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CONCENTRATION AND CHARACTERIZATION OF AIRBORNE PARTICLES IN TWO SUBWAY SYSTEMS OF ISLAMIC REPUBLIC OF IRAN AND INDIA

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ABSTRACT:

Introduction: Airborne particulate matter (PM) is responsible for serious immediate and long-term impacts on human health because airborne particulates easily reach the deepest recesses of the lungs that damage the respiratory system of human beings**.** The purpose of this study was to measure the airborne concentrations of PM_{10} and heavy metals (cadmium, chromium, lead, manganese, copper, zinc, iron and nickel) in Tehran-Iran and Pune-India.

Materials and Methods: In order to compare two polluted cities, Tehran-Iran and Pune-India, six stations from both cities were selected for air sampling and analysis. Sampling was performed from November 2011 to July 2012 in both countries**.**

Results: PM_{10} concentration range of 92.31 (µg/m^3) to 28.12 (µg/m^3) in Tehran while, PM_{10} concentration ranged from 90.54 (µg/m^3) to 48.19 (µg/m^3) in Pune. The heavy metal trends show higher concentrations at station one however, the lowest concentrations were observed at station three and four in Pune.

Conclusions: Results showed that there was a correlation between air pollution and number of vehicles. However this correlation was not statistically significant (R^2=0.376 for Tehran and R^2=0.083 for Pune). It is observed that station one in Pune and stations three and four in Tehran are highly polluted. The pattern of air pollution in Tehran was not the same.

INTRODUCTION

Particulate matter (PM) pollution is a serious issue of global concern. It has many negative impacts on humans, environment and atmospheric conditions including cloud formation, solar radiation, global warming, visibility and precipitation [1]. There are several sources of particulate matter such as combustion of fossil fuels, automobile exhaust, industrial processes, power plants, environmental tobacco smoke, cooking and natural sources such as sea salt, volcanic eruption, windblown dust, pollen grains and particles of soil [2]. Particulate matter led to serious health hazards in human beings and causing asthma, chronic bronchitis, rhinitis, irritation of lungs, pneumonia, decreased resistance to respi-

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ratory infection, chronic cough, phlegm production, allergy, headache, fatigue, lung cancer and premature death [3]. Elemental constituents of aerosol present in biosphere have been identified as potential hazards to human beings. Some of them are insidious pollutants because of their non-biodegradable nature [4]. In terms of adverse effects on human health, particulate matter perhaps is the most important air pollutant. Epidemiological studies have linked air pollution episodes to health problems and toxicological studies have been critically examined [5]. Because of the risks posed by elements in Suspended Particulate Matter (SPM) to human health and the natural ecosystems, it is important to develop effective controlling criteria for air particulate emissions. However, an important step in air pollution control program is the identification of pollutants, the contributing sources and the relative contribution of each source [6]. Several researchers have measured trace element concentrations in air borne aerosols in some cities of Iran and India. The present work will demonstrate the main results of the analyses of particulate matter samples in Pune city and Tehran city. Tehran is the capital of Iran and is the largest metropolitan city in Iran and one of the largest cities in western Asia. Tehran also is the centre of most Iranian industries including automotive, electrical, military, weaponry, textiles, sugar, cement, and chemicals production processes. There is an oil refinery located in south of the city. On the other hand, special topographical properties of Tehran make it vulnerable to pollutants [7]. Pune–India is the second largest city in Maharashtra-India and a thriving industrial centre with a population of nearly 2.5 million. Some of the most prestigious industries in India are located in Pune. The Pimpri-Chinchwad-Bhosari industrial complex is claimed to be one of the largest in country. The major industrial segments in Pune included automobile, machine tools, chemicals, electrical and electronics, instrumentation and control, iron and steel, castings and forgings, telecom, packaging, auto components, material handling equipment, fuel and pumps [8].

