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TRAFFIC RELATED AEROSOL EXPOSURE AND THEIR RISK ASSESSMENT OF ASSOCIATED METALS IN DELHI, INDIA

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Abstract

A pilot study was carried out in New Delhi, India, to assess the level of traffic related aerosol exposure, individually and associated metals. These investigations also try to formulate their risk assessment using different modes of transport on a typical journey to work route and compared Bus, Auto-rickshaws and Bike (Two Wheelers) during the journey. The inhalable particulate matter monitored in winter period and also evaluated the potential health risk due to inhalation in the study. The exposure of Particulate matter was observed maximum in the Bike (502 ± 176.38 μgm^{-3}) and minimum in the Auto-rickshaw (208.15 ± 61.38 μgm^{-3}). In case of human exposure to metals (viz. Cu, Cd, Mn, Pb, Ni, Co, Cr, Fe, Zn), it was mostly exposed by Fe, Zn and Co and least exposed by Cd, Cr and Pb. Human health risk was estimated based on exposure and dosage response. The assessment of particulate-bound elements was calculated by assuming exposure of 6 h. The findings indicated that the exposure to particulate bound elements have relatively more adverse health effects.

Key words: Inhalable Aerosol, Personal Exposure, Metals, Risk Assessment, Hazardous Quotient

Introduction

Vehicles are a major source of pollutants in Delhi; the daily pollution load has increased from 1,450 tons in 1991 to 3,000 metric tons in 1997 (MoEF, 1997). The share of the transport sector has increased from 64% to 67% during the same period while that of the industrial sector (including power plants) has decreased from 29% to 25% (MoEF, 1997). Suspended particulate matter is one of the most critical air pollutants in India, especially in Delhi; millions of people breathe air with high concentrations of dreaded pollutants. The air is highly polluted in terms of suspended particulate matter in most cities especially in Delhi (Prasad et al., 2003; Kushwaha et al., 2012). It is estimated the incidence of mortality and morbidity in different groups in India is due to exposure to PM_{10}. These impacts translated into economic values. The results indicated 2.5 million premature deaths and total morbidity and mortality costs ranges from Rs 885 billion to 4250 billion annually region wide. Urban air pollution is estimated to cause 250,000 death and billions of cases respiratory illnesses every year (World Bank, 2005). The rapid increases of private motor vehicles are also responsible for that. In Delhi, there are 5.5 million registered vehicles in the city, which is the highest in the world among all cities. The Delhi transportation sector is also increasing and growing source of air pollution in that metropolis (Narain et al., 2011). Research is going on all over the world which indicates that particle concentration in transportation microenvironments on and near roadways and inside vehicles often exceed nearby ambient levels. Therefore exposures of people while in transit and for those who live or work near road ways may not be well characterized by conventional air quality monitoring station (Leung et al., 2008; Kaul et al., 2007; Lin et al., 2005). Many epidemiological studies have documented significant positive correlation between daily mean concentrations of air pollution respirable particulate matter (PM_{10}, $PM_{2.5}$) and increased mortality and morbidity attributable to respiratory and cardiovascular causes (US-EPA, 1996; Schwartz et al., 2002; Pope et al., 2002). Only few investigations have been reported using particles from specific sources. Several studies have shown that traffic related particles seemed to be more toxic than others. Multi-city study has shown that association between PM_{10} concentrations and increased risk of death generally remains unchanged after control for other air pollutants (Domini et al., 2007; 2005). Exposures to particulate matter while commuting were examined in a few studies. Chan and co-workers examined the commuter exposure to respirable particulate matter in Hong Kong and concluded that the particulate level is greatly affected by mode of transport as well as ventilation system of the transport (Chang et al., 2002; Chang et al., 2009). Bus drivers in Delhi city spend a considerable amount of their time in transit and indoor microenvironments (MEs); they are therefore likely to be exposed to high level of $PM_{2.5}$ every working day. Although there is not any fix site station for air pollutants monitoring in this city and the concentrations of air pollutants were come from traffic, traffic flow in the city centre was more specially during the rush hours, exposure to respirable particles among Bus, Bike and Auto-rickshaw drivers is likely to be high [21].The above mentioned studies suggest the importance of understanding the aerosol exposure and its health effects. This is why the present study has been under taken with the objective to determine the aerosol exposure and its risk assessments of associated metal in Delhi.

