Soil as a Source Contributor in Mineral Dust Fallout at Urban Industrial Residential Area.

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ABSTRACT

The components and quantities of atmospheric dusts fallout has been reported to be the pollution indicator of large urban areas. The multiplicity and complexity of sources of atmospheric dusts in urban regions (e.g. industrial complexes composed of a variety of industrial processes, automobiles, construction activities etc.) has put forward the need of source apportionment of these sources indicating their contribution to specific environmental receptor. The study presented here is focused on investigation of source contribution estimates of dusts fallout in an urban-industrial area, Raipur, India. Six sampling sites have been identified on the basis of land use for development plan of anthropogenic activities and factors related to the transportation and dispersion pattern of atmospheric dusts. 12 samples of dusts fallout has been collected from each site (one in each month) and subjected to chemical analysis of selected chemical constituents known as markers of selected major dust emitting sources(Steel making average, Road traffic-borne dusts, construction activities, municipal waste burning, and soils). Chemical profiles alongwith SPECIATE of USEPA has been used for the preparation of source profiles. Source apportionment has been done using Chemical Mass Balance (CMB 8). Good fit parameters and relative source contribution has been analyzed and documented. Variations in source contribution estimates of selected indicator species has been occurred and justify the significant contribution of local area and line sources of dusts emission in various parts of the study region. Soil has shown different contribution for different radical.

Key words: Soil, Minaral Dust fallout, Urban industrial residential area

1. Introduction

Multiplicity and complexity of dusts emission and transportation has justified the need to determine relative contribution of coarse dusts from specific source (Begum *et al.*, 2007; Kothari *et al.*, 2008; Zhang *et al.*, 2008). It is possible to use statistical techniques to derive source category signatures, identify indoor-outdoor source category signatures, and estimation of their contribution to dusts of receptors (Yokovleva *et al.*, 1999; Andresen *et al.*, 2002; Chowdhury *et al.*, 2004). The effective variance weighed chemical mass can be used for source apportionment of air pollution studies (Watson *et al.*, 1997; 1998). A chemical mass balance model (CMB 8, EPA) consisting a set of solution of linear equations to express each receptor chemical concentration as a linear sum of products of source profile abundances and source contributions has been defined (Friedlander 1973; Cooper and Watson, 1980; Gordon, 1980; Watson, 1984; Watson *et al.*, 1984; Gordon, 1988; Hidy and Venkatraman, 1996). The presented work has been focused on source apportionment of dust

fallout in selected classified urban residential receptor of Raipur City, District Raipur, India which located in global scale of: 21°14'22.7" N latitude and 81°38'30.1" E longitudes. Regression analysis between various longitudinal measurements of selected and defined dust deposit regions has been utilized to identify possible sources/routes of dust transport to a receptor region. Chemical mass balance (CMB8, EPA) has been executed to investigate source contribution estimates of dust fallout in a specific ambient-outdoor receptor located in a residential area.

Increasing severity of dispersion and fallout of fugitive dusts in urban areas of India has shown spontaneous linkage with higher degree of health disorders especially bronchial ailments (Quraishi and Pandey, 1995; Goel and Trivedi, 1998; Bohm and Saldiva, 2000; Sharma and Pervez, 2003; Sharma and Pervez, 2005; Saxena *et al.*, 2008). Due to higher settling tendency of bigger particles of dust near emission sources on a regional scale, researchers have made classification of its reception pattern as ambient-outdoor, street-outdoor and indoor dust fallout (Quraishi and Pandey, 1993; USEPA 2003; Sharma and Pervez, 2004; Gadkari and Pervez, 2007; Dubey and Pervez, 2008). Due to presence of a variety of point, line and area sources of dusts emission alongwith higher degree of variation in meteorological parameters, a non-uniform distribution of dusts in various environmental media has been reported earlier (Sharma and Pervez, 2004). Close deposition pattern and higher degree of relative contribution from local sources, especially temporary dust formation sources, compared to suspended fine particulates has been reported in earlier investigations (Sartor and Boyd, 1972; Pitt and Amy, 1973; Pitt, 1979; Mustard *et. al.*, 1985; Schroder and Hedley, 1986; Schroder *et. al.*, 1987; Illinois State Water Survey, 2003). Adachi and Tainosho (2004) have characterize the street dusts to investigate Zn as tire dust indicator in Japan using reference work done in the field of chemical apportionment of road-traffic settleable dusts earlier (Smolders and Rogge *et al.*, 1993; Davis *et al.*, 2001; Degryse, 2002). Atmospheric deposition of vanadium, lead, chromium, copper, zinc and nickel has been described earlier (Barceloux, 1999; Arslan, 2001; Dundar and Altundag, 2002; Dundar and Pala, 2003; Dundar and Turkoglu *et al.*, 2003; Tuzen, 2003; Deryaoglu, 2005; Dundar, 2006). Large size particles of dusts fallout in urban regions has been reported to be the major cause of prevalence of asthma (occur at upper nasal area) compared to association of fine particulates with inner respiratory disorders (Wieringa *et al.*, 1997; Sax and Richard, 1984; Roosli, 2000; USEPA, 2003).