MATERIALS AND METHODS

Pune –India

The emission load inventory from vehicular sources undertaken by Central Institute of Road Transport (CIRT) approves that approximately 182 tons of pollutants are emitted from motor vehicles per day in Pune city. The emission inventory shows that 78% of total vehicular pollution is contributed by 2 wheelers whereas cars by 3 and 4 wheelers contribute 12 and 5% respectively. The key traffic and transportation problems in Pune are, disproportionate rise in number of vehicles, insufficient road area, severely impaired mass transport systems, etc. [9]. Vehicular subway passing is estimated at the range of 1000-12000 vehicular per day around Pune (Table 1). Data collected of registered vehicles on each toll plaza and some unregistered data is included in the following Table given by local authority.

Table 1. Vehicles passing from each station per day in Pune-India

Stations	Name of Station	Number of vehicles
1	Shivapur Toll collection centre- Pune to Bangalore	12000
2	Bhugaon- Pune to Mangaon-Konkan	3000
3	Telegaon- Chakan- Connecting road to Bombay Pune old highway to Nasik Highway	5000
4	Nasik- Pune highway, Near Hotel Vedant	7000
5	Pune- Ahmednagar Highway- Harshraj Garden Dhaba	8000
6	Pune-Solhapur highway- Near village Yavat.	1000

Tehran-Iran

Vehicular subway passing in Tehran is estimated to be at the range of 6500-20000 daily. Data are collected by registered vehicles on the police highway stations and some of unregistered data given by local authorities (Table 2).

Six stations were selected for air sampling and analysis presented in Tables 1 and 2. Samplings were performed from November 2011 to July 2012. The sampling areas selected from various locations covering industrial, commercial and residential zones. Excessively windy and wet conditions were avoided during the changing samples. Pre-loading in a filter cartridge assembly, temporary removal of the sampler to a protected area, or a wind or rain shield was used. The samples were replaced in inclement weather. The timer was set to the desired start and stop time. There was one flow recorded and it was necessary to replace the chart paper in the flow recorder. For accurate observations, proper time was set and marked the time and date on the chart. For a manually flow controlled sampler turn on the motor for 5 min and measure the exhaust pressure with a pressure gauge or rotameter. Flow rate was read accordance with its exhaust pressure from the calibration curve and recorded it on data sheet. The specified length of sampling was commonly 8 h or 24 h. During this period several readings (hourly) of flow rate were done. After sampling was completed, the final flow rate and the elapsed time in the same manner recorded. The collected filters samples were sieved into coarse and fine fractions. 2 g of well-mixed samples was placed in to 250 mL glass beakers and digested with 8 mL of aqua regia (mixture of nitric acid and hydrochloric acid) on a sand bath for 2 h. After evaporation to near dryness, the samples were dissolved with 10 mL of 2 % nitric acid, filtered and then diluted to 50 mL with distilled water [10]. Heavy metal concentrations of each fraction were analyzed by Atomic Absorption Spectrophotometer. Quality assurance was guaranteed through double determinations and use of blanks for correction of background and other sources of error. Data analysis was conducted by SigmaPlot 12.2 and SPSS 23 softwares.

RESULTS AND DISCUSSION

Concentration levels of particulate matter

The summary of the particulate matter collected at the sampling site during the studied period is presented in Tables 3 and 4. Normality of data was surveyed by Kolmogorov-Smirnov test (IBM, SPSS 23) that showed data were not normal for both Pune and Tehran cities. So non-parametric test (2 independent samples, Mann-Whitney U) was applied for data analysis. There was no statistically significant difference between all stations in both cities ($P_{value} < 0.05$). In Pune city, PM_{10} concentration range was between 48.19 and 90.54 µg/m^3. The highest mass concentration of particulates is equal to 90.54 µg/m^3 at station one and the lowest concentration is equal to 48.19 µg/m^3 at station three.

In Tehran city, PM_{10} concentration range was between 28.12 and 92.31 µg/m^3. The highest mass concentration of particulates is equal to 92.31 µg/m^3 at station three and the lowest concentration is equal to 28.12 µg/m^3 at station one.

