ATMOSPHERIC DEPOSITION OF HEAVY METALS IN A SEASONALLY DRY TROPICAL URBAN ENVIRONMENT (INDIA)

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ABSTRACT

The rapid industrialization and urbanization have lead atmospheric deposition of heavy metals to become a global problem. We investigated the atmospheric deposition of seven heavy metals (Pb, Cd, Cr, Ni, Zn, Mn, and Cu,) at selected urban and sub – urban sites of Varanasi (India). Based on the traffic density and preliminary air quality data, the city was categorized into four different zones namely, heavy traffic zone (Zone I), commercial zone (Zone II), residential zone (Zone III) and sub–urban zone (Zone IV). Three sampling stations were selected in each zone. Zone I include Ramnagar, Lahartara and Cantt railway station area. Zone II is characterized by the city centre including Maidagin, Lanka and Lahurabir. Sigra, Mahmoorganj, and Orderly Bazar areas have been included in Zone III and Shivpur, Umarahan and Banaras Hindu University Campus represent Zone IV. Particulate samples were collected from all the 12 urban and sub–urban locations of Varanasi using deposition collectors and metal concentrations were determined using atomic absorption spectrophotometer.

At Zone I, the annual dust fall rates were 17.36, 11.85 and 11.65 t/ ha/ yr for Ramnagar, Lahartara and cantt area respectively. At Zone II dust fall rates were 8.56, 9.47, 11.01 t/ha/yr for Maidagin, Lanka and Lahurber respectively. Annual dust fall rates of 8.02, 5.51 and 8.01 t/ ha/yr were recorded for Sigra, Mahmoorganj and Ordely Bazar (Zone III) and 5.39, 6.09 and 6.35 t/ ha/ yr for Shivpur Umarahan and Banaras Hindu University area respectively (Zone IV). Among the heavy metals, atmospheric deposition appeared maximum Mn (387.3 g/ha/ yr) followed by Zn (336.69 g/ha/y), Cr (124.4 g/ha/y), Pb (71.0 g/ha/y), Ni (51.2g/ha/y), Cu (39.8 g/ha/y), and minimum for Cd (6.93 g/ha/y). On the basis of heavy metals deposition rates, different zones considered in this study can be ranked in decreasing order as heavy traffic zone> commercial zone> residential zone> sub – urban areas. Distributions of air – borne heavy metals were correlated with meteorological variables such as temperature, relative humidity and wind velocity.

Key Words : Atmospheric deposition, Heavy metal, Particulate matter, Traffic zone

INTRODUCTION

Degradation of air quality, particularly in urban areas of developing countries is one of the most alarming problems of modern civilization. Human activities today are release a variety of gases and liquid/ soiled particles (aerosols) to the atmosphere. The cumulative effects of all these air pollutants on the climate of the earth and on the health of its life system[1].

In recent years, the level of particulate

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matter and dry deposition dust has been of concern the world over because several studies indicate that particles may induce severe effects on public health[2-4]. Yet in India, very few studies have reported the health implication of particulate matter. One of the correlating health's with air pollution in India comes from the World Bank in 1995.

A study conducted by J. N. Pande in All India Institute of Medical Science, New Delhi reveals that air pollution in Delhi is responsible for over 40% of emergency hospital admission with respiratory and heart problem[5].

The varying degree of metal concentration in dry deposition dust has a great significance because of toxic to the living organisms. During the past few years, a large amount of work has been carried out in different parts of the world to assess the environmental pollution by heavy metals in soil, vegetation and environment[4]. In urban atmosphere, these metals originate mainly from vehicular and industrial emission[6].

Metal pollutants are emit into the atmosphere from numerous sources including combustion of fossil fuels, metals smelter and alloy refineries, cement manufacturing plants and municipal incinerators. Metal and metallic compounds emitted in the atmosphere in three distinct physical forms: solid particulate matter, liquid droplets (mists) and vapours[7,8].

OBJECTIVE

The objective of this work was to determine the concentration of some of the toxic metals (Cr, Ni, Cd, Pb, Mn, Zn, and Cu) in air-born dust in different representative urban areas of Varanasi city (India).

MATERIAL AND METHODS

The study was conducted in the urban and subs – urban area of Varanasi city. It is situated in the eastern Gangetic plain (25^0 18'N latitude and 83^0 01'E longitude) of northern India. The climate of the area is tropical monsoonic, with three distinct seasons, hot and dry summer (March to June), warm and wet rainy (July to October) and a cool and dry winter season (November to February). The first half of the summer season experiences strong hot dry winds and high temperature, while the second half is generally hot and humid.