Materials and Method

The study was conducted at Ring Road in Delhi, a city of about 18 million inhabitants. There were about 65 lakh buses in centre of Delhi that serve public transportation journeys on different routes of Delhi (CCS-India, 2009). All buses and Auto-rickshaws were CNG fuel based. Some buses had air conditioning system. To measure the $PM_{2.5}$ concentrations, a size selective sampling cyclone was used in combination with a particle size was designed for $PM_{2.5}$ size fraction monitoring. A small personal sampling pump was used to provide a continuous 3 LPM airflow. Particle concentrations were monitored in bus, auto-rickshaw and bike driver breathing zone. Samplings were carried out two times a day, in the morning (ranged from 9:15 to 12:25 AM), and in the evening (ranged from 16:15 to 20:18 PM). The sampling site is shown in Fig. 1. First sampling was started when the bus was going from bus station to the terminal point. The second sampling was started when the bus was travelling through the Ring Road. In order to identify those factors related to personal exposures in bus, auto and bike a core questionnaire that covered the indoor bus air quality

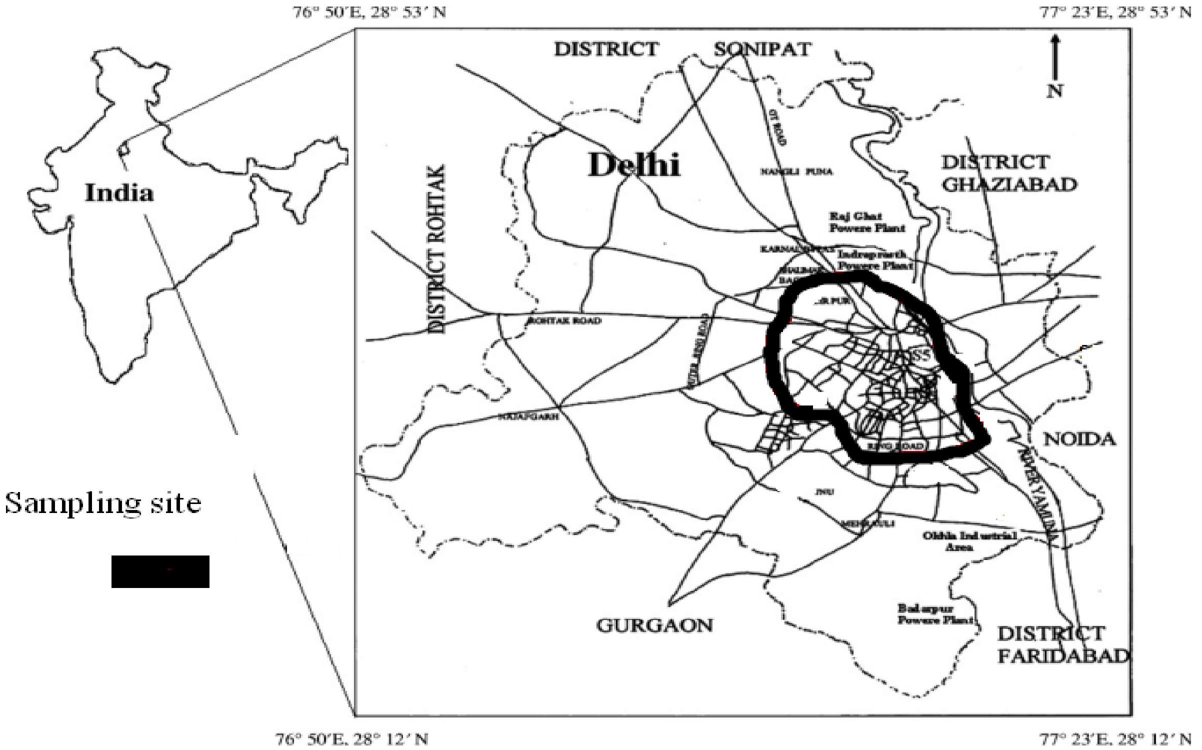

Fig. 1. Sampling route at Delhi (not in scale)

related characteristics such as number of passengers in the bus, picking up and dropping off the passengers, stopping at traffic light, traffic congestion etc.