Table 2. Vehicles passing from each station per day in Tehran-Iran

Stations	Name of station	Number of vehicles
1	Saidi high way (shahidbeheshty complex)	7000
2	Saidi high way(shah Tareeh)	6500
3	Tehran-Qom high way(Turouzabad)	20000
4	Tehran-Qom high way (Jalil Abad)	18000
5	Tehran-Varamin high way(near Amin Abad road)	15000
6	Tehran -Varamin high way(Firooz Abad)	14000

Table 3. Statistical summary of particulate matter mass concentration at Pune-India

Stations	Mean of PM_{10} (µg/m³)	Maximum	Minimum	Statistic (95% confidence intervals)		
				Lower bound	Upper bound	S.E
1	78.33	90.54	51.45	63.515	67.801	1.08
2	62.00	74.16	50.35			
3	55.24	66.14	48.19			
4	61.56	70.49	53.49			
5	65.32	78.36	53.15			
6	74.46	84.49	65.80			

Table 4. Statistical summary of particulate matter mass concentration at Tehran –Iran

Stations	Mean of PM_{10} (µg/m³)	Maximum	Minimum	Statistic (95% confidence intervals)		
				Lower bound	Upper bound	S.E
1	33.65	40.14	28.12	56.353	63.559	1.81
2	66.84	72. 91	51.31			
3	83.37	92.31	69.22			
4	79.50	85.44	51.45			
5	47.23	52. 61	40.23			
6	49.12	52.34	38.65			

Metal concentrations in particulate matter

The results of elemental concentrations obtained from PM_{10} are presented in Tables 5 and 6. Eight elements are determined for all the samples in particles matter and average concentrations of various elements are shown. In Pune, highest concentrations of heavy metals are recorded at station one while fewest concentration of chromium, iron, nickel and lead are observed at station four. However, minimum concentration of zinc was observed at station three and minimum copper was recorded at station two. The order of average concentrations of heavy metals in Pune atmospheric air were of Fe > Cu > Zn > Ni > Mn > Pb> Cr > Cd arrangement.

Table 5. Concentration of heavy metal (mg/kg) in ambient air along highways Pune

Metals mg/kg	Stations						Statistic (95% confidence intervals)		
	1	2	3	4	5	6	Lower bound	Upper bound	S.E
Cd	0	0	0	0	0	0	-	-	-
Cr	0.66	0.37	0.45	0.32	0.38	0.55	0.42	0.48	0.01
Ni	1.68	1.24	0.97	0.69	0.87	1.19	1.03	1.17	0.03
Pb	0.72	0.6	0.53	0.38	0.47	0.55	0.50	0.58	0.01
Zn	10.32	6.22	4.31	5.64	5.25	9.32	6.35	7.28	0.23
Cu	12.63	4.72	6.75	8.53	7.65	10.3	4.82	10.11	0.10
Fe	11.34	8.75	7.57	6.81	7.33	9.54	8.14	8.95	0.20
Mn	1.18	0.35	0.24	0.42	0.53	0.61	0.46	0.59	0.033

As seen in Table 6, highest concentrations of zinc, lead, cadmium, copper and nickel are recorded at station four while lowest concentrations of lead and zinc are observed at station two. Maximum concentrations of chromium and Iron are observed at station three and minimum copper is recorded at station three. Maximum concentrations of manganese are recorded in station two and three and minimum concentrations of chromium are observed in station one and two. The order of average concentrations of heavy metals in Tehran atmospheric air are in arrangement of Zn > Cu > Fe > Pb > Ni > Cr > Mn > Cd. As Fig.1 shows there is a positive correlation between number of vehicle and PM_{10} concentrations. Statistically this correlation is not significant (P_{value}=0.195) but as it can be concluded that the concentration of PM_{10} in air atmospheric of Tehran is more dependent to number of vehicle (R^2=0.376) compared to Pune (R^2=0.082). This may be due to this fact that legislations of vehicle pollution standards in Pune are more effective compared to Tehran.