Sampling of Atmospheric Dust :

The samples of atmospheric dust were collected in a cylindrical plastic container having 6.8 cm to 7.8 cm diameters. The containers were at placed height of about 3 to 5 meter from the earth surface at selected sites. After the collection of dust container, measured the dust fall rate. The dust fall rate calculated by:

$$\text{Dust fall rate} = \frac{\text{Wt. of dust}}{\text{Area}}\,\text{T / ha / yr}$$

Analysis of Dust Samples :

After collection of samples from each sites and this atmospheric dust analyzed by Nitric acid + Sulfuric acid + Perchloric acid (ternary acid) triacid digestion methods.

A Perkin – Elmer model 2130 Atomic Absorption Spectrophotometer was used to determine the concentrations of heavy metals (Cd, Cu, Zn, Pb, Ni, Mn and Cr) in the filtrate of dust samples.

RESULTS AND DISCUSSION

The annual average dust fall were measured at 12 different sites of Varanasi city, which are the representative of four Zones. At Zone, I (Heavy Traffic Zone) included Ramnagar, Lahartara and Cantt. Railway station area received high amount of dust fall – out as 17.36 T/ha/yr, 11.85 T/ha/yr and 11.65 T/ha/yr respectively. At Zone II (Commercial zone), which include Maidagin, Lanka, Lahurabir areas received the dust load as 8.56 T/ha/yr, 9.47 T/ha/yr and 11.30 T/ha/yr respectively. At Zone III (Residential zone) included Sigra, Mahmoorganj, Orderly Bazar areas received dust load as 8.02 T/ha/yr, 5.51 T/ha/yr and 8.01 T/ha/yr respectively and at Zone IV (Sub–urban zone) which included Shivpur, Umarahan and B.H.U campus

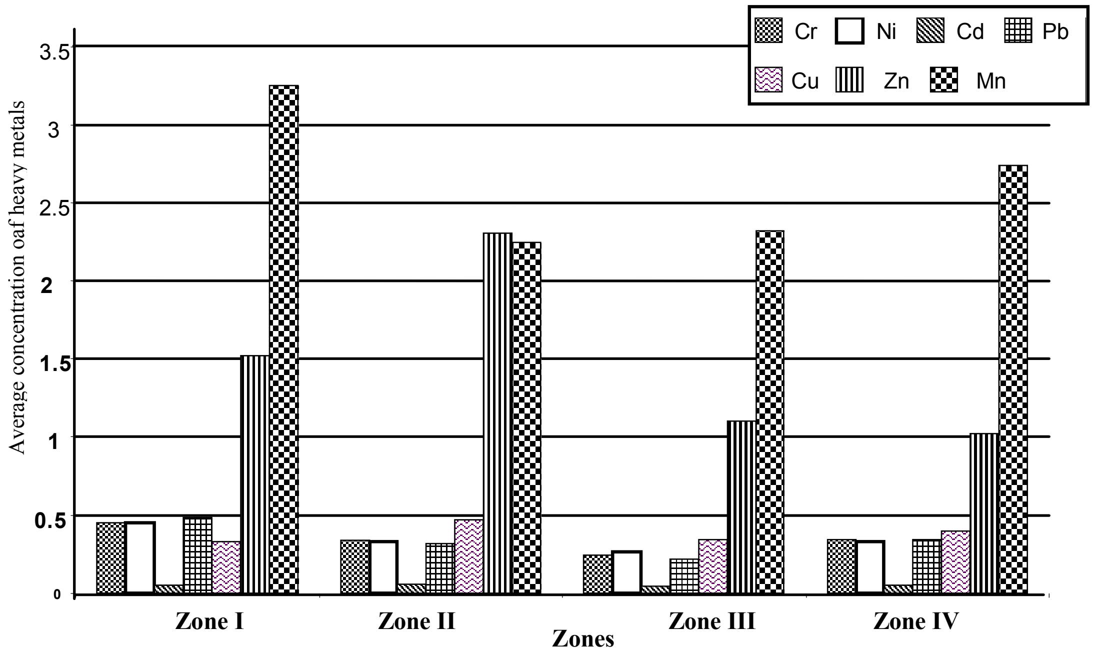

Fig. 1 : Average concentrations of selected heavy metals in different Zones of Varanasi (India).

received 5.39 T/ha/yr, 6.09 T/ha/ yr and 6.35 T/ha/yr respectively.