2. Materials and method (study design, sampling plan and data analysis)

2.1 Study Design

The study was undertaken in urban areas. The goal of the study is to evaluate relative source contribution estimates of various routes of dust fallout in urban residential environment. The objectives here are: (1) To measure and characterize dust fallout at identified sources (2) to analyze statistically, the relationship between dust fall measurements of source-routes and residential receptors and (3) to carryout apportionment of dust fall at residential-receptors, taking identified atmospheric routes as possible sources using Chemical mass balance Model (CMB8). A residential area (Birgaon) located in close proximity to a major industrial area (Siltara) has been selected for the study. Apart from two major industrial sources of dusts emission, local soils, paved road dusts and automobile exhaust emissions along with

construction activities have also been identified to cluster of source profiles for source apportionment. The details of location of residential colony (receptor), major industrial complexes, windrose and wind channels have been shown in Fig 1.

2.2 Sampling Design

A comprehensive study about source contribution estimates of major possible and observable sources of dusts emission to dust fallout of urban areas (residential, commercial and sensitive regions) was started from yr 2007. Source apportionment study of dust fallout of a specific urban-residential region has been presented here. A non-probability based longitudinal stratified random sampling design in space-time frame work has been chosen to achieve the objectives (Gilbert 1987; USEPA, 2003). Ambient-outdoor has been decided as atmospheric measurement levels at identified sources of dust emissions and residential-receptor, respectively (Table 1).

2.3 Sampling Method of Dust Fallout

Dust emission sources were identified using layout map, anthropogenic activity patterns and urban-industrial development plan of the study area. The identified sources **(Table 1**) were classified in point, line and regional sources of dust emission (Goel and Trivedi, 1998). Dust collection Jars (Dimension: dia- 23" ht- 45") with standard specifications(Katz, 1977; Thakur and Deb, 1999) has been placed for a month at a height of 10 ft (ambient-outdoor) at each source and receptor sites, respectively. In case of sampling at paved road (S-3), sampler was installed at the height of 5 ft at major cross road passing through the residential colony. As far as soil (S-6) profile is concern, samples of soils (1 kg) have been collected from open land of residential colony. Soil (S-6) samples were collected after removing surface soils upto 6 cm depth (Gadkari and Pervez, 2008). Frequency of sampling was twelve (one in each month) at each source-receptor site throughout the sampling year. About a liter of double distilled water was placed in each Jar and a net sheet (size: 20 mesh) was placed on mouth of the Jars.

Water soluble and insoluble fraction of dust fallout has been measured separately and by adding them, total dust fallout was measured. Five replicate measurements were done to minimize weighing error (Table 2). Black smoky dust emitted and deposited in automobile exhaust silencers of diesel fuel based heavy duty trucks and petrol based cars have been collected and scum were mixed together for development of chemical profile of automobile source (S-4). Vehicles have been selected randomly which mostly passes through that road junction. About 5-10 g of exhaust emitted black smoky dust has been collected. Frequency of sampling was 12 (one in each month) at each source-receptor site throughout the sampling period (December 2007 to November 2008).

2.4 CHEMICAL ANALYSIS OF DUST FALLOUT

Dried samples of soils and automobile exhaust scum have been powdered using a milling machine. Powder and dust samples were digested in Teflon digestion bomb and nitric acid (HNO_3) and hydrogen peroxide (H_2O_2) (3:1). Teflon bomb was then kept in an electric oven at 80 ^{0}C for 8 h, cooled, and contents filtered in a volumetric flask and washed with dilute HNO_3. Final volume of digested sample was made up to 25 ml using distilled water. Digested samples and soluble fraction of dust fallout measured during field sampling were analyzed

for selected species using inductive coupled plasma-atomic emission spectrophotometer (ICP-AES) (JOBIN-YVON HORIBA ICP Spectrometer Version 3.0).

