



## Characterization of dust and its impact on the environment at Hyderabad

P.Venkateshwarlu<sup>a\*</sup>, TejavathNageswraRao<sup>a</sup>, B.Dasharam<sup>b</sup>

<sup>a</sup>Analytical Chemistry Division, Indian Institute of Chemical Technology, Tarnaka, Hyderabad, India, 500607.

<sup>b</sup>Geochemistry Division, National Geographical Research Institute, Uppal road, Hubsiguda, Hyderabad.

### Abstract:

This article deals with the determination and comparison of heavy metals and water-soluble ions in dust samples at Hyderabad, one of the major cities in south-central India. Samples were collected at three different characteristicsampling sites. The samples were analyzed for heavy metals (Sc, V, Cr, Co, Ni, Cu, Zn, Sr, Pb, Ba and Zr) using inductively coupled plasma mass spectroscopy(ICP-MS), and water-soluble anions (F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, and SO<sub>4</sub><sup>2-</sup>) and cations (Li<sup>+</sup>, Na<sup>+</sup>, K<sup>+</sup>, Mg<sup>2+</sup>, and Ca<sup>2+</sup>) were determined using ion chromatography (IC). The highest lead concentration was found in traffic area and the lowest concentration was found in research institute. The range of Co in dust sample was 0.3-0.1 ppm and the highest concentration of Co was found in the industrial area and research institute and, lowest concentration was reported in the traffic area.

**Keywords:** Dust fall; Heavy metals; correlation analysis;

Corresponding author e-mail:pabbathireddy@gmail.com

### 1. Introduction:

Heavy metals are natural components of the Earth's crust neither they can be degraded nor destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some of heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of human body. However, at higher concentrations, they can lead to poisoning. Studies on the contamination of airborne particulate with heavy metals indicate two main sources, anthropogenic and soil erosion patterns. Main anthropogenic sources of heavy metals exist in various industrial point sources, e.g. present and former mining activities, foundries, smelters and diffuse sources such as piping, constituents of products, combustion by-products, traffic, industrial and human activities. Vehicle emissions have been found to be a significant source of particulate contamination<sup>(1)</sup> and the particulate matter concentration depends on atmospheric conditions<sup>(2,3)</sup>. Heavy metals at trace levels present in natural water, air, dusts, soils and sediments play an important role in human life<sup>(4-6)</sup>. Street dust makes a significant contribution to the pollution in the urban environment and street dust consists of vehicle exhaust, sinking particles in air, house dust, soil dust and aerosols that carried by air and water.

Many studies have been focused on elemental concentrations and source identification of dust. Pt, Pd and Rh contents were determined in samples of road dust, tunnel dust and common grass

as well as pine needles collected from the residential areas of Bialystok, northeast Poland<sup>[7]</sup>. High resolution (HR) and quadrupole inductively coupled plasma mass spectrometry (ICP-MS) were compared for their adequacy in the environmental analysis of Pt and Rh. Palladium was determined by total X-ray fluorescence (TXRF) and HR-ICP-MS after matrix separation by reductive co-precipitation with Hg. The highest platinum group elements (PGEs) concentration was found in road dust samples. In Jordan, at Karak Industrial Estate (KIE) studied for heavy metals content. Samples of dust, street dust and soil were analyzed for their content of Fe, Cu, Zn, Ni and Pb after digestion with nitric acid to determine major sources and magnitude of heavy metals pollution using ICP-MS. There are two possible sources of heavy metals (Zn, Cu, Ni and Pb) anthropogenic and industrial activities from the work place in KIE<sup>[8]</sup>. Significant contribution from industrial sources at KIE was evident at nearby places. Eight samples of road dust were collected from three different localities (industrial, urban, peripheral) of the town of Gela (Italy) to characterize their chemical composition, and to assess the influence of the petrochemical plant and the urban traffic on the trace element content in different grain-size fractions of street dust and the solid-phase speciation of the analyzed metal using sequential extraction using ICP-MS<sup>[9]</sup>. The concentrations of metals (Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn) in 29 dust samples collected from the