The widespread problem of dry deposition in the country is due to the synergistic effects of both anthropogenic and natural sources. Some of the sources are extensive urbanization, industrialization, construction activities, increased vehicular pollution, biomass burning, increasing desertification and decreasing vegetation cover.

The result of dust – fall measurement in 12 sites representing three each of residential,

Table 1 : Average concentrations of selected heavy metals in four Zones of Varanasi (India)

Zones	Concentration of heavy metals in ppm						
	Mn	Zn	Cr	Pb	Ni	Cu	Cd
Zone I	3.25 (2.131 – 3.873)	1.519 (0.53 – 3.093)	0.453 (0.315 – 0.622)	0.483 (0.32 – 0.71)	0.452 (0.390 – 0.512)	0.328 (0.183 – 0.470)	0.05 (0.042 -0.061)
Zone II	2.249 (1.30 – 3.034)	2.309 (0.952 – 3.741)	0.335 (0.168 – 0.432)	0.316 (0.21 – 0.40)	0.329 (0.181 – 0.441)	0.467 (0.253 – 0.673)	0.059 (0.043 – 0.077)
Zone III	2.321 (2.230 – 2.390)	1.104 (0.588 - 2.092)	0.245 (0.204 – 0.235)	0.22 (0.20 – 0.25)	0.266 (0.271 – 0.315)	0.341 (0.244 – 0.468)	0.042 (0.041 – 0.042)
Zone IV	2.742 (2.303 – 3.214)	1.020 (0.379 -1.929)	0.343 (0.280 – 0.460)	0.343 (0.28 – 0.46)	0.333 (0.28-0.46)	0.397 (0.166 – 0.796)	0.053 (0.041 – 0.70)

commercial, heavy traffic and sub – urban areas for a period of one year are recorded in table. 1. The results showed that the dust deposition rate varied between 5.39 to 17.36 T/ha/yr. Minimum values were found during monsoon and maximum in the summer. During March – April, high rate of dust – fall could be due to air borne dust as a result of frequent nor – western. During monsoon, they are washed out more or less efficiently by rain but in other season, dry deposition is predominant. Experiments done by U. S. researchers indicates dust – fall rate in tropical environment, like India is found to be many times higher than that in temperate countries climate, like U.S.A cities[9].

The concentration of ecotoxic heavy metals, namely Pb, Cd, Cr, Ni, Zn, Mn and Cu are mentioned in Table. 1. Heavy metals compositions of dust showed the following characteristics Mn> Zn > Cr > Pb > Ni > Cu > Cd. Level of Heavy Metal Concentrations in Varanasi:

