goods for the last twenty years. Many of these industries discharge their treated or untreated effluents either on the open land or into unlined water streams/rivulets.

The average annual rainfall in the study area is about 860 mm, of which 700 mm falls in the months of June to October during the southwest monsoon season. The

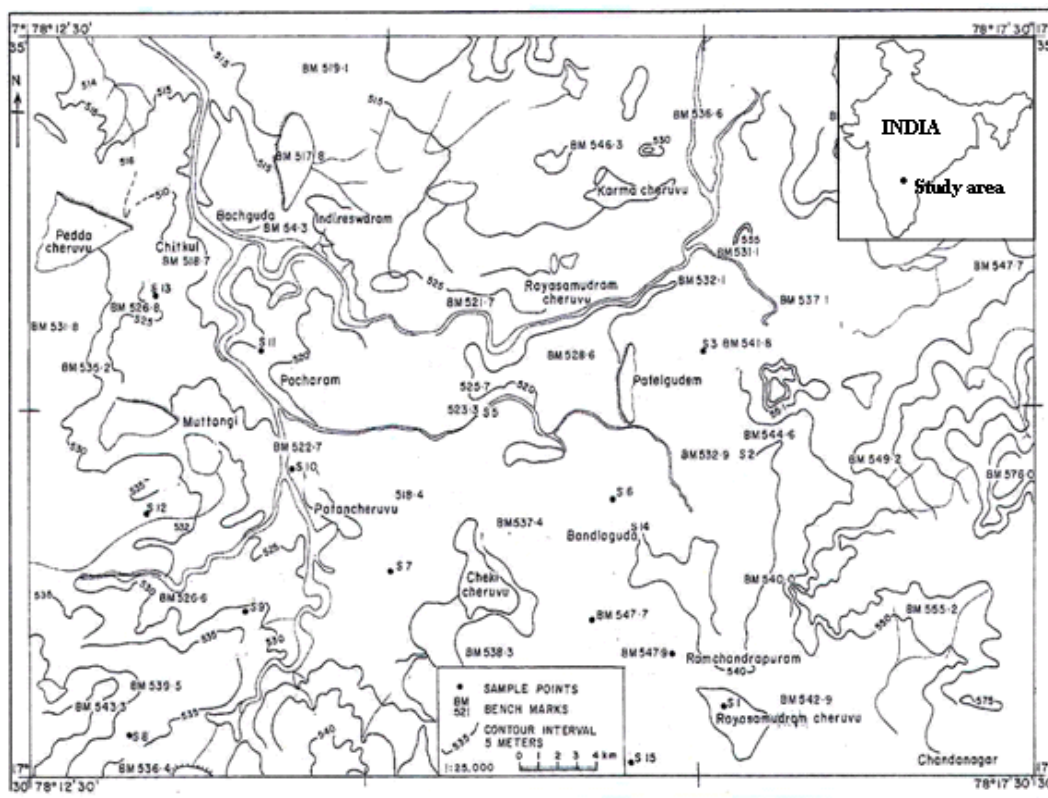


Fig. 1: Drainage and contour map of the study area showing sample locations

Achaean granites of both pink and grey varieties occur as the basement rock. Alluvium occurs all along the banks of Nakkavagu stream, and the thickness of the alluvium varies from 4 to 10 m in-land. Weathered granites are observed under the layers of alluvium. An assessment of the soil layer was carried out by collecting soil samples systematically.

**Sampling:** About fifteen soil samples (BDR-S1 to BDR-S15) were collected during the month/year of June 2005 from almost equi-spaced sample stations (Fig. 1) covering all parts of the Patancheru industrial area, Hyderabad. Most of the soil samples were collected from the upper surface of the soil with depth ranging from 5-10 cm. It has been demonstrated by (Chang *et al.*, 1984). That more than 90% of applied toxic trace metals in soils are found at a depth of 15 cm from the surface. However there are many authors who report maximum toxic trace metal concentration in the surface layer from up to 6 cm (Iwegbue *et al.*, 2006; Haiyan and Stuanes, 2003). Generally content of toxic trace metals is significantly higher in top soils than in subsoils with a very few exceptions as they have little downward movement because of their strong affinities with soil solid phase (Banuelos and Ajwa, 1999; Sterckeman *et al.*, 2000). A sharp edged plastic spatula was used for sample collection. The samples were collected in a thick self-

sealing polythene bags and were labeled accordingly before bringing to Geochemical Laboratory at National Geophysical Research Institute, Hyderabad, for analysis.