1. Toxicological risk assessment

1.1. Non-carcinogenic risks

Heavy metals exposed through ingestion, inhalation and dermal pathways. But here, we have taken only inhalation and dermal pathways with the purpose to estimate the health risk of human during working hours of service life, health risk assessment was carried out in this study. The average daily dose contacted through Inhalation ($ADD_{inhlation}$), and average daily dose absorb through skin (ADD_{dermal}) was calculated as follow (US-EPA, 1997).

$$\text{ADD Inhalation} = \frac{C \times InhR \times ED}{BW \times AT} \qquad \text{Eq. (1)}$$

Where, C is the concentration of the contaminant in the air (mg/m^3). For inhalation, the intake rate, InhR, 100 mg/day for adult male (US-EPA, 1997). For dermal contact, the exposed skin area, SA = 1150 cm^2; the skin adherence factor, SL = 0.2 mg/cm^2/day; the dermal absorption factor, ABS = 0.001 (Chang et al. 2009). The average body weights (BW) of Indian people are 50.7 kg for adult (Dind et al., 2001). The exposure duration (ED) is the length of time that contaminant contact lasts and it can be calculated by working days (350 days per year) time the service life (10 years) (Li et al., 2010). The average time (AT) was 1825 days.

The formula for determination the HQ as follows

$$HQ = \frac{ADD}{RfD} \qquad \text{Eq. (2)}$$

The Hazard Quotient (HQ) was calculated for non-cancerous risk in order to bring a comparative analysis with respect to a health guideline given by (US EPA, 1996). The

Reference Dose (RfD) is estimated of daily exposure below which adverse non-cancer health effects are unlikely, if the HQ is < 1 then non-cancerous effects are unlikely, if the HQ is ≥ 1, then adverse health effects might be possible. If the HQ is > 10, then it suggests the high chronic risk (Xinhui et al., 2010; Lewne et al., 2005; Biptista et al., 2005).

1.2. Carcinogenic risks

Among nine metals (Ni, Pb, Mn, Fe, Zn, Co, Cu, Cd and Cr) only Cd, Ni and Cr are carcinogenic (Biptista et al., 2005; IARC, 1980; 1990; 1993) in case of carcinogenic the average daily dose has to be considered for entire life. Therefore, life time average daily dose (LADD) can be calculated from equation. In this average time (AT) will be 70 years (average life) multiplied by 365 days. For carcinogenic LADD is multiplied by the slope factor (SF) to produce cancer risk level.

$$\text{LADD Inhaltion} = \frac{\text{C} \times \text{InhR} \times \text{ED}}{\text{BW} \times \text{AT}} \qquad \text{Eq. (3)}$$

$$\text{LADD Dermal} = \frac{\text{C} \times \text{SL} \times \text{ABS} \times \text{ED}}{\text{BW} \times \text{AT}} \qquad \text{Eq. (4)}$$

Risk = LADD × SF

Results and discussion

In this study, a total of nine samples were collected from Bus, Bike, and Auto-rickshaw breathing zone during the field study period. The Average means $PM_{2.5}$ exposure was 502 ± 176.38 µgm^{-3} for Bike, 208.15 ± 61.38 µgm^{-3} for Auto-rickshaw, 306.48 ± 189.13 µgm^{-3} for Bus in a study period shown in Fig. 2.