streets of the Organized Industrial District (OID) in Kayseri (Turkey) were determined by FAAS. The modified three-step BCR sequential extraction procedure was used in order to evaluate mobility, availability and persistence of trace elements in street dust samples<sup>[10]</sup>. Keiko Suzuki<sup>(11)</sup> *et al.*, reported the heavy metals in Particulate matter accumulated on tree bark of the sargent cherry (*Prunussargentii*) and sugar maple (*Acer saccharum* Marsh) from four locations: Drax (North Yorkshire), Darley Dale (Derbyshire), Galway (Ireland) and Tristan da Cunha to investigate its potential use as a natural monitor to study the impact on local atmospheric conditions. Pb, As, Cr, Sb, Sn and Zn characterised by SEM-EDX and LA-ICP-MS to provide information on the particle composition and morphology. The platinum group elements (PGEs), particularly platinum, palladium and rhodium in dust, emitted into the environment from automotive catalytic converters, were reported by Matti Niemelä *et al.*<sup>[12]</sup> using microwave-assisted sample digestion and ICP-MS determination. Spectral interferences in ICP-MS determination were corrected using mathematical correction equations based on signal ratio measurement. Lars Hergren *et al.*<sup>[13]</sup> analysed the Road-deposited sediments for heavy metal concentrations at three different land uses (residential, industrial, commercial) in Queensland State, Australia. The sediments were collected using a domestic vacuum cleaner, which was proven to be highly efficient in collecting sub-micron particles. Five particle sizes were analyzed separately for eight heavy metal elements viz., Zn, Fe, Pb, Cd, Cu, Cr, Al and Mn. Dust fall and office dust samples collected at Jordanian petroleum refinery complex were analyzed for water-soluble anions ( $F^-$ ,  $Cl^-$ ,  $Br^-$ ,  $NO_3^-$ ,  $C_2O_4^{2-}$ , and  $SO_4^{2-}$ ) and cations ( $Li^+$ ,  $Na^+$ ,  $K^+$ ,  $Mg^{2+}$ , and  $Ca^{2+}$ ) using auto-suppressed ion chromatography and , heavy metals (Pb, Cd, Cu, Zn, Cr, Fe, and Al) were determined using FAAS. No correlations were found between heavy metal concentrations in dust fall and office dust samples, indicating different sources. High enrichment factors for heavy metals were found in dust-fall samples, except for Fe and Cr. Zinc showed the highest and cadmium the lowest flux rates<sup>[14]</sup>.

In the present study we have characterized the composition of inorganic fraction and heavy metals in three different environment sites of Hyderabad in February 2006. Concentrations were determined by using ion chromatography (IC) and Inductively Coupled Plasma Mass Spectrometer (ICP-MS).

## 2. Experimental:

### 2.1 Area description:

Hyderabad is located in the south-central of India and is one of the major industrial city in India which lies (17.5 N, 78.5 E) about 536 m above sea level with an area of 640 Km<sup>2</sup>. The prevailing wind direction is gusting from westerly to southwesterly. The population of the city is 80, 00,000 inhabitants. Potential sources of pollution are limited to vehicle traffic, private heating and small-scale industries. The overall number of vehicles registered in Hyderabad is approximately 600,000 in 2006.

### 2.2 Sampling Sites:

The sampling strategy was designed to ensure representative coverage of three different environment sites i.e. the major traffic area, industrial area and research institute.

The sampling was carried out in February 2006 during dry and warm weather. The samples of First site i.e. traffic area site, samples were collected from the major intersection located at ISKON temple, near to Secundarabad railway station (Traffic density; 30000 vehicles per day in 2006), at a distance of 5 meter and 1 meter height from the footpath. Second site i.e. Industrial area site which is located in the Industrial development area (IDA), Nacharam and it is surrounded with nearly 350 small scale, mid and large scale industries and third site i.e. Research institute site (Indian institute of chemical technology) which is located in tarnaka and it is surrounded with fire station, dispensary, a huge garden, canteen, power generating plant and another research Institute. Sampling was done on the terrace of the discovery building, midst of the research institute and from the sampling site at a distance of 500 m busy road is running which has traffic density of around 10<sup>4</sup>-10<sup>5</sup> vehicle per day.