2.5 DATA ANALYSIS

Measurement data of dust fallout has been documented as geometrical mean and standard deviation of twelve measurements at each monitoring site and presented in Table 2. Regression analysis between annual mean of dust fallout measured at defined receptor site (local-outdoor, indoor and street of Birgaon residential region) and selected source sites (Siltara Industrial complex, Urla Industrial complex, paved road and construction sites) has been conducted and presented in **Fig. 2**.

The source profile abundances (mass fraction of chemicals in the emissions from each source type) and the receptor concentrations, with appropriate uncertainty estimates, serve as input data to the CMB model. The output consists of the amount contributed by each source type represented by a profile to the total mass and each chemical species. The CMB calculates values for the contributions from each source and the uncertainties of those values. The CMB is applicable to multi-species data sets. The CMB modeling procedure requires: (1) Identification of the contributing source type; (2) selection of chemical species or other properties to be included in the calculation; (3) estimation of the fraction of each of the chemical species which is contained in each source type (source profile); (4) estimation of the uncertainty in both receptor concentrations and source profiles; and (5) solution of the chemical mass balance equations. The CMB is implicit in all factor analysis and multiple linear regression models that intend to quantitatively estimate source contributions (Watson, 1984). The chemical mass balance consists of a least squares solution to a set of linear equations which expresses each receptor concentration of a chemical species as a linear sum of products of source profile species and source contribution.

Exact knowledge of dispersion factor of emissions is not necessary in receptor models (Watson, 1984). Geometric mean and standard deviation values of chemical parameters have been utilized for the concentration and uncertainties of corresponding species of specific site for development of source/receptor profiles. All prepared source and receptor profiles has been introduced in CMB model using an INFRA control file to execute source apportionment program (Watson *et al.*, 1997; 1998). Results of CMB execution have been presented in Figs. 3, 4and 5.

3. RESULTS AND DISCUSSION

Profuse and highly skewed dust fallout at outdoor receptor of Birgaon residential area has been observed. It has been observed that geometrical mean level of dust fallout at residential outdoor receptor is thousand times higher than maximum permissible limits (0.01 metric tonn/km2/month) developed in Australia (Ferrari, 2000) and also shown significant increase within a decade (Thakur and Deb, 1999). Dust fallout levels in Siltara industrial area has shown higher deviation pattern in annual geometrical mean compared to that in Urla Industrial area. Soil has shown dominating contribution in annual mean of dust fallout in all monitoring locations. Annual mean of dust fallout at civil construction source site has shown thousand times higher level compared to maximum permissible limits.

Annual mean of selected chemical species measured in dust fallout of S-1 to S-4 has been utilized as source profile for the source apportionment of dust fallout at Birgaon residential outdoor (R-1). Besides, chemical profiles of vehicle exhaust (S-5) and local soils (S-6) have also been prepared and used for source apportionment modeling. Output of CMB8 with good fit parameters has been presented (Fig. 4 and 5). Model calculated source profiles have also been presented (Fig. 3). Multiple source contribution has been observed with dominance of soil (S-6). Lower contribution of Urla Industrial source (S-2) compared to Siltara Industrial source (S-1) has been observed. In contrast to international scenario, vehicle exhaust has shown lower contribution due to predominance of soil dust source.

Iron has shown different pattern of occurrence at the residential outdoor site. Natural soil (S-6) has shown dominance in iron compared to industrial sites due high deposition of industrial waste in soil near to receptor site. In case of manganese contribution, S-1, and 6 have shown similar share with dominance on other source(S-2, 3, 4 and 5). Nickel has shown major contribution from industrial source (S-1) followed by soil. S-1 has shown dominance on lead contributor (38%) to receptor dust fallout (R-1) and soil has shows low contribution relatively to other sources. Local construction, paved road and vehicle exhaust have shown significant relative contributions.

In conclusion, dust fallout at outdoor atmospheric level in Birgaon residential area (R-1) is not only affected by a single source but soil (S-6) has shows significant contribution remaining all sources. Siltara Industrial area (S-1) has also shows good contribution in dust fall at receptor site (R-1). Except Lead all other elements (Fe, Mn and Ni) shows good emission from soil (S-6) at urban industrial residential area Birgaon (R-1) due to highly precipitation of industrial waste in the soil of the residential area.