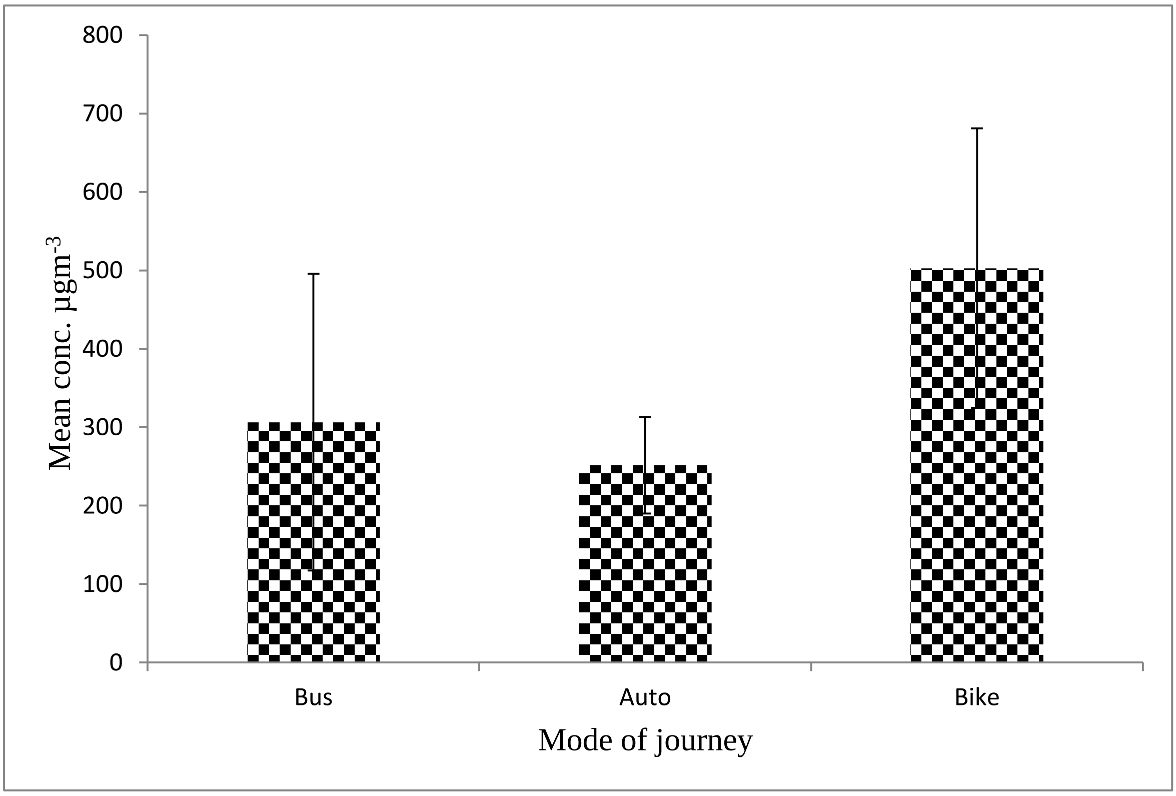

Fig.2. Mean aerosol exposure during all mode of journey

Daily mean exposure to $PM_{2.5}$ among Bus, Bike and Auto-rickshaw drivers were demonstrated in Fig 3.

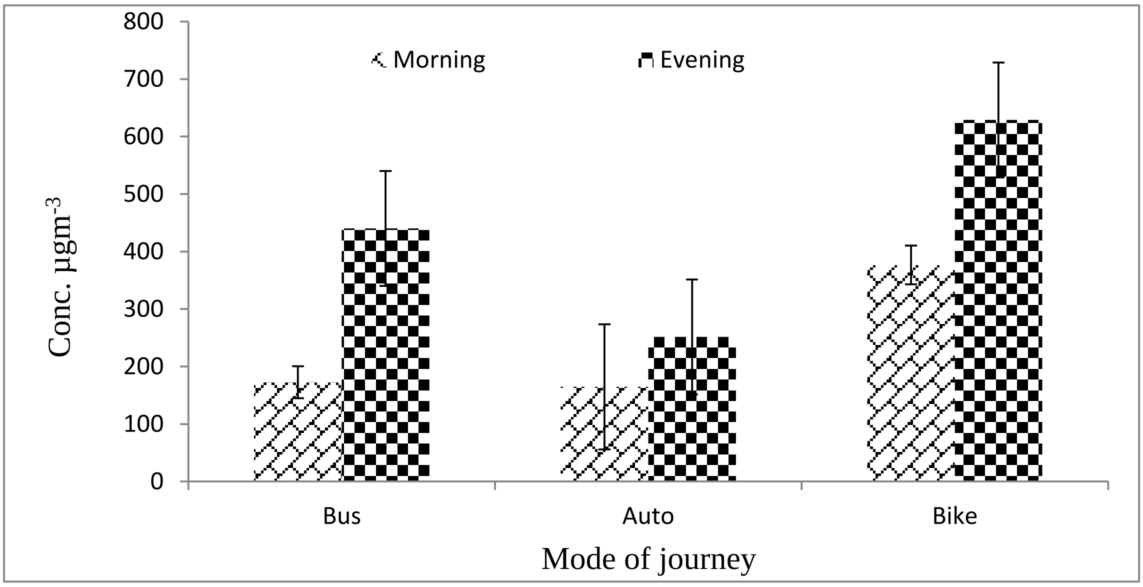

Fig. 3. Aerosol exposure during morning and evening of journey

Total aerosol concentrations at all the mode of transportation (Bus, Bike and Auto-rickshaw) are found to be well below the standards prescribed by OSHA (5000 µgm $^{-3}$) (US-OSHA, 2011).