Deposition of heavy metals (HM) is generally the result of anthropogenic activities and to a lesser extent due to geogenic origin (i.e. volcanic eruptions) [11]. These metals are liberated to the atmosphere by manifold industrial activities and depending on particle size and the gravitation field of the earth. They are more or less rapidly deposited, leading to a direct contamination of vegetation or after periods of accumulation in soils to an indirect contamination of plants via root uptake [12]. Heavy metals have to be differentiated into those elements essential for plant nutrition, exhibiting phytotoxic effects only in relatively high concentrations (Cu, Fe, Mo, Zn, Co, Ni) and into the non-essential elements like As, Cd, Cr, Hg, Pb and Ti which due to frequent use in industrial processes, are deposited even in remote ecosystems and exhibit a potential phototoxic risk [13]. Amount of availability and element-specific mobility determine the degree of plant contamination via roots or leaves and hence the entrance into the biological chain. They are passed thought the ecosystems to other organisms at higher trophic levels by the uptake of

Table 6. Concentration of heavy metal (mg/kg) in ambient air along highways Tehran

Metals mg/kg	Stations						Statistic (95% confidence intervals)		
	1	2	3	4	5	6	Lower bound	Upper bound	S.E
Cd	0.008	0.009	0.005	0.015	0.007	0.001	0.0062	0.0075	0.000
Cr	0	0	0.05	0.03	0.001	0.003	0.01	0.018	0.001
Ni	0.14	0.28	0.31	0.34	0.32	0.27	0.26	0.29	0.007
Pb	0.36	0.24	0.3	0.4	0.33	0.34	0.316	0.344	0.006
Zn	10.24	5.49	15.5	16.07	10.85	14.88	11.42	12.93	0.38
Cu	10.63	6.72	3.55	12.13	5.31	8.32	4.70	10.31	0.29
Fe	0.4	0.33	0.41	0.29	0.31	0.35	0.34	0.37	0.006
Mn	0.003	0.004	0.004	0.003	0.003	0.002	0.0032	0.0039	0.000