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Table 01: Identification and grouping of defined sources and receptor in the study area

S.No.	Name of Source/receptor	Type	Classification of monitoring level	Site characteristics	Sampling Frequency
Source sites					
S-1	Siltara industrial area	Stationary point	Ambient-outdoor	Most of the industries are: casting, sponge iron, steel foundries.	**12** samples throughout the sampling year(One in each month)
S-2	Urla Industrial, area	Stationary point	Ambient-outdoor	Most of the industries are: casting, chemical, oil production, glass and plastics.	
S-3	Paved road	Line	outdoor	Re-suspended dusts of road side runoff measured at 3ft height	
S-4	Civil construction	Area	Ambient-outdoor	Dusts emitted from handling of raw materials used in civil construction site	
S-5	Automobile	Point	Emission outlet	Mixed dust fraction emitted from silencer of truck, cars and two wheelers	
S-6	Local soils	Area source	-	Re-suspension of soil dusts	
R-1	Birgaon, Raipur	Residential area	Residential area located northeasterly and downwind to industrial complexes		**12** samples throughout the sampling year(One in each month)

Table2. Dust fallout at selected source/receptor sites in Raipur, India.

S-1	S-2	S-3	S-4	S-5	S-6
181.186±77.974 (131.51-391)	217.429±24.414 (178.54-245.29)	141.435±18.324 (122.73-186.25)	87.845±16.366 (67.71-116.54)	ND	ND

Values in parenthesis are minimum and maximum levels throughout sampling period in (metric tonn.km^{-2}.month^{-1}).