There were significant difference between evening and morning mean $PM_{2.5}$ exposure during the study period. Mean bus drivers' exposure to $PM_{2.5}$ in the evening (440 ± 108 µgm $^{-3}$) was significant higher than those resulted in the morning (172.8 ± 27.61µgm $^{-3}$). It could be high traffic congestion, frequent stops and boarding a large number of passengers in the buses. However, mean exposure to $PM_{2.5}$ in the morning and in the evening showed significant difference to all mode of journey like Bus, Bike and Auto rickshaws. Some other author in countries previously carried out personal exposure and indoor monitoring in the Bus, Car etc.

Table 1 Mean aerosol exposure in Bus, Bike and Auto-rickshaw.

Study	Location	Type of sampling	Pollutants	Meanconc. (µgm $^{-3}$)
Current study	Delhi	Bus, Bike, Auto-rickshaw	$PM_{2.5}$	307, 503, 252
Siman etal.1998	England	Bus, Car, Bike and Train	$PM_{2.5}$	5.3, 7.6, 6.3, 5.7
Mohammadya et al., 2006	UK	Commuter exposure	$PM_{2.5}$	53.8
Chan et al.,2002	China	Commuter exposure	PM_{10}	128, 203
Adam et al.2001	UK	Commuter exposure	$PM_{2.5}$	39
Pramal et al.2000	Germany	Commuter exposure	$PM_{2.5}$	110-165
Lewne etal.,2002	Sweden	Driver's exposure	$PM_{2.5}$	44

Table 1 compares the present study with other studies. In general, higher mean $PM_{2.5}$ concentration found when the compare other results. The mean exposure level of $PM_{2.5}$

resulted in the study was considered was higher than those measured in overseas studies such as in Bradford, UK (Mohammadyan and Ashmore 2006; Simon et al., 1998; Pramal and Schierl, 2000; Smit, 1996), While this study measured personal exposure in the breathing zone, some of those studies relied on equipment carried by commuters, suggesting that they may systematically underestimate true personal exposure. The higher exposure level was related to the time of picking up and dropping off the passengers, suggesting an effects of re-suspension of particulate matter due to movement of passenger as well as vehicles' and penetration of outdoor particulate matter to the Bus and Auto-rickshaws through the open doors. However, these studies showed the bus model and number of passenger inside bus have significant positive effects on Bus personal exposure. One possible explanation is that passenger movement can increase re-suspension of fine particulate matter in the bus. This study is carried out to measure a health concerned pollutant, $PM_{2.5}$ in the breathing zone of bus, auto and bike drivers. The results showed that personal exposure to $PM_{2.5}$ among bike drivers was greatly affected by the climate conditions and other air pollutions related factors such as wind movement, storm. The highest exposures to $PM_{2.5}$ were found during the evening with high traffic congestion. The current studies were higher than those measured for commuter in other studies. The high exposure to particles in the current study are due to the slow moving traffic patterns with frequent stops and boarding a large number of passenger in the buses.

1. Particulate-Bound Elemental Concentrations

Particulate bound elemental concentrations were analysed on Atomic Absorption Spectrophotometer (AAS) made by thermo scientific (Model No: GF 95Z). The result is shown in Fig. 4.

Maximum Fe and Zn exposed by Bus because Fe and Zn emitted due to engine and tyre wear and tear (Wang et al., 1998). The iron concentration of Bike and Auto-rickshaw significantly decrease when compared to Bus. Cr and Cd were found to be at very low level at all mode of transportation due to less exhaust emission. In case of nickel, high concentrations were observed in each mode of transportation due to high level of Ni in diesel and petrol especially non-CNG vehicles. Nickel can also be released through the engine exhaust due to wear and tear of the engine (Wang et al.,1998; Menzie et al., 2009). Cadmium was present in very low levels as compared to the other carcinogenic elements. Cadmium presence is almost same in each mode of transportation. Cobalt, manganese, copper presences were low. Lead presence was very low when compared to iron and zinc. The reason could be the road side dust which still contains lead. However, lead based fuel has been banned in Delhi since 2000. Particulate Matter (PM) can interact antagonistically and potentially carry toxicological risk (Menzie et al.,2009). For example, Ni, Cd, Cr, Co, Cu and other PM metals are increasingly being linked to respiratory and cardiac symptom, lung injury and in some regions human mortality (Dreher et al., 1997; Gravett et al., 2003; Cho et al., 2003).