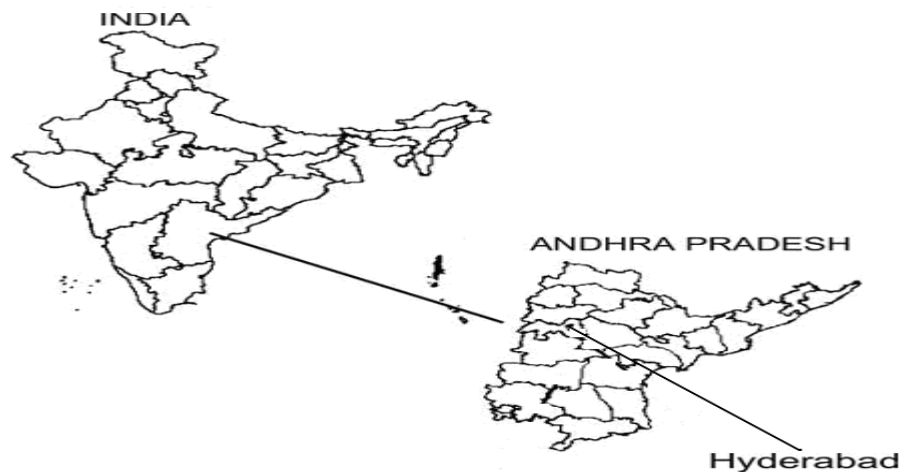
### 2.3 Sample collection and preparation

The funnel (14cm diameter) was used to collect the samples. The collected dust in the funnel was accurately weighed (approximately 0.056gr) and washed with distilled water (40ml) then transferred into a polyethylene bottles.

The pH and electrical conductivity of dust samples were measured by mixing 1:2.5 (w/v) soil-distilled water suspensions. For heavy metal analysis, dust sample was transferred into 5ml of concentrated HNO<sub>3</sub> solution in a test tube and left overnight. The digested dust sample was transferred into 25 ml of deionized distilled water then digested by using ultrasonic digestion system for 75 min.

### 2.4 Instrumentation:

For heavy metal analysis inductively coupled plasma mass spectrometer (ICP-MS, Perkin Elmer) was used. The instrument conditions are; Plasma parameter: flow of Coolant argon is 15.5 L/min, auxiliary argon is 1.40 L/min and Nebulizer argon



0.95 L/min, respectively. Power pump rate 1.2 KV, 25 rpm scanning parameters are Spacing 0.1 AMU, Dwell time 200  $\mu$ s, Replicate per sample 5 and Scans per replicate is 25. Cations and anions were determined by using Ion Chromatography (Metrohm 792, Basic system) with conductivity detector. For anions, separation was done using Metrosep A supp5-100 column. A mixture of 3.2mM  $\text{Na}_2\text{CO}_3$  and 1mM  $\text{NaHCO}_3$  was used as eluent at a flow rate of 0.7ml/min. Cation separation was done using Metrosep C2-250 column using a mixture of 4mM tartaric acid and 0.75mM pyridine 2, 6 dicarboxylic acids as eluent at a flow rate of 1.0ml/min. For analysis we used standards purchased from FLUKA.

### 2.5 Reagents and materials

Concentrated 69% Nitric acid was purchased from Fluka, Switzerland. National institute of standards and technology traceable plasma standards were purchased from J.T Baker, USA. Solvents and chemicals were analytical grade (FlukaChemika).

### 2.6 Preparation of standards

Preparation standards were made by diluting plasma standards in nitric acid (5% v/v). Two-multi element calibration standards of 200 and 500 ng/mL were prepared by directly diluting the plasma stock standard solution.

## 3. Results and discussion:

### 3.1 Heavy metal analysis

The mean values of heavy metals like Sc, V, Cr, Co, Ni, Cu, Zn, Sr, Pb, Ba and Zr in samples collected at three different environments in Hyderabad have been given in Table 1 and Figs. 1–2. Spatial distribution of major anions and cations of dust samples collected at three sites were shown in Table-2. Lead concentrations were in the range 1–34.5 ppm. The highest lead concentration (34.5 ppm) in traffic area samples while the lowest concentration (1ppm) were found in research institute samples. It is noted that the lead concentration increases with increase of motor