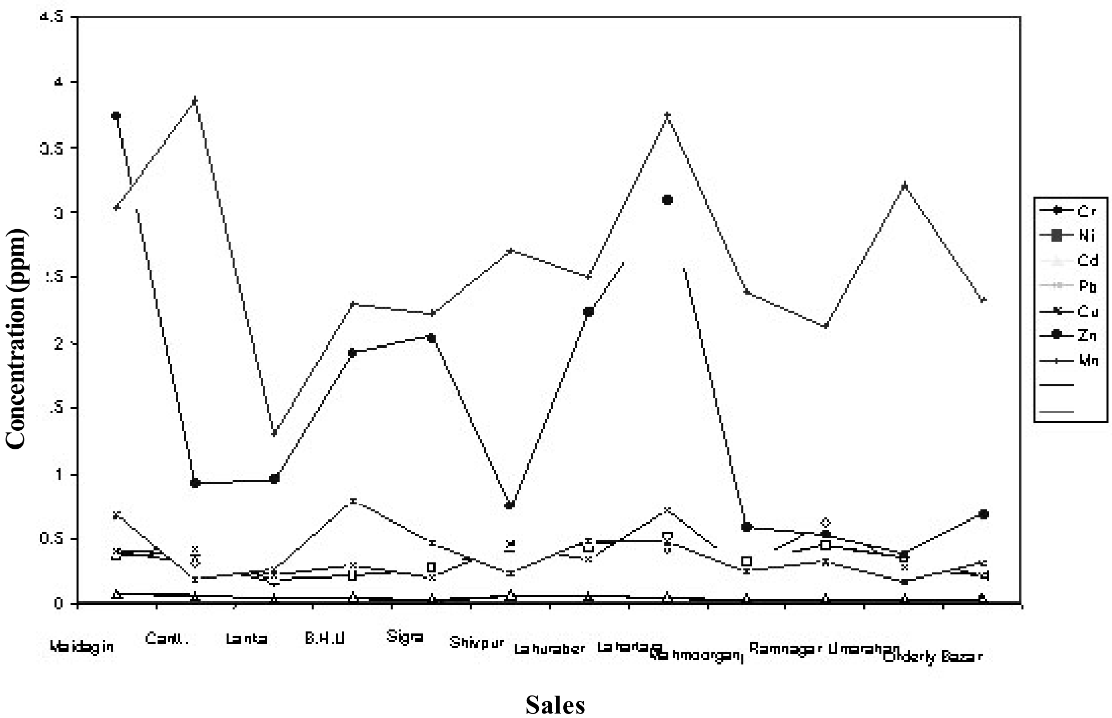

Fig. 2 : Concentration of selected heavy metals in different sites

Mn :

The average value of Mn at Zone I (heavy traffic zone) has been found to be 3.25 ppm and ranges between 2.131 – 3.873 ppm. This is highest value of average Mn among all of Varanasi city studied and is 1.5 times more than the lowest value found in different zones. The concentration of Mn at zone II ranges between 1.308 – 3.034 ppm, 2.230 – 2.390 ppm at zone III and 2.303 – 3.214 ppm at zone IV.

As a whole, the percentage concentration of Mn in the total annual dust – fall of the city is calculated to be 42.4×10^{-4} %. On an average, the whole urban part of the city encircling an area of 112.3 Km^2 is calculated to receive a huge amount of 387.3g/ha/yr.

Zn :

The average value of Zn at zone I have been found to be 1.519 ppm and ranges between 0.530 – 3.093 ppm. The concentration of Zn at Zone II is 2.309 ppm, which ranges between 0.952 – 3.741 ppm. This is the highest value among all zones of city Varanasi studied. The concentration of Zn at zone III ranges between o.588 – 2.042 ppm and at zone IV between 0.379 – 1.929 ppm.

As a whole, the percentage concentration of Zn in the total annual dust – fall of the Varanasi city is calculated to be 36.8×10^{-4} % .On an average, the whole urban part of the city encircling an area of 112.3 Km^2 is calculated to receive a huge amount of 336.9g/ha/yr.

Cr :

The average value of Cr at zone I has been found to be 0.453 ppm. It ranges between 0.315 – 0.622 ppm. These are the higher concentration than the Cr found in commercial, residential or sub – urban zones. At zone II the average concentration of Cr has been found to be 0.335 ppm which ranges between 0.168 – 0.432 ppm. The average concentration of Cr at zone III was 0.245 ppm, which ranges between 0.204 – 0.235 ppm and at zone, IV, was 0.343 ppm, which ranges between 0.204 – 0.460 ppm.

As a whole the percentage concentration of Zn in the total annual dust – fall of the Varanasi city is calculated to be 13.16×10^{-4}%. On an average, the whole urban part of the city encircling an area of 112.3 Km^2 is calculated to receive a huge amount of Cr as 124.4 g/ha/yr. Cr originates from combustion of fossil fuel and industrial activities can cause irritation of respiration system, perforation of nasal passages and lung cancer, chronic exposure may also lead to liver and kidney damage.

Pb :

The average value of Pb at zone I have been found to be 0.483 ppm and range between 0.32 – 0.71 ppm. This is highest value of average Pb among all the areas of Varanasi city studied. The concentration of Pb at zone II has been found to 0.316 ppm and is ranges between 0.21 – 0.40 ppm. At zone III the concentration is found to 0.22 ppm, which ranges between 0.20 – 0.25 ppm and at zone IV the Pb concentration was 0.343 ppm and is ranges between 0.28 – 0.46 ppm.

As a whole, the percentage concentration of Pb in the total annual dust – fall of the Varanasi city is calculated to be 7.7×10^{-4} %. On an average, the whole urban part of the city encircling an area of 112.3 Km^2 is calculated to receive a huge amount of 71.0 g/ha/yr

The concentration of Pb found in various environmental compartments boarding a roadway is a function of a number of factors, including distance and meteorology[10] . Pb constitutes over 20% of total mass of fine particles emitted from cars, burning leaded gasoline. Approximately 75% of Pb contained in leaded gasoline emitted directly to the atmosphere. However, it has been recorded that only 25% of Pb emitted by vehicle are in coarse fraction and thus deposit close to roads.