**Sample preparation:** All the soil samples were dried in sunlight for a week and care was taken to avoid aerial contamination of the samples. The dry soil samples was disaggregated with a mortar and pestle, and was finely powdered to -240 mesh size (63 microns) using an agate mortar. Pressed pellets were prepared for analysis by X-ray fluorescence (XRF) spectrometry, using a boric acid binder, the details of which are given elsewhere (Krishna *et al.*, 2009).

**Instrumentation:** Toxic trace metals (Ba, Co, Cr, Cu, Ni, Pb, V, Zn) in all the soil samples were determined using a wavelength dispersive X-Ray Fluorescence Spectrometry (Philips PW-2440 Magix-PRO fully automatic with 100-KW X-ray generator, microprocessor controlled, 72-position automatic sample changer) following standard procedures. Suitable software was used to take care of dead-time correction, inter-element effects, etc. Reference materials from the US Geological Survey, Geological Survey of Canada, International Working Group-France, and National Geophysical Research Institute-India, were used to prepare calibration curves for toxic trace metals (Govil *et al.*, 1998).

Table 1: Analytical data (in ug/g) of toxic trace metals in soil samples from Patancheru Industrial Area

Sample	Ba	Co	Cr	Cu	Ni	Pb	V	Zn
BDR-S1 (lake sediment)	412.5	3.0	49.1	16.9	17.2	23.6	23.5	44.5
BDR-S2 (lake sediment)	630.4	12.4	64.8	23.6	34.0	34.5	82.3	50.3
BDR-S3 (agriculture land)	425.7	5.7	44.0	13.1	10.2	35.1	48.1	42.8
BDR-S4 (agriculture land)	644.1	14.3	60.7	30.8	31.0	22.3	94.8	57.6
BDR-S5 (near lake)	615.4	16.9	85.1	95.2	39.4	51.7	81.5	198.5
BDR-S6 (resident colony)	501.4	15.6	78.1	106.1	66.1	68.2	77.3	111.1
BDR-S7 (highway)	685.9	20.3	84.0	30.0	43.1	27.6	112.1	130.9
BDR-S8 (agriculture land)	775.4	16.9	73.1	31.3	39.6	18.5	117.6	113.3
BDR-S9 (agriculture land)	767.7	15.7	68.1	29.2	35.6	24.9	113.8	79.2
BDR-S10 (industrial area)	743.4	26.0	91.6	32.3	53.0	34.1	132.6	66.4
BDR-S11 (garden)	637.1	14.6	68.7	30.4	34.4	26.0	97.6	56.1
BDR-S12 (resident area)	857.6	6.1	43.2	16.0	15.0	24.3	59.7	49.6
BDR-S13 (resident area)	738.1	20.3	106.3	39.9	45.6	40.4	119.0	275.7
BDR-S14 (resident area)	1021.0	13.0	62.6	35.4	31.6	58.8	128.1	86.4
BDR-S15 (resident area)	605.7	7.2	72.5	25.0	16.2	24.8	55.6	45.6
Residential soil quality*	500.0	50.0	64.0	63.0	50.0	140.0	130.0	200.0

\*: Canadian soil quality guidelines (2001) for the protection of environmental and human health

