Elemental Characterization of Aerosols in Wet Deposition along a Dense Traffic Highway in Ogbomoso, Nigeria

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ABSTRACT

Atmospheric samples of wet deposition were collected at seven sampling locations along a dense traffic highway in Ogbomoso, Nigeria for one month. Wet deposition flux evaluated ranged from 0.4926-0.6015 $\mu\text{g}/\text{m}^2\cdot\text{d}$. Particulate matters samples were analyzed for ten trace metals through Atomic Absorption Spectrophotometer (AAS). Trace metals were extracted from filters with digestion method using a mixture of HNO_3 and H_2O_2 . The average concentration of the trace metals: Cd, Cr, Mn, Pb, Zn, Cu, As, Ca, Ni and Fe, in wet deposition were 45.42, 52.46, 15.29, 71.23, 458.9, 747.2, 22.92, 291.3, 63.32, 744.2 $\mu\text{g}/\text{m}^3$ respectively. These concentrations were higher than WHO and FEPA standard limits of trace metals in air. The mean concentrations of trace metals in wet deposition were found in the order of $\text{Cu} > \text{Fe} > \text{Zn} > \text{Ca} > \text{Pb} > \text{Ni} > \text{Cr} > \text{Cd} > \text{As} > \text{Mn}$. Correlation studies showed that the trace metals originated from common source along the highway: Cd was highly correlated with Cr ($r=0.7607$), Cr was highly correlated with Zn ($r = 0.912$), Pb with Cu ($r=0.9559$), Ca ($r=0.7632$) and Ni ($r=0.9114$). Enrichment factor analysis showed that Cd, Cr Zn, Cu, As Pb and Ni originated from anthropogenic sources, majorly traffic and industrial activities while Fe and Ca were of crustal origin.

Keywords: Anthropogenic, Highway, Particulate matter, Trace metals, Wet deposition

1. INTRODUCTION

The urban atmosphere is exposed to various atmospheric pollutants, which include a range of chemical species, ranging from metals to organic and inorganic compounds [1,2]. Trace metals are important inorganic compounds emitted from natural sources as well as anthropogenic activities [3-5]. The natural sources include windborne dust, sea spray, volcanic activities and biomass burning, while emissions of particles attributable to human activities arise primarily from sources such as fuel combustion, industrial processes, non-industrial sources and traffic emissions [6-8]. Some of these trace metals, particularly, Ca, As, Cd, Cu, Fe, Pb, Zn, Cr, Ni, and Mn are classified to be of major concern, because of their persistence in the environment, toxicity, potential carcinogenic characteristics, and increased mortality rates [9-17]. Traffic related emissions have been identified as one of the most significant sources contributing to urban air pollution [3,18,19]. Non-crustal elements associated with particulate matter near the highways mostly come from vehicle emissions [20,21]. Studies conducted on vehicular emissions along highway in several urban regions such as New Jersey, (US), Helsinki Metropolitan area (Finland) and Dhaka, (Bangladesh) have shown that the concentration of trace elements varied as a function of distance from highway [22-25].

Ogbomoso axis of Ibadan-Ilorin highway being a major route linking northern and southern region of Nigeria has witnessed an increased traffic level by cars and motor cycles due to the influx of both staff and students to the University and the University Teaching Hospital, which were not in existence some years ago, coupled with traffic flow of heavy trucks. In addition, the government has opened up road construction work along the highway for more than three years and the roads have not been well covered with bitumen. All these have given rise to high traffic emission and dust generation along the highway. Although, deposition of aerosols in urban areas is widely recognized, only few studies have been devoted to the Ogbomoso area. Yet the reported studies focused on gases in aerosols [26], while those that focused on trace metals used soil and vegetation as the study media [27]. Hence, there is need to investigate wet deposition and characterize trace metals associated with wet deposition of aerosols along the highway. This research aimed at investigating the characteristics of wet deposited aerosols along Ogbomoso Section of Ibadan - Ilorin highway.