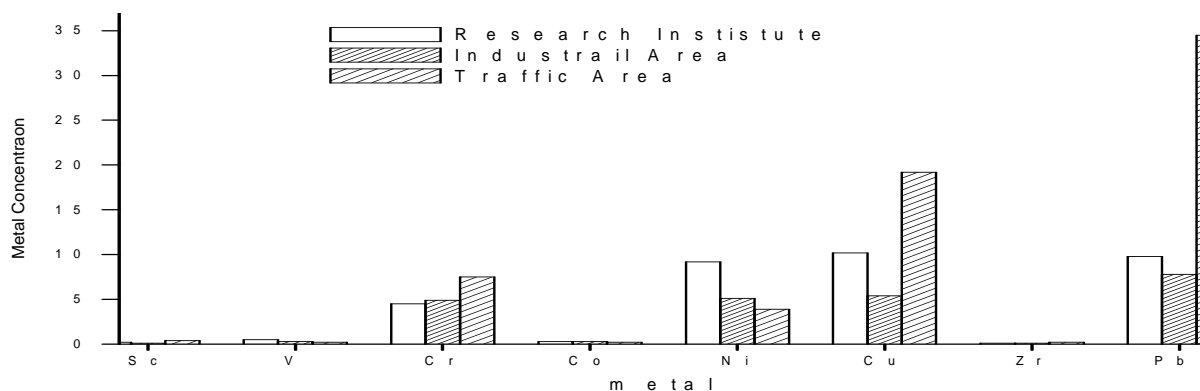
vehicles, ovens and scrap yard of discarded vehicles. The range of the Cu in the dust sample was 2.2 to 19.2 ppm. The highest Cu concentration (19.2 ppm) in traffic area samples and the lowest concentration (2.2 ppm) were found in industrial area samples. The high concentration of Cu in all three sites support the idea that vehicular, traffic movement and industrial activities were the source of heavy metals in this area. The overall concentration of Scandium in all the dust samples were low and range was 0.1 to 0.4 ppm. The highest Sc concentration was found in the traffic area samples and the lowest concentration was found in the industrial area as well as research institute sampling site. Like Sc, the overall concentrations of Vanadium were low and range was 0.1–0.5 ppm. The highest V concentration was found in the research institute site samples and the lowest concentration was found in the traffic area samples. The most important source of atmospheric V is oil and coal combustion<sup>(15, 16)</sup>. Among all the metals Zinc and the Barium concentrations were high and the ranges were 5.3–477 ppm and 23.5–342.5 respectively. The highest concentration of Zn was in the research institute site samples and lowest concentration was found in the traffic site dust sample. The possible important sources for Zn are lithopone (66%  $\text{BaSO}_4$ /34%  $\text{ZnSO}_4$ ), which is widely used as a filler in paint and linoleum,  $\text{ZnO}$ , which is used in paint and rubber fabrication, and zinc chromates, which are the basis of several yellow pigments. It may derive from mechanical abrasion of vehicles<sup>(17)</sup>, and from lubricating oils and tyres of motor vehicles<sup>(18-19)</sup>. The highest concentration of Ba was observed in the traffic area site dust sample and lowest concentration was found in the industrial dust sample. Ba is used as  $\text{BaSO}_4$  to increase the density of brake pads. Sternbecket al.<sup>(20)</sup> found that heavy-duty vehicles are strong emitters of Ba containing fine particles. The range of Zirconium was 0.5–0.2 ppm. The highest

concentration of Zr was observed in traffic area and research institute, industrial area was having very low concentration of Zr. The range of Chromium and Nickel were 7.5-4.5 ppm and 9.2 -1.6 ppm respectively. The highest amount of Cr was found in traffic area, research institute and industrial area were having same mean concentration of Cr. Cr is an important constituent of many metal alloys. It is also contained in cement. Crude oil and coal contain traces of chromium (III), which may oxidize to the chromium (VI) state during fuel combustion. The highest amount of Ni was found in research institute, the traffic area and industrial area were having same

mean concentration of Ni. The origin of Ni in the local atmosphere may also be attributed to the anthropogenic activities, combustion of fossil fuels for power generation<sup>(9)</sup>. The range of Strontium were 52.1 and 4.8 ppm and the highest concentration of Sr was observed in the traffic area and lowest concentration (almost same) of Sr was found in the industrial area and research institute site. The range of Cobalt is 0.3-0.1 ppm and the highest concentration of Co was found in the industrial area and research institute, lowest concentration was found in traffic area.