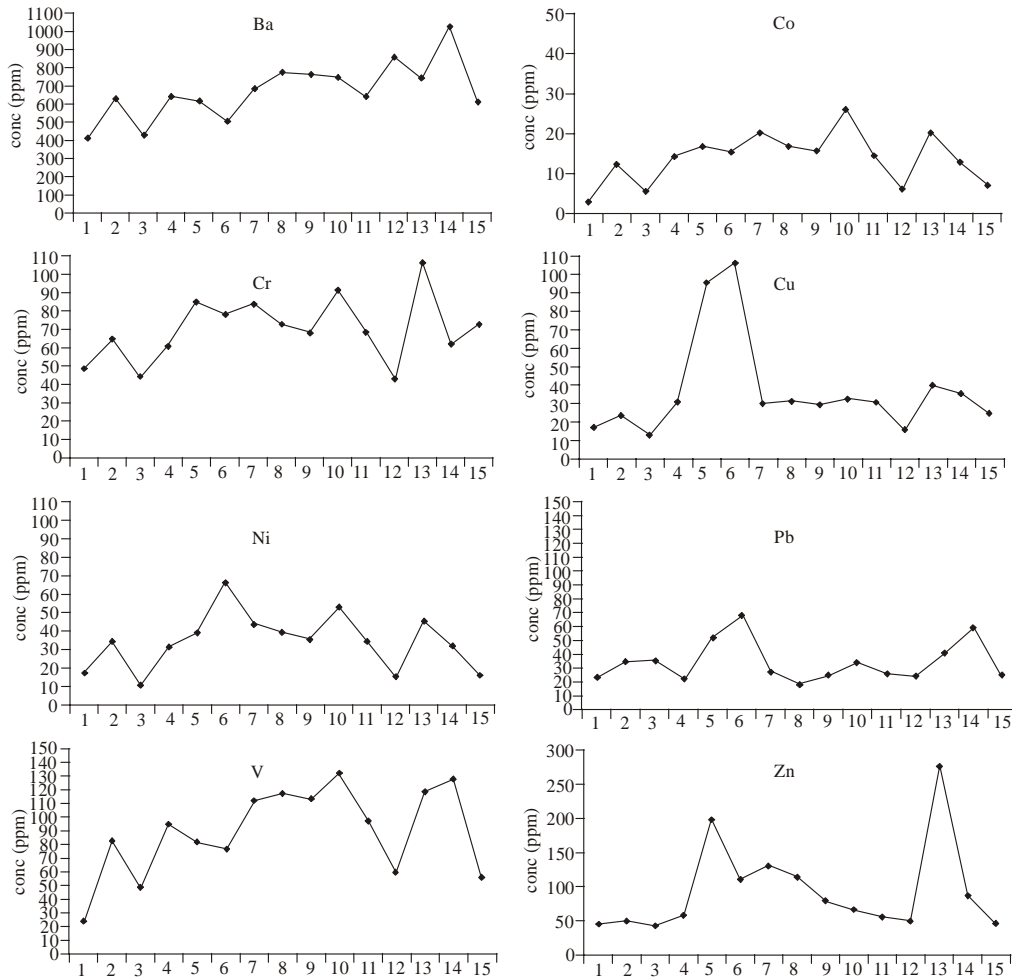


Fig. 2: Graph showing comparison of residential soil quality guidelines with soil samples from Patancheru Industrial Area. Dark line represents soil quality guideline value

**RESULTS AND DISCUSSION**

The analytical results of the toxic trace metals in soil samples (BDR-S1 to BDR-S15) collected from Patancheru industrial area are presented in Table 1.

Graphical representation of the same in comparison with the Canadian soil quality guideline for residential area (CEQG, 2002) is given in Fig. 2, which show that all the toxic metals, except V, Co and Pb, have concentrations beyond the acceptable range in one way or the other.

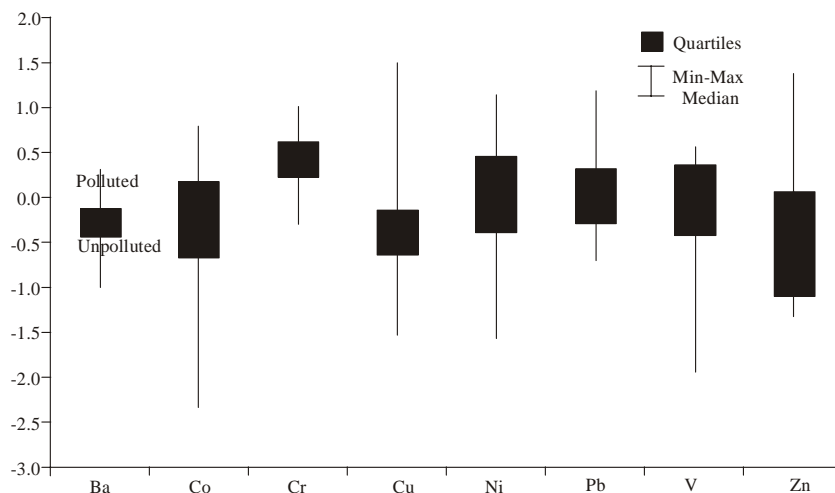


Fig. 3: Graphical representation of Index of geoaccumulation.  $I_{geo}$  was calculated using the relation  $I_{geo} = \log_2 [C_n/1.5B_n]$ , where  $C_n$  concentration of the element n,  $B_n$  is geochemical background value (Loska *et al.*, 2004)

While only few samples show feeble contamination in Ni, Cu and Zn, most of the soil samples were highly contaminated with Ba and Cr. The comparison was made with guideline value for ‘residential area’ since it represents the limiting value wherein human dwellings can thrive. It is important to note that there are no such guideline value existing for Indian soil, and hence a comparison was made with (CEQG, 2002).