Abbreviation: ND- Not measured

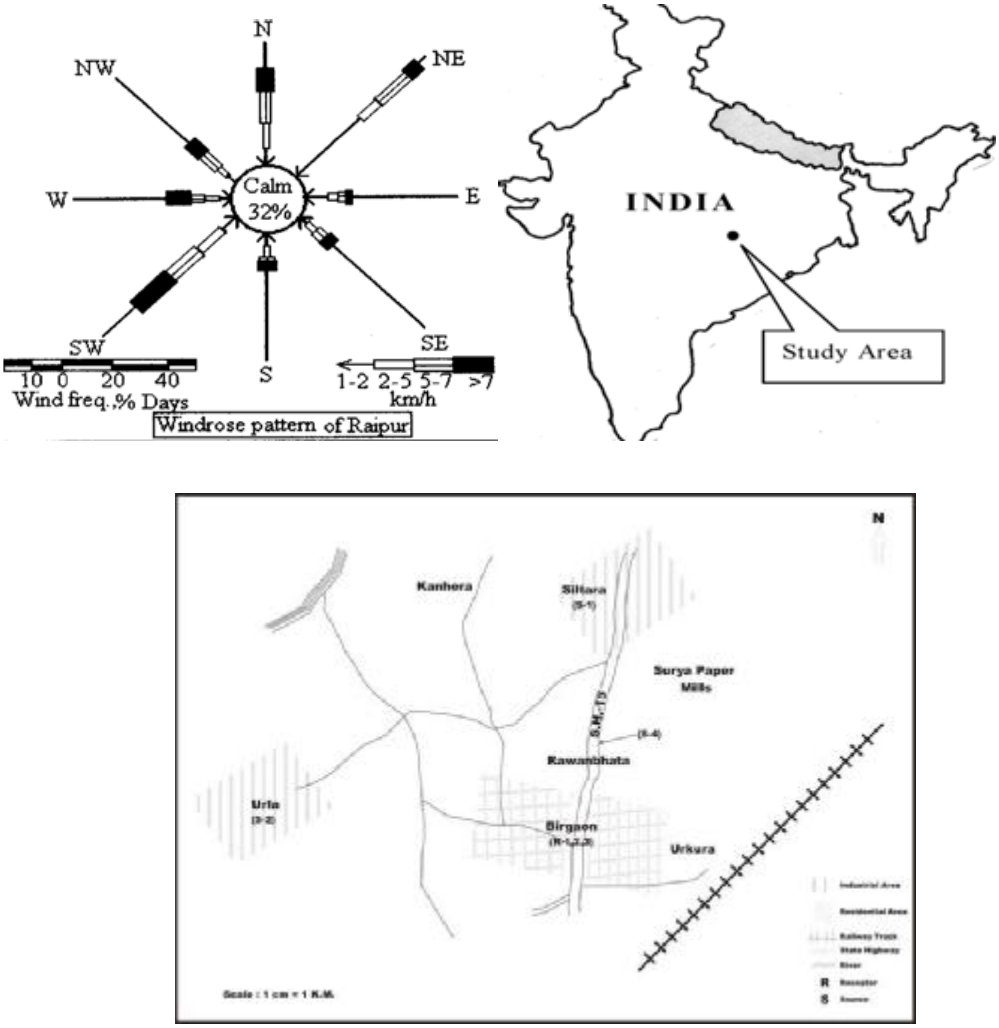


Fig. 1. Local ap of source and receptor sites in Raipur City along with annual windrose of the region.

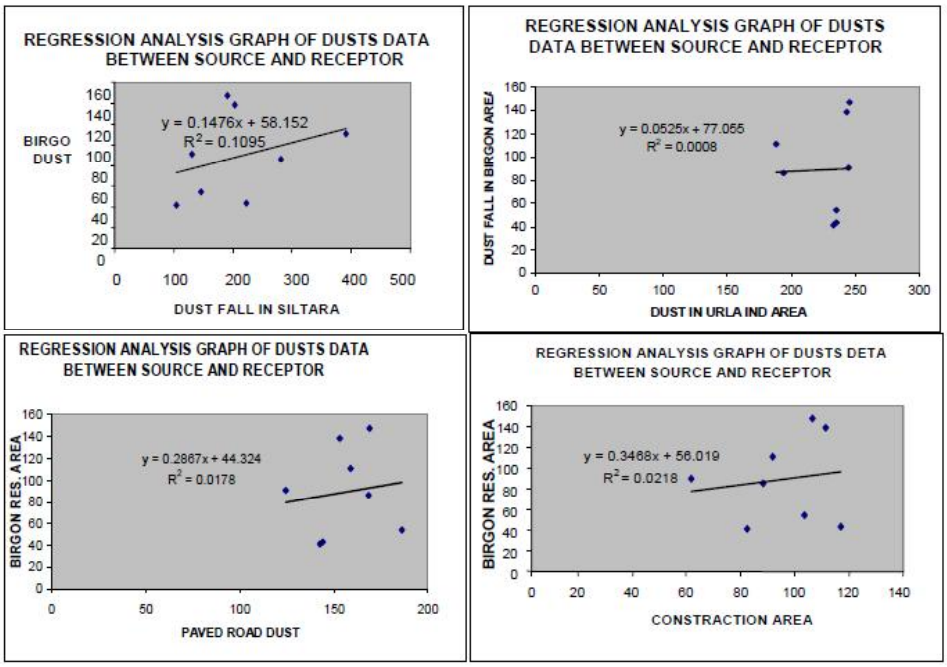
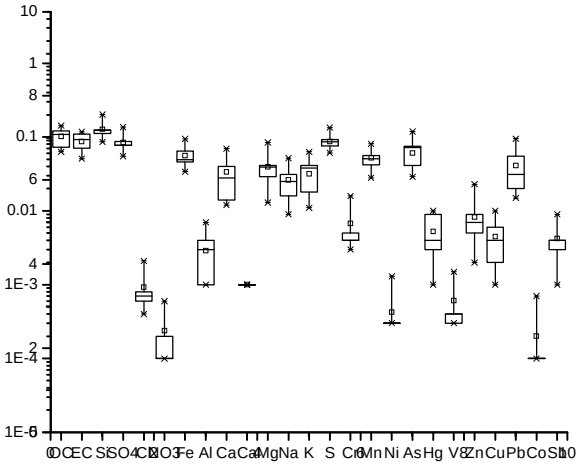
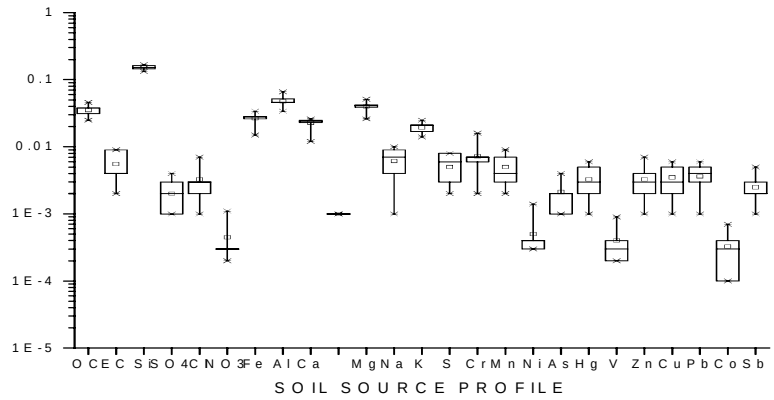
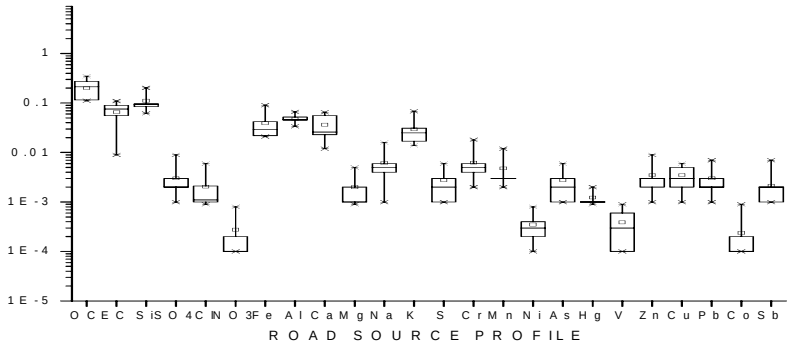
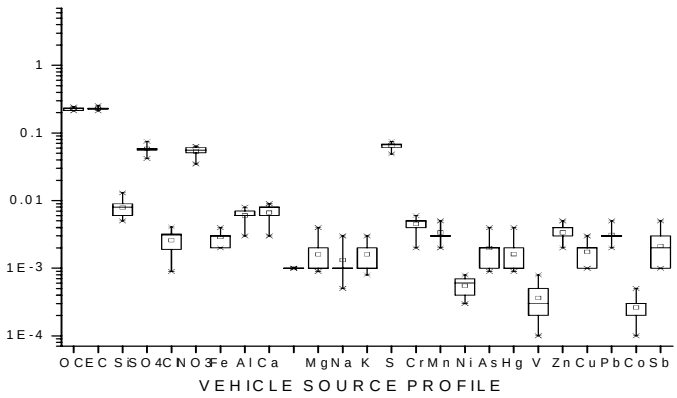