S.No	Ions	Industrial area			Traffic area			Research institute		
		Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	Cl <sup>-</sup>	2054.84	362.50	1078.34	1381.22	875.81	1128.63	3195.97	387.50	1649.03
2	NO <sub>3</sub> <sup>-</sup>	1138247.50	5179.17	112930.84	65929.76	8351.02	22890.26	189279.48	2331.76	39774.79
3	SO <sub>4</sub> <sup>2-</sup>	2946.08	734.74	1417.96	2822.06	1252.70	1651.17	3055.71	1081.00	1777.45
4	Na <sup>+</sup>	720.78	77.55	438.89	1258.06	272.50	757.58	2603.23	347.02	1141.14
5	NH <sub>4</sub> <sup>+</sup>	2777.96	0.00	484.32	2939.96	160.43	1024.67	4293.33	0.00	948.86
6	K <sup>+</sup>	1819.23	325.71	922.00	1453.06	344.71	835.77	2374.29	310.17	1141.55
7	Ca <sup>2+</sup>	8111.30	2783.67	4963.29	6455.88	2732.68	4330.43	10238.33	3687.35	6437.69
8	Mg <sup>2+</sup>	425.00	158.43	256.88	411.76	179.59	260.98	584.61	171.21	324.53

**Table-1.** Minimum, maximum and mean concentration (ppm) of heavy metals in three sites



**Figure. I.** Heavy metal comparison in three different sites.

### 3.2 Analyses of water soluble ions

The concentrations of the major water-soluble anions and cations in dust samples have been given in Table 2. The highest levels of NO<sub>3</sub><sup>-</sup>, Ca<sup>2+</sup>, SO<sub>4</sub><sup>2-</sup>, Cl<sup>-</sup>, and NH<sub>4</sub><sup>+</sup> were observed at all the three sites. Elevated levels of ions were observed due to the Industrial area site which is located near the major industrial units and in the path prevailing of southern winds that may well transfer the industrial emissions to this site, similarly traffic area site which is at a distance of 5 meter and 1 meter height from the footpath. Significant correlations between major anthropogenic contributors. A major chemical species originating from anthropogenic sources is

anions and cations were observed in office dust samples, as shown in Table 3 to 5. These correlations indicating the common sources of the ions.

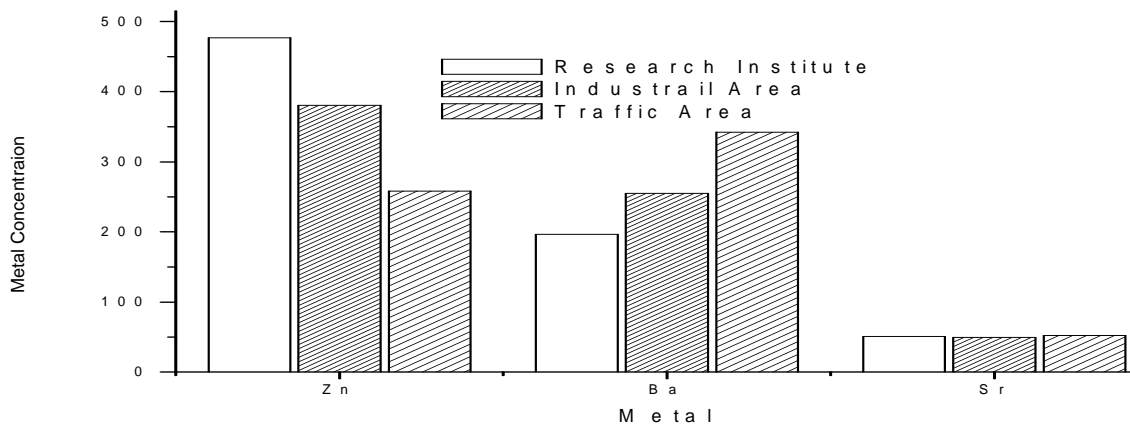
#### 3.2.1 Anthropogenic contribution.

Commonly known sources are two types which are Natural and anthropogenic. Among the natural sources, the major ones of importance to surface loading are sea spray, wind-blown dust, biomass burning/forest fires and anthropogenic activities. Industrial emissions and fossil fuel burning are the SO<sub>4</sub><sup>2-</sup>, formed from conversion of SO<sub>2</sub> (gaseous phase), a major industrial pollutant, by gas to

particle conversion mechanisms. This could be one of the main reasons for the enhancement of species like  $SO_4^{2-}$ .