The spatial distribution maps (not shown) were prepared for the analyzed toxic trace metals which indicate that the soils in the central and eastern part (residential area) of the study area exhibit higher concentrations compared to rest of the area. It is likely that these elements, particularly Ba, Cr, Ni, Cu and Zn have got accumulated in soil over a period of time and that the soil obviously has acted as a sink for depositing these elements from industrial waste/effluents. In order to assess the impact of toxic trace metals in soil, a methodology was adopted wherein various indices such as i) index of geoaccumulation, ii) normalized enrichment factor, iii) contamination factor and iv) degree of contamination, were calculated and evaluated (Loska *et al.*, 2004).

**Index of geoaccumulation:** The index of geoaccumulation ( $I_{geo}$ ) enables the assessment of contamination by comparing current and pre-industrial concentrations (Muller, 1981). In this study the background concentration of trace metals in the earth’s crust was used as a reference value implicating pre-industrial environment.  $I_{geo}$  is computed using the following equation:

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

Table 2: Six classes of the geoaccumulation index (Muller, 1981)

Class	Value	Soil Quality
0	$I_{geo} < 0$	Practically uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated to moderately uncontaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately to heavily contaminated
4	$3 < I_{geo} < 4$	Heavily contaminated
5	$4 < I_{geo} < 5$	Heavily to extremely contaminated
6	$5 < I_{geo}$	Extremely contaminated

Table 3: Contamination categories recognized on the basis of the enrichment factor (Sutherland, 2000)

Enrichment factor	Category
EF < 2	Deficiency to mineral enrichment
EF > 2-5	Moderate enrichment
EF > 5-20	Significant enrichment
EF > 20-40	Very high enrichment
EF > 40	Extremely high enrichment

where  $C_n$  is concentration of the element ‘n’ and  $B_n$  is geochemical background value. The background values provided by (Taylor and McLennan, 1985) were used to calculate the index of geoaccumulation. The constant 1.5 allows us to analyze natural fluctuations between the content of given substance in environment and very small anthropogenic influences. Muller (1981) has distinguished six classes of the geoaccumulation index (Table 2). It was observed that the  $I_{geo}$  values of Cr, Ni, Pb and V in residential area is much higher than those in agricultural area, and that they are moderately contaminated. The values range from 0 to 1 in these areas, and are more towards unity in case of residential area. A plot of these indices (Fig. 3) show wide variation in the ranges of these toxic trace metals indicating differential accumulation of elements and existence of discrete pockets of sinks for these trace elements in the study area.

**Enrichment factor:** The Enrichment Factor (EF) was based on the standardization of a tested element against a reference one. A reference element is the one

Table 4: Enrichment factor of soils from Patancheru industrial area

Sample	Particulars	EF-Ba	EF-Cr	EF-Cu	EF-Ni	EF-Pb	EF-V	EF-Zn
BDR-S1	Lake sediment (Rayasamudram Cheruvu)	2.50	4.68	2.25	2.87	3.93	1.31	2.09
BDR-S2	Lake sediment (Rayasamudram Cheruvu)	0.92	1.49	0.76	1.37	1.39	1.11	0.57
BDR-S3	Patelgudem	1.36	2.21	0.92	0.89	3.08	1.41	1.06
BDR-S4	Agricultural field	0.82	1.21	0.86	1.08	0.78	1.10	0.57
BDR-S5	Agricultural field, Bandlaguda	0.66	1.44	2.25	1.17	1.53	0.80	1.65
BDR-S6	Alwain colony (Habibgudam)	0.58	1.43	2.72	2.12	2.19	0.83	1.00
BDR-S7	Near Highway (Bhanur Road)	0.61	1.18	0.59	1.06	0.68	0.92	0.91
BDR-S8	Agricultural field	0.83	1.24	0.74	1.17	0.55	1.16	0.94
BDR-S9	Srinivasa farms	0.89	1.24	0.74	1.13	0.79	1.21	0.71
BDR-S10	Residential area (Sai Krishna gas agency)	0.52	1.01	0.50	1.02	0.66	0.85	0.36
BDR-S11	Ganapati garden	0.79	1.34	0.83	1.18	0.89	1.11	0.54
BDR-S12	Near College of Engineering	2.56	2.02	1.05	1.23	1.99	1.63	1.15
BDR-S13	Chitkul (Near Hanuman temple)	0.66	1.50	0.79	1.12	1.00	0.98	1.91
BDR-S14	Near Bandalguda school	1.43	1.38	1.09	1.22	2.26	1.64	0.94
BDR-S15	Patancheru residential area	1.53	2.88	1.39	1.13	1.72	1.29	0.89