Fig. 2. Regression analysis of selected source dust fallout measurements with its component measured at receptor site.




1
0.1
0.01
1E-3
1E-4
1E-5
OCEC SiSO4C NO3Fe AlCa MgNa K S CrMnNiAsHg V ZnCuPbCoSb
SOIL SOURCE PROFILE


1
0.1
0.01
1E-3
1E-4
1E-5
OCEC SiSO4C NO3Fe AlCaMgNa K S CrMnNiAsHg V ZnCuPbCoSb
ROAD SOURCE PROFILE


1
0.1
0.01
1E-3
1E-4
OCEC SiSO4C NO3Fe AlCa MgNa K S CrMnNiAsHg V ZnCuPbCoSb
VEHICLE SOURCE PROFILE

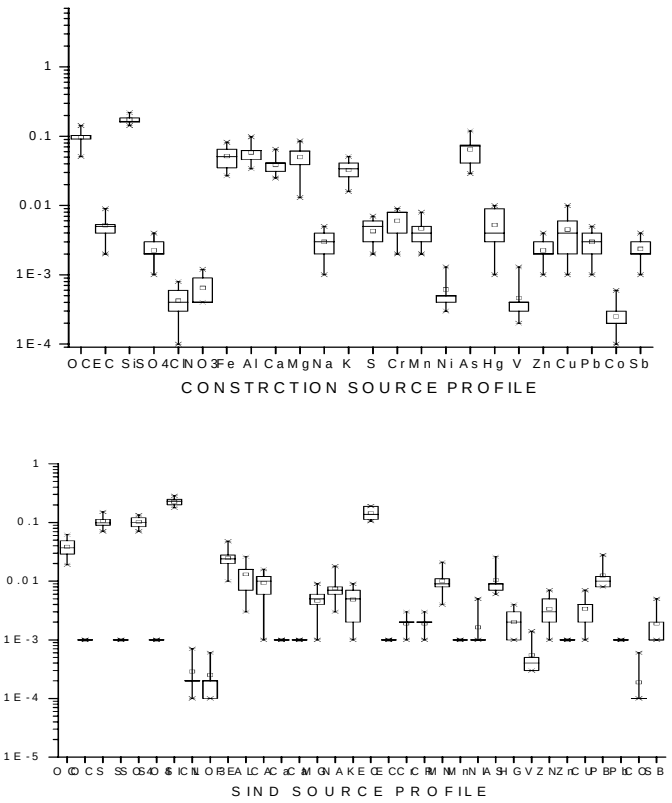


Fig.3. Profiles of identified sources developed by Chemical Mass Balance Model (CMB 8).