The remaining 75% is in fine fraction and so may remain airborne[11,12]contaminating areas more remote from the point of its emission.

Ni :

The concentration of Ni in the dust – fall of zone I is found to be 0.452 ppm which is ranges from 0.390 – 0.512 ppm. This is the highest among the all zones studied at Varanasi city. At zone II the concentration of Ni is found to be 0.329 ppm, which ranges between 0.181 – 0.441 ppm. At zone III the average Ni concentration is 0.266, ranges between 0.217 – 0.315 ppm and at zone IV the Ni has been found to be 0.333 ppm which ranges b/w

0.28 – 0.46 ppm

As a whole, the percentage concentration of Ni in the total annual dust – fall of the Varanasi city is calculated to be 5.6×10^{-4} %. On an average, the whole urban part of the city encircling an area of 112.3 Km^2 is calculated to receive a huge amount of 51.2 g/ha/yr.

Ni in the Atmosphere originates from the combustion of fossil fuels, smelting and volcanoes. It is also found that combustion of oil and incineration of waste contributes more than 70% of total Ni to the atmosphere from man made sources followed by refining process with 17% (IPCS, 1991b). Continuous and prolonged exposure to Ni can produce dermatitis and disorders in the respiratory system and it is a possible carcinogen.

Cu :

Copper has been found to be in the dust – fall out at different sampling sites of Varanasi. At Zone, I the average concentration of Cu found to 0.328 ppm, which ranges between 0.183 – 0.470 ppm. The highest average concentration of Cu was observed at zone II i.e. 0.467 ppm and is ranges between 0.253 – 0.673 ppm. At zone III the average Cu concentration was 0.341 ppm, which is range between 0.244 – 0.468 ppm, and at zone IV the average Cu concentration was 0.397 ppm, ranges between 0.166 – 0.796 ppm

On an average of whole urban part of Varanasi city encircling an area of 112.3Km^2 receives a moderate amount of 39.8 g/ha/yr and the percentage concentration of Cu in the annual dust – fall is calculated to be 4.3×10^{-4} % in the total dust – fall out.

Cd :

Cadmium has been found to be present in the dust fall out at different zones of Varanasi city. At Zone I the average concentration of Cd was found to 0.05 ppm, which is ranges between 0.042 – 0.061 ppm. The highest average concentration of Cd was observed at zone II i.e. 0.059 ppm, which is ranges between 0.043 – 0.077 ppm. At zone III, the average Cd concentration was 0.042 ppm, which is range between 0.041 – 0.042 ppm and at zone IV the average Cd concentration was found to be 0.053 ppm, range between 0.041 – 0.070 ppm. On an average of whole urban part of the city encircling an area of 112.3 Km^2 receive a moderate amount of 6.93 g/h/yr and the percentage concentration of Cd in the annual dust fall is calculated to be 0.75×10^{-4} % in the total dust fall - out.

Most of Cd comes from anthropogenic sources. The important sources of pollutant Cd are coal and oil combustion, polymetallurgical non – ferrous metal production such as Pb, Cu – Ni, Zn – Cd production and mining and other manufacturing. Chronic exposure to Cd can result in respiratory illness, hypertension and heart enlargement resulting in premature death.

This result indicated that the dust fall rate, as discussed, so also the concentration of trace metals are increased with higher percentage relative humidity, lower temperature and silent wind situation. From the data, it may be inferred that the meteorological factors play important role in the deposition of metal pollutants from dust fall at all the sampling sites, barring few cases.

CONCLUSION

The present work is an effort to provide a common picture on the current load of pollutants in the form of dust in a rapidly growing urban city. In heavy traffic zone normally the metal concentration (Mn, Cr, Pb, Ni) are higher in comparison to other zones. Average and singly sample metal concentrations always lower in residential composition of particulate matter shows highest level for Mn and the lowest for Cd. Higher level of Pb and Ni metal concentration in heavy traffic area is quite obvious and is due to vehicular emission, apart from the other contributing sources. Anthropogenic activities, wind velocity etc. are major contributor for the dust fall –out and other metals elements in the dry deposition. The meteorological parameters Viz. temp, Relative Humidity, wind velocity and rainfall have shown the correlation with dust fall in a particular site. Overall the occurrence of metal concentration was found in the order heavy traffic zone > commercial zone > residential zone > suburban zone.

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