characterized by low occurrence variability such as Sc, Mn, Ti, Al and Fe. In this study Co was used as reference element since its concentration in earth crust is low. The enrichment factor was calculated using the formula based on the equation suggested by Buat-Menard (1979):

$$EF = [C_n(\text{sample})/C_{ref}(\text{sample})]/[B_n(\text{background})/B_{ref}(\text{background})]$$

where,  $C_n(\text{sample})$  is the content of the examined element in the examined environment,  $C_{ref}(\text{sample})$  is the content of the reference element in the examined environment,  $B_n(\text{background})$  is the content of the examined element in the reference environment and  $B_{ref}(\text{background})$  is the content of reference element (viz. Co in this case) in reference environment. Co is attributed to the geogenic source from the granitic rocks occurring in the study area (Wedepohl, 1991). Moreover Co data provided the nearest equivalent for considering as a reference element among other trace elements analyzed from the study area.

Five contamination categories are recognized on the basis of the enrichment factor (Sutherland, 2000) (Table 3). Enrichment factor values (Table 4) revealed that soils are moderately enriched with Cr, Cu, Ni and Pb. The samples collected from residential area show moderate enrichment of these toxic trace metals, than those collected from agricultural area. One lake sediment display moderate enrichment in almost all the toxic trace metals, which indicates that sediments are the preferred sinks for these metals.

**Contamination factor:** The assessment of the soil contamination was also carried out using the contamination factor and degree of contamination. The contamination factor was calculated using the relation described by Hakanson (1980):

$$C_f^i = C_{0-1}^i / C_n^i$$

where,  $C_{0-1}^i$  is the mean content of metals from at least five sampling sites and  $C_n^i$  is the pre-industrial

Table 5: Categories of contamination factors (Hakanson, 1980)

Contamination factor	Category
$C_f^i < 1$	Low contamination factor indicating low contamination
$1 < C_f^i < 3$	Moderate contamination factor
$3 < C_f^i < 6$	Considerable contamination factor
$6 < C_f^i$	Very high contamination factor

Table 6: Classes of contamination degree ( $C_{deg}$ ) (Hakanson, 1980)

Contamination degree	Category
$C_{deg} < 8$	Low degree of contamination
$8 < C_{deg} < 16$	Moderate degree of contamination
$16 < C_{deg} < 32$	Considerable degree of contamination
$32 < C_{deg}$	Very high degree of contamination

concentration of individual metal. In this study the concentration of elements in the earth's crust is used as a reference value (Taylor and McLennan, 1985).

(Hakanson, 1980) defined four categories of Contamination Factors (CF) (Table 5). The CF data (Table 7) invariably shows that the soil in both residential as well as agricultural area are moderately contaminated ( $1 < CF < 3$ ) with Cr, Cu, Ni and Pb. In fact, considerable level of contamination was observed more in residential area rather than in agricultural field. This data again confirms that soil acts as a sink for trace metals and that the residential area is moderately contaminated with toxic trace metals. The sources of contamination that exist within Patancheru industrial area are:

- Dumping of solid waste, randomly throughout the area
- Untreated industrial effluent discharged into ditches and streams
- Emission from smokestacks

The discharging of the industrial effluent affects the contamination of the soil throughout the area and this source is considered as a major cause for soil pollution. The untreated fallout from smokestacks can reach the residential areas depending on the prevailing wind directions. It is known that untreated or un-filtered emissions from most types of combustion and incineration will also carry different trace metals, especially Cr, Ni, Cu, Zn and Pb (Sanka *et al.*, 1995; Govil *et al.*, 2008).