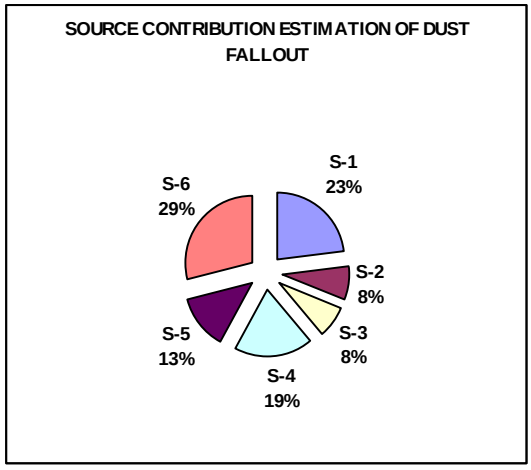


Fig.4. Relative source contribution estimates of atmospheric dust fallout (Annual average) at Birgaon-residential area of Raipur, India.

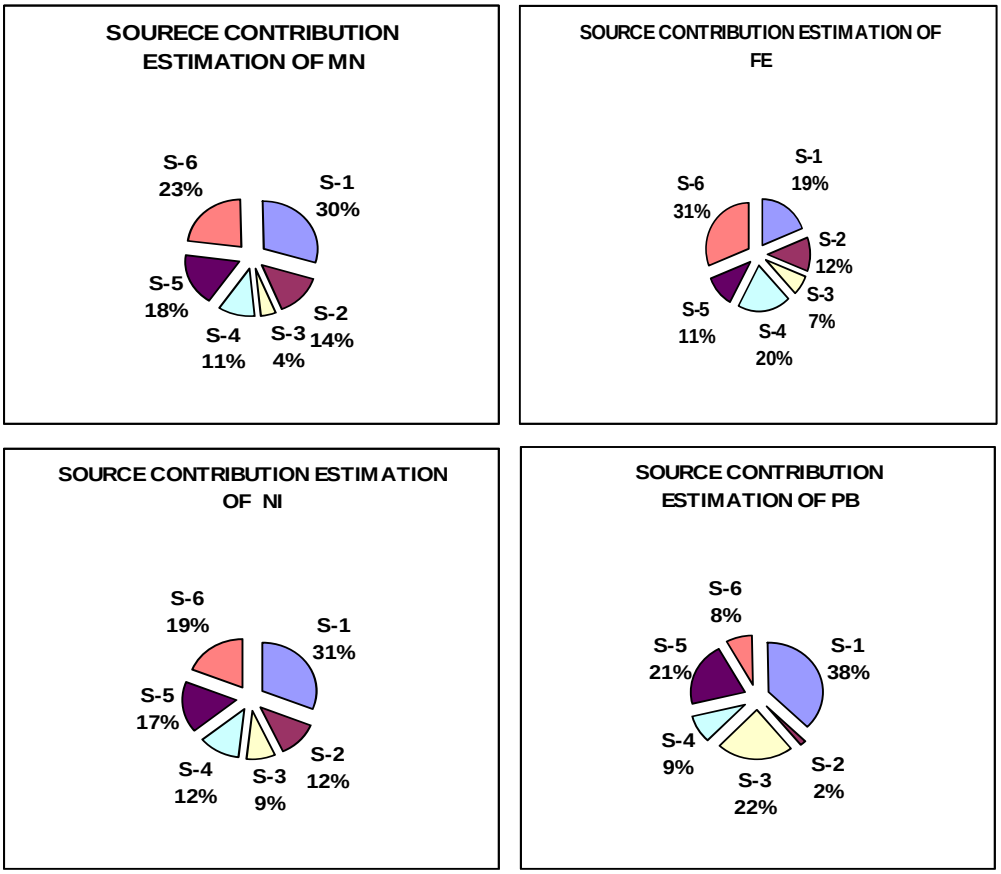


Fig.5. Relative source contribution estimates of selected parameters at receptor.