S.No	Metal	Traffic area			Industrial area			Research institute		
		Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1	Sc	0.4	0.2	0.35	0.2	0.15	0.1	0.1	0.2	0.2
2	V	0.2	0.1	0.15	0.3	0.2	0.2	0.5	0.3	0.3
3	Cr	7.5	0.2	5.4	4.5	0.9	2.5	4.5	1.9	2.6
4	Co	0.2	0.1	0.15	0.3	0.1	0.3	0.3	0.2	0.3
5	Ni	3.9	2.2	3.2	5.1	1.6	3.2	9.2	2.0	5.1
6	Cu	19.2	5.6	12.5	5.4	2.2	4.1	10.2	3.1	7.7
7	Zn	258.2	23.12	121.6	380.3	5.3	178.1	477.0	341.9	424.4
8	Sr	52.1	6.8	22.5	49.5	4.8	19.4	50.9	29.1	41.0
9	Zr	0.2	0.1	0.15	0.1	0	0	0.1	0	0.5
10	Pb	34.5	7.9	18.6	9.8	2.3	5.1	7.8	1	6.4
11	Ba	342.5	23.5	280.6	255.0	50.7	151.7	196.4	69.1	124.7

**Table-2.** Spatial distribution of major anions and cations ( $\mu\text{g}/\text{gr}$ ) in dust samples collected at three sites



**Figure-2.** Heavy metal comparison in three different sites.

**Table-3.** Correlations matrices between major anions and cations in Research institute Sample

	$Cl^{-1}$	$NO_3^{-}$	$SO_4^{-2}$	$Na^{+}$	$NH_4^{+}$	$K^{+}$	$Ca^{+2}$	$Mg^{+2}$
$Cl^{-1}$	1							
$NO_3^{-}$	-0.44	1						
$SO_4^{-2}$	0.47	-0.24	1					
$Na^{+}$	0.89	-0.39	0.42	1				
$NH_4^{+}$	-0.05	0.05	-0.22	-0.02	1			
$K^{+}$	0.34	0.07	0.73	0.57	0.09	1		
$Ca^{+2}$	0.96	0.53	0.07	-0.29	-0.04	0.03	1	
$Mg^{+2}$	0.88	-0.11	0.83	0.23	0.18	0.14	0.14	1

**Table-4.** Correlations matrices between major anions and cations in industrial area samples

	Cl	NO3	SO4	Na+	NH4	K+	Ca	Mg
Cl	1.00							
NO3	-0.15	1.00						
SO4	0.70	-0.07	1.00					
Na+	-0.40	-0.53	-0.11	1.00				
NH4	-0.36	-0.42	-0.15	0.49	1.00			
K+	0.45	-0.04	0.30	-0.69	-0.56	1.00		
Ca	0.58	-0.31	0.85	0.27	-0.26	0.16	1.00	
Mg	0.81	0.14	0.90	-0.20	-0.34	0.17	0.78	1.00

**Table-5.**Correlations matrices between major anions and cations in traffic area site

	Cl	NO3	SO4	Na+	NH4	K+	Ca	Mg
Cl	1.00							
NO3	-0.15	1.00						
SO4	0.70	-0.07	1.00					
Na+	-0.40	-0.53	-0.11	1.00				
NH4	-0.36	-0.42	-0.15	0.49	1.00			
K+	0.45	-0.04	0.30	-0.69	-0.56	1.00		
Ca	0.58	-0.31	0.85	0.27	-0.26	0.16	1.00	
Mg	0.81	0.14	0.90	-0.20	-0.34	0.17	0.78	1.00

Ion	Industrial Area (present study)	Research Institute Area (present study)	Traffic Area (present study)	In Jordan (Q.M. Jaradat et al., 2004)
Cl <sup>-</sup>	1078.34	1649.03	1128.63	7967
NO <sub>3</sub> <sup>-</sup>	112930.84	39774.79	22890.26	1533
SO <sub>4</sub> <sup>2-</sup>	1417.96	1777.45	1651.17	8137
Na <sup>+</sup>	438.89	1141.14	757.58	8870
NH <sub>4</sub>	484.32	948.86	1024.67	-
K <sup>+</sup>	922.00	1141.55	835.77	7962
Ca <sup>2+</sup>				3054
Mg <sup>2+</sup>	4963.29	6437.69	4330.43	
	256.88	324.53	260.98	710