2. MATERIALS AND METHODS

2.1. Sampling site and sampling procedures

Sampling site: The Ogbomoso city is a pre-colonial urban center and the second largest city, both in terms of population and spatial extent, in Oyo State, Nigeria. The city is situated in South-Western Nigeria ($4^{\circ} 16' 0''$ East; $8^{\circ} 8' 0''$ North) Fig.1. It is located at a distance of about 100 km north of Ibadan, the Oyo State capital, and about 52 km from Ilorin, Kwara State capital. The study area (Figure 1) is one of the important gateways to the Northern part of Nigeria from the Yoruba land. It develops laterally towards the north and south along the Ibadan-Ilorin road²⁸. The city is characterized by two distinct seasons: dry (November – February) and wet (March – October) with a mean annual rainfall of 1200 mm distributed seasonally. Temperature ranges are small and constant throughout the year. Its hottest month records 32.48°C (90°F) and its coolest month 26.88°C (70°F) with the temperature range of not more than 8°C (20°F). Being located along Ibadan – Oyo – Ilorin route, Ogbomoso has witnessed growth in road traffic [26]. There has not been an increase in industrial activities along the highway. Major industries in the town include small agricultural processing industries, welders' workshop, paint and pharmaceutical industries. On the other hand, there has been an increase in the number of vehicles for personal and commercial use in the town. Thus, traffic emission

Fig. 1: Location of Ogbomoso in Oyo State.

and road dust are expected to be the major sources of air pollution along the highway. The selection of the sampling site was based on several factors including nearness to the highway, safety of the deposition gauges, minimizing potential for sample contamination, and ease of access. Based on the above criteria, seven sampling spots were chosen along Ogbomoso section of Ibadan-Ilorin highway. The characteristics of the sampling spots are given in Table 1. This research work was carried out along Ibadan- Ilorin highway that spans Ogbomoso township. Wet deposition samples were collected, filtered, and wet deposition fluxes of trace metals were evaluated considering the collection area and sampling period. The filters were analyzed for ten trace metals using Atomic Absorption Spectrometry (AAS).

Sampling procedure: Wet deposition samples were collected for thirty days in in the month of October. All the filters used to collect samples were kept in a desiccator for 2 hrs before use for conditioning. The weight of the conditioned filters were measured by a microbalance before use. The loaded filters were encased in sealed plastic

bag to minimize contamination and kept in freezer until chemical analysis to limit losses of volatile components [25]. Filter blanks were stored and processed in an identical manner as the loaded filters.

Wet deposition samples were collected with the use of deposition gauges, each of dimension 0.2 m diameter by 0.15 m depth at the seven sampling spots during the raining season [29-31]. The gauges were positioned in-between the pillar rods on the upper deck of some buildings along the highway. The buildings were approximately 3–14 m above the ground to avoid collection of local emissions such as re-suspended particles [32]. The gauges were exposed for one month during the sampling period in order to measure the flux of settle-able particulate matter.

Table 1: Characteristics of the Sampling Locations

Sampling location	^a Height (m)	^b Distance (m)	Description	Industrial Activities
High school	3.5	12.5	Intersection with high traffic	
Idi Oro	4.8	6.7	Medium traffic	welding, fuel service station
California	10.6	16	Medium traffic	Welding
Oloparun	5	15.3	Medium traffic	welding, animal feed processing
Takie	7.4	4.2	High traffic	fuel service station, motor park, road construction, market
Starlight	4.67	16.9	High traffic	Fuel service station, motor park.
Sabo	6.5	5.8	High traffic	Market

^aHeight of the sampling location (m) and ^bDistance from the highway (m)

The height of the opening area of the collector was at least 1.5 m above ground in order to avoid sample contamination by soil particles during heavy rains. All parts of collectors were made in inert material such as high-density polyethylene (HDPE), in order to avoid metals contaminations and the sample containers were cleaned prior to sampling with distilled water and a 1% nitric acid solution to eliminate particles deposited or adsorbed onto container walls [33-35]. The rainwater in the gauges were collected and then filtered through a dry and pre-weighed Whatman-41 filter paper. The net aerosol load on the filter papers were determined by weighing the filter papers with a microbalance before and after filtration. The filters were dried in a desiccator to a constant weight and then re-weighed to determine change in the weight of the filter. The loaded filters were then placed in an aluminium foil and a zip-lock bag until analysis [36].

2.2 Measurement of Wet Deposition Flux of Aerosols

The wet deposition flux of aerosol was calculated as weight deposited per unit area per unit time [37].

$$\text{Wet depositon Flux} = \frac{W_p}{A.t.} \quad 2.1$$

Where: W_p = Weight of particulate matter in μg , A = Area of the deposition gauge in m^2 and t = Duration of exposure in day.