Table 7: Contamination factor of soil from Patancheru Industrial area

Sample	CF-Ba	CF-Co	CF-Cr	CF-Cu	CF-Ni	CF-Pb	CF-V	CF-Zn	Deg. Cont.
BDR-S1	0.75	0.30	1.40	0.68	0.86	1.18	0.39	0.63	6.19
BDR-S2	1.15	1.24	1.85	0.94	1.70	1.73	1.37	0.71	10.69
BDR-S3	0.77	0.57	1.26	0.52	0.51	1.76	0.80	0.60	6.79
BDR-S4	1.17	1.43	1.73	1.23	1.55	1.12	1.58	0.81	10.62
BDR-S5	1.12	1.69	2.43	3.81	1.97	2.59	1.36	2.80	17.76
BDR-S6	0.91	1.56	2.23	4.24	3.31	3.41	1.29	1.56	18.52
BDR-S7	1.25	2.03	2.40	1.20	2.16	1.38	1.87	1.84	14.12
BDR-S8	1.41	1.69	2.09	1.25	1.98	0.93	1.96	1.60	12.90
BDR-S9	1.40	1.57	1.95	1.17	1.78	1.25	1.90	1.12	12.12
BDR-S10	1.35	2.60	2.62	1.29	2.65	1.71	2.21	0.94	15.36
BDR-S11	1.16	1.46	1.96	1.22	1.72	1.30	1.63	0.79	11.23
BDR-S12	1.56	0.61	1.23	0.64	0.75	1.22	1.00	0.70	7.70
BDR-S13	1.34	2.03	3.04	1.60	2.28	2.02	1.98	3.88	18.17
BDR-S14	1.86	1.30	1.79	1.42	1.58	2.94	2.14	1.22	14.23
BDR-S15	1.10	0.72	2.07	1.00	0.81	1.24	0.93	0.64	8.51

**Degree of contamination:** The contamination factor described above is a single element index. The sum of contamination factors for all elements examined represents the contamination degree ( $C_{deg}$ ) of the environment and four classes are recognized (Table 6).

The sums of contamination factors for all metals examined are listed in Table 7 (last column) which shows that the degree of contamination in soil of the study area is moderate to considerable. It can be seen from the data that the principle contributors among toxic trace metals are Cr, Cu, Ni and Pb. The degree of contamination is considerable in residential area rather than in agricultural area, which again reiterates that the most affected zone is the inhabited part of Patancheru Industrial area. Uptake of toxic trace metals by plants cultivated in agricultural area is possibly one of the reasons that can be attributed for comparatively low level of toxic trace elements in agricultural region than in residential area. It needs to be seen whether there are any specific bioaccumulators that can help in phytoremediation of Cr, Ni, Cu and Pb in residential area.

### CONCLUSION

The soil is the sink for toxic trace metals in Patancheru industrial area and the level of enrichment of each metal is varying depending on its chemical characteristics. The Index of geoaccumulation, enrichment and contamination factor invariable shows that the soil from residential area is moderately contaminated with Cr, Ni and Pb (Cu to some extent). The agricultural soil indicated relatively less contamination indices and it is presumed that plant/crop uptake of these elements along with other macro and micro nutrients during its growth has effectively removed the toxic metals from the soil. All other metals analyzed (Ba, Co, V and Zn) display low level of contamination in soil. The sum of contamination factors for all metals examined indicates considerable degree of contamination in soil. It is inferred that the contamination is from the anthropogenic sources like dumping of solid waste, discharge of untreated industrial waste and emission from

smokestacks. The study also shows the need for bioaccumulators that is capable of removing toxic metals, particularly Cr, Ni and Pb from the study area.

### ACKNOWLEDGEMENT

The authors thank Director, NGRI, and Hyderabad for according permission to publish this paper. Our sincere thanks are also due to Dr.V.Balaram, Head, Geochemistry Division, NGRI, and Hyderabad for his constant encouragement and support.