**Table.6.** Average values (µg/gr) of major ions of 3 sites at Hyderabad and comparison with Jordan Industrial area.

### 3.2.2 Crustal contribution

Commonly found element in surface crustal material is Ca. However, Ca has both continental and oceanic sources. Our analysis showed that shows the major contribution to Ca comes from sources other than sea salt, i.e., soil dust. As the concentration of species originating from the CaCO<sub>3</sub> source will vary directly with the source strength. The mean values (µg/gr) of major ions in samples collected at 3 sites in Hyderabad and with a comparison of major ions in Jordan Industrial area<sup>(14)</sup> have been given in Table. 6.

### 4. Conclusion:

The present study indicate that dust samples collected within and around Hyderabad contain non-soil-derived elements whose primary contributors are vehicular traffic and the nearby industries. Traffic appears to be responsible for the high levels of Ba, Cu, Cr, Pb, and Zn. High level of water soluble ions NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, Cl<sup>-</sup>, and NH<sub>4</sub><sup>+</sup> and high concentrations of Ni, V and, Ba are associated with emissions from the industries. Ca<sup>2+</sup> is commonly found in surface crustal material. As regards the grain-size fraction, trace metals in road dust follow different trends. In general, most metals bound to urban sources are independent of particle size and are prevalently enriched in medium-sized particles. This may be due to the fact that these metals derive from the mechanical erosion of vehicular parts or, once emitted into the atmosphere, adhere to pre-existing particles of any nature and dimension.

### 5. References

1. A G Clarke; J M Chen; S Pipitsangchand; ABougar; Sci. Total Environ. (1996), 189/190, 417–422.
2. EB Gonzalez; JMAGarda; ES Velasco; PL ahia., Science Total Environment., (1997), 196, 131–139.
3. C M R Kroger; Environ. Pollut. (1990), 68, 161–170.
4. S Juvanovic; F Carrot; N Deschamps; P Vukotic., Journal of Trace Microprobe Techniques (1995), 13, 463–471
5. G Lapitajs; UGreg; L Dunemann; J Begerow; L Moens; P Verrept., International Laboratory (1995), 5, 21–27.
6. M B Mokhtar, A B Awaluddin; C W Fong; M Woojdy; Bulletin of Environmental Contamination and Toxicology (1991), 52, 149–154.
7. Barbara A. Lesniewska, Beata Godlewska-Zylkiewicz, Beatrice Bocca, Stefano Caimi, Sergio Caroli, Adam Hulanicki. Science of the Total Environment (2004) , 321 , 93–104.
8. Omar. A. Al-Khashman. Atmospheric Environment (2004), 38, 6803–6812.
9. G Dongarra; D Ottonello; G Sabatino; M Triscari; Environmental Geology (1994), 26, 139–146.
10. Serife Tokalioglu, Senol Kartal. Atmospheric Environment (2006), 40, 2797–2805.
11. Keiko Suzuki.. Atmospheric Environment 40 (2006) 2626–2634.

12. MattiNiemelä; PaavoPerämäki; JuhaPiispanen ,JarmoPoikolainen.. Analytica Chimica Acta (2004) ,521,137–142.
13. Lars Herngren ;AshanthaGoonetilleke; AGodwin ; AnalyticaChimicaActa(2006) ,571, 270–278.
14. Qasem ;AJaradat Kamal; Momani ; QAbdel-Aziz ; Jbarah; Adnan Massadeh. Environmental Research (2004),96, 139–144.
15. H Heinrichs;HJ Brumsack,.. V.M. Goldschmidt Conference,31 March–4 April, Heidelberg, Germany, (1996),vol. 1, . 245.
16. G H McTainsh;WGNickling;A W Lynch., Africa. Catena (1997) 29, 307–332.
17. Ajiries; H H Hussein;Z Halaseh; Hydrology Processes.,( 2001),15, 815–824.
18. M S Akhter,IMMadany; Water, Air, Soil Pollution (1993), 66, 111–119.
19. H Arslan;. Journal of Trace and Microprobe Techniques (2001),19 (3), 439–445.
- 20.JSternbeck;ASjodin;KAndreasson; Atmospheric Environment (2002), 36, 4735–4744.