2.3 Determination of Elemental Composition

The filters were digested using a mixture of nitric acid (HNO_3) and perchloric acid (HClO_3) in ratio 2:1 [38]. The content was heated on a hot plate at 105°C for about 1 hour until the colour changed from reddish brown to colourless under a fume cupboard. The solution was cooled to room temperature, filtered with a Whatman No. 42 filter paper and made up to 25 ml with distilled water. The digest (25 ml) was used to determine the concentrations of the selected trace metals (Ca, As, Cd, Cu, Fe, Pb, Zn, Cr, Ni and Mn) using Atomic Absorption Spectrometer (AAS Buck Scientific VGP 210 Model) at the Centre for Energy Research and Development (CERD) at Obafemi Awolowo University, Ile Ife, Nigeria. The instrument was calibrated with appropriate standards to obtain calibration curves. The blank filters were treated in a similar manner.

2.4 Evaluation of Trace Metals Enrichment Factor

The observed concentrations of trace metals in wet deposition should be explained by natural sources in the absence of anthropogenic sources. However, emissions from the various man-made sources have drastically increased concentrations of metals in our environment. To identify the origin of trace metals in precipitation, enrichment factors (EF) are normally applied, to show the degree of enrichment of a given element compared to the relative abundance of that element in crustal material [39-41]. Na, K, Al, Mg, Ca, Mn and Fe are used as the reference metals in most cases. Concentration of trace metals detected in wet deposition samples were correlated and Fe showed the best correlation with all other metals hence, selected as the reference element [42,43]. Efs < 10 indicate metals having crustal origin; $10 < Efs < 100$ indicate moderate anthropogenic enrichment, showing greater concentrations of a particular metal in the precipitation than would be expected from the crustal origin and metals with Efs > 100 are considered to be of anthropogenic origin [44].

The enrichment factor for wet deposition was calculated using Equation (2.2)

$$EF(X) = \frac{(X/Fe)_{precipitation}}{(X/Fe)_{Crust}} \quad 2.2$$

Where: $EF(X)$ = enrichment factor, $(X/Fe)_{precipitation}$ = mean concentrations of the target element and Fe in precipitation, and $(X/Fe)_{Crust}$ = mean concentrations of the target element and Fe in continental crust.

3. RESULTS AND DISCUSSION

3.1 Wet Deposition Fluxes of Aerosols along the Highway

Wet deposition flux of aerosol measured along the highway were 0.4962, 0.4853, 0.4461, 0.4694, 0.6015, 0.5938, 0.5915 $\mu\text{g}/\text{m}^2\cdot\text{d}$ for High School, Idi Oro, California, Oloparun, Takie, Starlight and Sabo, respectively (Fig.2). The measured deposition flux ranged from 0.4461 $\mu\text{g}/\text{m}^2\cdot\text{d}$ at California to 0.6015 $\mu\text{g}/\text{m}^2\cdot\text{d}$ at Takie. Anthropogenic sources like traffic-related emissions and construction activities could be responsible for higher deposition flux at Takie than the other sampling locations along the highway. This implied that Takie was more polluted than the remaining sampling locations.

Fig.2: Sampling Locations along Ogbomosho Section of Ibadan-Ilorin Highway.

3.2 Concentration of Trace Metals in Wet Deposition

The concentrations of Cd, Cr, Mn, Pb, Zn, Cu, AS, Ca, Ni and Fe, were in the ranges 31.19–64.23 $\mu\text{g}/\text{m}^3$, 10.61–87.02 $\mu\text{g}/\text{m}^3$, 8.27–22.45 $\mu\text{g}/\text{m}^3$, 60.45–88.71 $\mu\text{g}/\text{m}^3$, 281–620.82 $\mu\text{g}/\text{m}^3$, 549.47–969.35 $\mu\text{g}/\text{m}^3$, 13.47–30.61 $\mu\text{g}/\text{m}^3$, 213.88–403.26 $\mu\text{g}/\text{m}^3$, 38.34–86.25 $\mu\text{g}/\text{m}^3$ and 623.99–930.28 $\mu\text{g}/\text{m}^3$, respectively, at the seven sampling spots along the highway (Table 2).