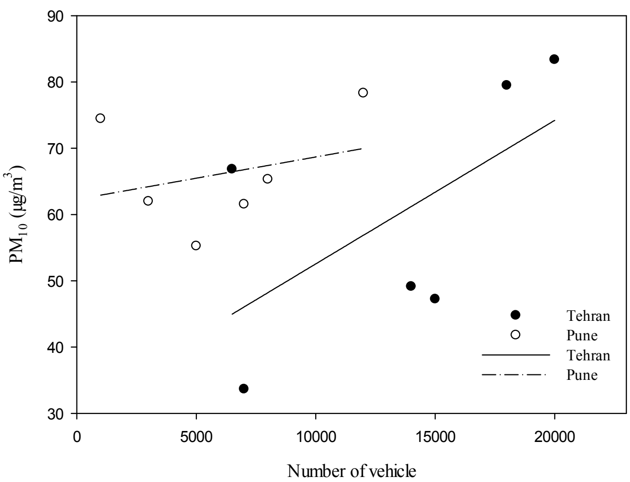

Fig.1. Correlation between number of vehicles and PM_{10} concentration

contaminated plant material [14]. However, vegetables can uptake a lot of essential nutrients and certain trace elements in a short period. Therefore, the safety of vegetables is very important [15]. In leaves as edible plant parts, heavy metals are generally accumulated to a larger extent than in fruits or seeds. Heavy metal contamination of plants occurs directly via the path ambient "air plant" or indirectly via "soil plant" by dry or wet deposition of particulate matter or suspended particles. Concentration and characterization of heavy metals in ambient air quality has been the major focal point of this study. Nickel emissions to the atmosphere may occur from natural sources such as windblown dust, Volcanoes, and vegetation. The main anthropogenic sources of nickel emissions into the ambient air are the combustion of oil for heat or power generation, nickel mining and primary production, the incineration of waste and sewage sludge, steel manufacture, electroplating, and coal combustion [16]. Volcanic activity is a major natural source of cadmium in the plume of Mount Etna, Sicily concentrations of about 90 ng/m^3 have been found. Anthropogenic emissions are mainly due to non-ferrous metal production (copper, zinc, cadmium), iron and steel production, incineration of refuse (cadmium pigments and stabilizers in plastics, nickel-cadmium batteries), and combustion of coal and oil [13]. Airborne lead is one of the most harmful particulate pollutants. Young children are especially vulnerable. Lead poisoning of children leads to permanent brain damage, causing learning disabilities, hearing loss, and behavioral abnormalities. In adults lead absorption causes hypertension, blood pressure problems, and heart disease. The main sources of airborne lead are motor vehicles using leaded gasoline, industrial processes such as ferrous and nonferrous metallurgy, and coal combustion [17]. The concentration of zinc in nature without the additional influence of human activities (anthropogenic emissions) is called "natural background." The natural background levels in surface water, soil and rock vary over a wide range of concentrations [18]. Copper and its compounds are naturally present in the earth's crust. Natural discharges to air and water, such as windblown dust, volcanic eruptions, etc., may be significant. Therefore, it is important to consider the copper concentrations within a specific environment, geographical region, or human population study site that has been minimally affected by anthropogenic sources of copper in order to accurately assess the contribution of an anthropogenic activity to human exposures to copper. In air, the mean copper concentrations in the atmosphere range between 5 and 200 ng/m^3 in rural and urban locations. Airborne copper is associated with particulates that are obtained from suspended soils, combustion sources, the manufacture or processing of copper-containing materials and mine tailings. The median concentration of copper in natural water (e.g., rivers, lakes, and oceans) is 4–10 mg/L. It is predominantly in the Cu(II) state. Most of it is complexes or tightly bound to organic matter. Little is present in the free (hydrated) or readily exchangeable form. The combined processes of complexes adsorption, and precipitation control the level of free Cu(II) [19]. The chemical conditions in most natural water are such that, even at relatively high copper concentrations, these processes will reduce the free Cu(II) concentration to extremely low values. The mean concentration of copper in soil ranges from 5 to 70 mg/kg and is higher in soils near smelters, mining operations, and combustion sources [20]. Station of one recorded the maximum vehicular load of 12000 per day and represents the highest heavy metal concentration of Cr, Ni, Pb, Zn, Cu, Fe and Mn .It is safe to say that Tehran doesn't have uniform pattern of heavy metal concentration in ambient air quality. Zn, Pb, Cd, Cu and Ni were higher in station four and Cr, Fe and Mn were higher in station three. Accordingly the number of passing vehicles in station number of four was 20000 vehicles per day whereas 18,000 vehicles per day were observed in station three.

The World Health Organization (WHO) ambient air quality health guidelines were available for restricted toxic metals including arsenic, cadmium, chromium (VI), lead, manganese, mercury, nickel and vanadium [21]. On these guidelines all the levels are reported in mg/kg Cd level 0.005, Cr, 0.008 which are classified as carcinogens and Pb 0.05, Mn 0.15.

In present study Cd level in Pune was 0.00 mg/kg in all stations and 0.015 mg/kg in station four of Tehran. Cr level in Pune is 0.66 at station one and in Tehran 0.05 mg/kg in station three. Pb level in Pune was 0.72 mg/kg at station one and 0.40 mg/kg in station four in Tehran. Mn level in Pune was 1.18 in station one and station two and three 0.004 mg/kg. It can be concluded that station number one in Pune and Station number three and four in Tehran were alarmingly polluted due to transportation of vehicles.

CONCLUSIONS

Air pollution around Pune and Tehran has been considered for the present study. In Pune-India the data confirms that maximum passing vehicles had been registered from station one (Shivapur Toll collection centre- Pune to Bangalore) i.e. 12000 vehicles per day and minimum in station 6 (Pune-Solhapur highway- Near village Yavat) 1000 vehicles per day. Data was made available from toll plaza authorities, which includes unregistered vehicles as well. In case of Tehran, 20,000 vehicles passing from station three and minimum in station two 6500 per day. Data was collected from police records. Results showed that there was a correlation between air pollution and number of vehicles. It is observed that station one in Pune and stations three and four in Tehran are highly polluted. The pattern of air pollution in Tehran is not uniform.

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COMPETING INTERESTS

Hereby the authors declare no conflict of interest.

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ETHICAL CONSIDERATIONS

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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