### REFERENCES

- Banuelos, G.S. and H.A. Ajwa, 1999. Trace elements in soils and plants: An overview. *J. Environ. Sci. Health A.*, 4: 951-974.
- Buat-Menard, P., 1979. Influence of Atmospheric Deposition on the Chemistry of Trace Metals in the Material Suspended in the North Atlantic. Thesis, University Paris, 4: 434 (in French).
- CEQG (Canadian Environmental Quality Guidelines), 2002. Summary table for soil quality guidelines. Canadian Council of Ministers of the Environment, pp: 210.
- Chandra, S.K., N.S. Chary, C.T. Kamala, J. Venkateswara Rao, V. Balaram and Y. Anjaneyulu, 2003. Risk assessment and pathway study of arsenic in industrially contaminated sites of Hyderabad: A case study. *Environ. Int.*, 29: 601-611.
- Chang, A.C., J.E. Warneke, A.L. Page and L.J. Lund, 1984. Accumulation of heavy metals in sewage sludge treated soils. *J. Environ. Qual.*, 13: 87-91.
- Ferguson, J.E., 1990. *The Heavy Elements: Chemistry, Environmental Impacts and Health Effects.* Pergamon Press, Oxford.
- Govil, P.K., J.E. Sorlie, N.N. Murthy, D. Sujatha, G.L.N. Reddy, K. Rudolph-Lund, A.K. Krishna and K. Ram Mohan, 2008. Soil contamination of heavy metals in the Katedan industrial development area, Hyderabad, India. *Environ. Monit. Assess.*, 140: 313-323.

- Govil, P.K., T. Gnanashwara Rao, and R. Raghava, 1997. Environmental monitoring of toxic metals in industrial development area: A case study. 3rd International Conference on the Analysis of Geological and Environmental Materials at Colorado, USA, 77: 1-5.
- Govil, P.K., T. Gnaneshwar Rao and A.K. Krishna, 1998. Arsenic contamination in Patancheru Industrial Area, Medak District, Andhra Pradesh. *Environ. Geochem.*, 1: 5-9.
- Govil, P.K., G.L.N. Reddy and A.K. Krishna, 2001. Contamination of soil due to heavy metals in the Patancheru industrial development area, Andhra Pradesh, India. *Environ. Geol.*, 41: 461-469.
- Gurunadha Rao, V.V.S. R.L. Dhar and K. Subramanyam, 2001. Assessment of contaminant migration in ground water from an industrial development area, Medak district Andhra Pradesh, India. *Water, Air, Soil Pollut.*, 12: 369-89.
- Haiyan, W. and A.O. Stuanes, 2003. Heavy metal pollution in air-water-soil-plant system of Zhuzhou city, Hunan province, China. *Water, Air, Soil Pollut.*, 147: 79-107.
- Hakanson, L., 1980. An ecological risk index for aquatic pollution control. A sedimentological approach. *Water Res.*, 14: 975-1001.
- Iwegbue, C.M.A., N.O. Isirimah, C. Igwe and E.S. Williams, 2006. Characteristic levels of heavy metals in soil profiles of automobile mechanic waste dumps in Nigeria. *Environmentalist*, 26: 123-128.
- Krishna, A.K., K. Rama Mohan, N.N. Murthy and P.K. Govil, 2009. Comparative study of X-ray fluorescence and inductively coupled plasma optical emission spectrometry of heavy metals in the analysis of soil samples. *Atom. Spectrosc.*, 29: 83-89.
- Loska, K., D. Wiechula and I. Korus, 2004. Metal contamination of farming soils affected by industry. *Environ. Int.*, 30: 159-165.
- Muller, G., 1981. The heavy metal contamination of sediments of the Neckar River and its. *Chemiker-Zeitung*, 6: 157-161 (in German).
- NEERI, 1989. A Report on Patancheru Industrial Area, National Environmental and Engineering Research Institute, Nagpur, India., pp: 85.
- Sanka, M., M. Strnad, J. Vondra and E. Paterson, 1995. Sources of soil and plant contamination in an urban environment and possible assessment methods. *Int. J. Environ. Anal. Chem.*, 19: 2066-2072.
- Sterckeman, T., F. Douay, N. Prioix and H. Fourrier, 2000. Vertical distribution of Cd, Pb and Zn in soils near smelters in the North of France. *Environ. Pollut.*, 107: 377-389.
- Subrahmanyam, K. and P. Yadaiah, 2001. Assessment of the impact of industrial effluents on water quality in Patancheru and environs, Medak district, Andhra Pradesh, India. *Hydrogeol. J.*, 9: 297-312.
- Sutherland, R.A., 2000. Bed sediments associated trace metals in an urban stream, Oahu, Hawaii. *Environ. Geol.*, 39: 611-627.
- Taylor, S.R. and S.M. McLennan, 1985. *The Continental Crust: Its Composition and Evolution*. Blackwell, London, pp: 312.
- Wedepohl, K.H., 1991. Chemical composition and fractionation of the continental crust. *Geol. Rundschau.*, 80: 207-223.