The order of abundance of the heavy metals, based on the average quantification, is given as $\text{Cu} > \text{Fe} > \text{Zn} > \text{Ca} > \text{Pb} > \text{Ni} > \text{Cr} > \text{Cd} > \text{As} > \text{Mn}$. The highest ($64.23 \mu\text{g}/\text{m}^3$) and lowest ($31.20 \mu\text{g}/\text{m}^3$) concentrations of Cd were detected at Takie and California, respectively. These concentrations are above the WHO, EPA and ATSDR standard value of $0.005 - 0.5 \mu\text{g}/\text{m}^3$ [44-46] (Table 3). The presence of Cd in the environment could be from natural sources but the other possible sources of Cd in this study may be through anthropogenic activities. Fatoba *et al.*, [47] concluded that the presence of industries and several combustion processes like the car emissions contributed to the atmospheric Cd in the study area. Arditsoglou and Samara [6] reported wear of the brake lining and of other metallic parts of vehicles as the major source of Cd in the environment. In the study carried out by Moaref *et al.*, [48], it was also discovered that the most concentration levels of Cd were recorded in traffic zone. Scerbo *et al.* [49] (2010) reported that Cd in the environment is traced to Di-methyl cadmium used in the production of tetraethyl lead and its emission can be traced to vehicles.

The higher concentrations of Cr at Takie ($87.02 \mu\text{g}/\text{m}^3$) and starlight ($74.29 \mu\text{g}/\text{m}^3$) than those obtained at the other sampling locations along the highway could be attributed to the elevated concentrations of these metals in the atmosphere at these spots. These concentrations in wet deposition are above EPA standard value of $0.006 \mu\text{g}/\text{m}^3$ [46] (Table 3). Gunawardena *et al.*, [50] attributed the high concentrations of Cr in bulk depositions to the elevated concentrations of these metals in the atmosphere.

Table 2. Concentration of Trace Metals in wet deposition along the Highway

Sampling Locations	Trace metals ($\mu\text{g}/\text{m}^3$)									
	Cd	Cr	Mn	Pb	Zn	Cu	As	Ca	Ni	Fe
High School	45.88	38.20	11.23	76.04	302.5	756.8	21.43	225.3	74.27	623.9
Iidi Oro	50.47	63.67	17.96	65.14	493.5	715.4	30.61	238.4	62.30	658.3
California	31.20	10.61	13.47	60.45	281.2	549.5	15.31	213.9	38.34	626.3
Olopermarun	41.29	27.53	13.47	67.59	435.1	710.2	18.37	305.3	47.92	790.9
Takie	64.23	87.02	22.45	88.71	620.8	969.4	36.74	403.3	86.25	930.3
Starlight	48.17	74.29	20.20	76.04	557.1	826.8	24.49	375.5	76.67	898.3
Sabo	36.70	65.92	8.265	67.59	522.7	702.4	13.47	277.6	57.50	681.1
Average	45.42	52.46	15.29	71.23	458.9	747.2	22.92	291.3	63.32	744.2

Lead is one of the major trace elements in urban environment due to its long residence time in the environment [51]. The average concentration of Pb ($71.23 \mu\text{g}/\text{m}^3$) in wet deposition is

Table 3: Comparison of Concentration of Trace Metals with Regulatory Standards

Body	Trace Metals ($\mu\text{g}/\text{m}^3$)									
	Cd	Cr	Mn	Pb	Zn	Cu	As	Ca	Ni	Fe
WHO ^a	0.005-0.5	NA	0.150	NA	NA	NA	0.007	NA	0.02	NA
EPA ^b	0.006	0.006	NA	1.500	0.103	0.290	NA	NA	NA	NA
ATSDR ^c	0.005	NA	NA	0.500	NA	NA	NA	NA	NA	NA
This Study	45.42	52.46	15.29	71.23	458.9	747.2	22.92	291.3	63.3	744.2

^aWHO [44]; ^bEPA [46]; ^cATSDR [45]; NA(Not Available)

higher than EPA standard value of $1.50 \mu\text{g}/\text{m}^3$ ⁴⁶ and $0.50 \mu\text{g}/\text{m}^3$ [45] (Table 3). The presence of Pb in the environment could be due to several emission sources such as carbon black plant, non-ferrous metal smelting, steel and pipe manufacturing plants, gas flare burning and heavy traffic of vehicles [48]. However, the presence of Pb in wet deposition along Ogbomoso section of Ibadan- Ilorin highway could be attributed to heavy traffic of vehicles since most of these industrial activities are rare along the highway. Meena *et al.*, [52] reported that concentration of Pb in wet deposition was high in zones with higher anthropogenic activities such as heavy traffic of vehicles. The study showed that Pb concentration in wet precipitation was due to the effects of industrial and traffic activities on rain chemistry in urban area. Fatoba *et al.*, [47] also noted that high concentration of Pb was always associated with high traffic density in some parts of Ogun State.

The primary source of Zn along Ogbomoso section of Ibadan-Ilorin highway may be probably from motor vehicle tyre wear caused by poor road surfaces, and the lubricating oils in which Zn is found as part of many additives

such as zinc Dithiophosphates because no major industry such as smelting, exist along the study area [53]. Moaref *et al.*, [48] reported that the highest levels of Zn in wet deposition were shown in traffic and industrial stations.

Gunawardena *et al.*, [50] attributed the high concentrations of Zn in bulk depositions to the elevated concentrations of this metal in the atmosphere. Xia and Gao [22], as well as Councell *et al.*, [54] have noted that tyre wear is one of the primary sources of Zn in the urban atmosphere. The fact that Zn primarily originates from the wear of vehicle tyre and other components can be further supported by the findings from the studies undertaken by Bai *et al.*, [53], Councell *et al.*, [54] and Adedeji *et al.*, [55]. The average concentration of Zn ($458.9 \mu\text{g}/\text{m}^3$) in wet deposition is higher than EPA standard value of $0.103 \mu\text{g}/\text{m}^3$ [46] (Table 3).

The average concentration of Cu ($747.2 \mu\text{g}/\text{m}^3$) in wet deposition is higher than EPA standard value of $0.290 \mu\text{g}/\text{m}^3$ [46] (Table 3). High Copper concentration in wet deposition along the highway could be due to vehicular emissions in the environment. Farmaki and Thomaidis, [56] attributed the presence of Cu to vehicular emissions or oil combustion and re-suspended road dust. Wang *et al.*, [57] also attributed the presence of copper to chemical industries and intensive traffics. Most of man-made emissions of As originate from metal smelters which is emitted in form of arsenites or arsenates whereas natural sources are from volcanic activities. These activities are rare in the study areas and this explains the low concentration of As in the environment.

Ni pollution along the highway could result from the combustion of coal, diesel oil and fuel oil. Natural sources of atmospheric nickel include wind-blown dust, derived from the weathering of rocks and soils, volcanic emissions, forest fires and vegetation [58]. The average concentration of Ni ($63.32 \mu\text{g}/\text{m}^3$) in wet deposition is above the WHO standard value of $0.020 \mu\text{g}/\text{m}^3$ [44] (Table 3). Fe highest ($930.3 \mu\text{g}/\text{m}^3$) and lowest ($623.9 \mu\text{g}/\text{m}^3$) concentrations were detected at Takie and High School, respectively. The presence of Fe in the particulate from the wet deposition along the highway could be due to the natural origin of the studied area and tear of certain parts of vehicles moving on the road. It can also be from dropping of metal scraps by the roadsides. Adefemi *et al.*, [59] attributed a very high concentration of Fe to the occurrence of Fe at high concentrations in Nigerian soils, while Vallius [60] also reported the presence of Fe in emissions from heavy-duty vehicles

3.4 Pearson's correlation matrix among the trace metals measured in wet deposition

Correlation coefficient is a measure of the linear correlation between two variables and giving a value between +1 and -1. Where 1 is total positive correlation, 0 is no correlation, and -1 is the total negative correlation. It is usually performed to distinguish the possible common sources of constituents [25, 31].

The Pearson's correlation matrix among the trace metals measured in wet deposition along Ogbomoso section of Ibadan-Ilorin Highway are presented in Table 4. All positive and strong correlations indicate relationship among the trace metals in the same trend such that increase in the concentration of any suggests increase in concentration of the other. Concentration of Cd was moderately correlated with Cr ($r = 0.7607$) and Mn ($r = 0.7823$) and highly correlated with Pb ($r = 0.8538$), Cu ($r = 0.9231$), As ($r = 0.9529$) and Ni ($r = 0.8653$). Cr was highly correlated with Zn ($r = 0.912$), Cu ($r = 0.824$) and Ni ($r = 0.81$) and moderately correlated with Ca ($r = 0.71$). Mn was strongly correlated with As (0.8662) and moderately correlated with Fe ($r = 0.741$). This strong correlation among metals shows that they originate from common source along the highway; traffic source.

3.5 Enrichment Factor Analysis

The result obtained for enrichment factors (EFs) is presented in Table 4. Cd, Pb, Zn, Cu and As were significantly enriched with EFs of 11413.37, 104.124, 427.378, 830.879 and 719.147 respectively. High EFs (> 100) were obtained for Cd, Pb, Zn, Cu and As, indicating their anthropogenic origins. Among these elements, Cu is an additive in high-temperature lubricant and is present in brake linings, approximately 1–10% by weight [61], and it has been used successfully as a good tracer for wear emission of road traffic [62]. Zn is associated with wear tire debris because Zn is added to tires during vulcanization and is responsible for 1–2% of the tires by weight [63, 64] and emissions from vehicle exhaust and wear abrasion are both important sources of Pb. Correlation analyses (Table 3) illustrated that Cd, Pb, Zn, Cu and As are well correlated with ($r > 0.75$), suggesting that, similar to Cu, these metals along

Table 4: Pearson's correlation matrix among the trace metals measured in wet deposition

	Cd	Cr	Mn	Pb	Zn	Cu	As	Ca	Ni	Fe
Cd	1									
Cr	0.7607	1								
Mn	0.7823	0.599	1							
Pb	0.8538	0.685	0.5747	1						
Zn	0.672	0.912	0.5881	0.5708	1					
Cu	0.9231	0.824	0.6627	0.9559	0.7547	1				
As	0.9529	0.666	0.8662	0.6929	0.5832	0.7768	1			
Ca	0.6734	0.713	0.6855	0.7632	0.8333	0.8371	0.5411	1		
Ni	0.8653	0.81	0.5749	0.9114	0.5946	0.9233	0.7374	0.6383	1	
Fe	0.6613	0.63	0.741	0.7227	0.7771	0.7978	0.5549	0.987	0.5855	1

Significance level of 0.05

Ogbomoso section of Ibadan-Ilorin highway originated mainly from wear-abrasive sources. This showed that they are contributed primarily by traffic emissions, rather than a natural origin. This is in concert with previous results [54, 65-67].

Cr and Ni were moderately enriched by anthropogenic activities with EFs of 42.745 and 5.408 respectively. EFs (> 10) was obtained for Cr, which was well correlated with Cu ($r > 0.75$), this suggests its anthropogenic origin. Mn and Ca were not enriched by anthropogenic sources due to very low EFs of 1.239 and 0.743 respectively, Enrichment factor of Ca was close to unity, which suggest that a dust source could account for at least half of the aerosol Ca budget. The EF values obtained for Ca was consistent with the results observed by Lin *et al.*, [68] at Hsuehshan Tunnel in Taiwan. The authors found out that Ca originated mainly from the resuspension of soil and road dust.

The values showed that in the most cases, the heavy metals in wet precipitation had anthropogenic origins. This result is similar to the results obtained in by Farahmandkia *et al.*, [66], where the heavy metals in precipitation had anthropogenic origins. Elements of anthropogenic origins (Cd, Pb, Zn, Cu and As) were highly enriched with respect to crustal composition indicating the influence of anthropogenic input for these metals. Iron (Fe), which is considered an important crustal element, correlated well with Ca ($r = 0.9875$, Tables 3.), demonstrating that crustal source is the major source of Fe. This is different from the results obtained Lin *et al.*, [68] at Hsuehshan Tunnel in Taiwan where wear dust was the major anthropogenic source of Fe in Hsuehshan Tunnel.

4. CONCLUSION

We have reported wet deposition samples collected along a heavily trafficked highway in Ogbomoso, Nigeria. The wet deposition flux of aerosol ranged from 0.4461 to 0.6015 $\mu\text{g}/\text{m}^2/\text{day}$. The peak values in the concentrations of the heavy metals were typically observed at Takie with the highest traffic density. The Pearson's correlation matrix among the trace metals measured in wet deposition along the highway ranged from 0.7547- 0.9875. All positive and strong correlations indicate relationship among the trace metals in the same trend such that increase in the concentration of any suggests increase in concentration of the other. Enrichment factor ranged from 0.76 - 11413.37. Cd, Pb, Zn, Cu and As were highly enriched with respect to crustal composition indicating the influence of anthropogenic input for these metals. Several of our observations also support the need for extended observations and analysis of these heavy metals in the urban environment.

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