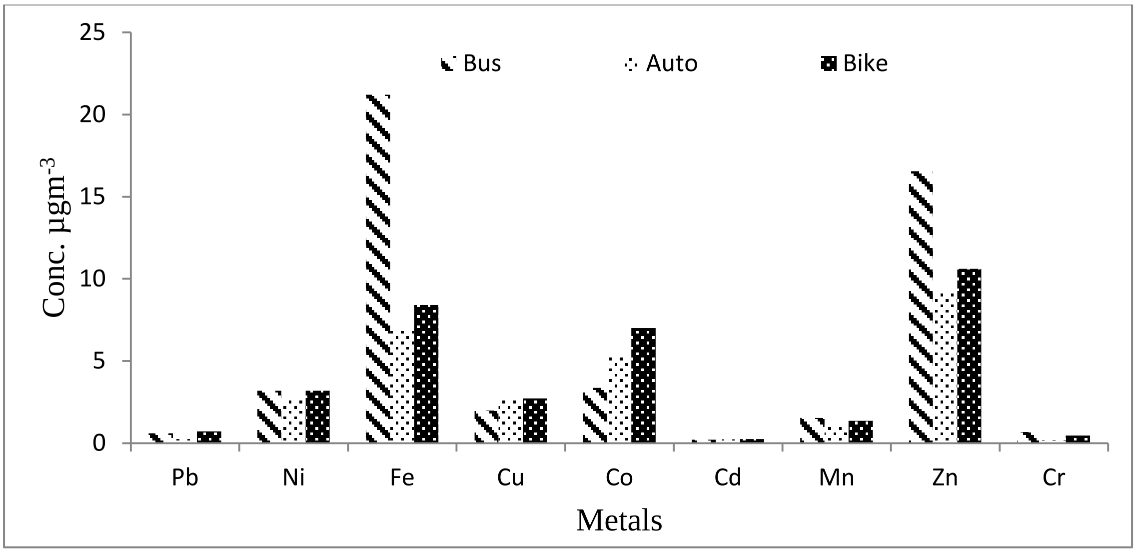

Fig. 4. Particulate bounded metals concentration of bus, auto-rickshaw and bike

2. Human Health Risk Assessment

The human health risk happens due to particulate-bound elements emitted from vehicles as well as road side dust. The pertinent information of RfD and Slop Factor (SF) for adults are given in Table 2. Mean concentration of elements were used for calculations.

Table 2. Reference dose and Carcinogenic factor for metals

Metals	Reference Dose Mg /kg /day	Slope Factor
Pb	6.0×10^{-3}	
Fe	3.0×10^{-1}	
Zn	3.0×10^{-1}	
Mn	5.0×10^{-3}	
Cu	4.0×10^{-2}	
Co	6.0×10^{-2}	
Ni	2.0×10^{-2}	*1.2*
Cd	5.0×10^{-4}	*6.3*
Cr	*1.00*	*42*

**Data from Smith, 1996*

2.1. Human health risk travel by Bus

As shown in Table 3, the levels of non-carcinogenic risk (total HQ) were estimated to be 124×10^{-3} for bus and inhalable carcinogen risk (total inhalable risk) to be 5.367×10^{-4} for Bus.

Table 3. Human health risk (travel by Bus)

Pollutant	**Hazardous Quotient (HQ)**	**Inhalation Carcinogenic risk**	**Dermal Carcinogenic risk**
Pb	19.45×10^{-3}		
Fe	13.93×10^{-3}		
Zn	10.84×10^{-3}		
Mn	59.96×10^{-3}		

Cu	9.66×10^{-3}		
Co	11.04×10^{-3}		
Ni		7.34×10^{-5}	1.47×10^{-10}
Cd		2.43×10^{-5}	4.86×10^{-11}
Cr		4.39×10^{-4}	1.07×10^{-9}
	$\sum = 124 \times 10^{-3}$	**$\sum = 5.367 \times 10^{-4}$**	**$\sum = 1.265 \times 10^{-9}$**

This study also tries to find dermal carcinogenic risk (total dermal risk) to be 1.265×10^{-9} for Bus. From the result, it can be deduced that the non-carcinogenic risk indicated by both individual HQ and total HQ stand below acceptable levels (acceptable level for HQ = 1). On the other hand, inhalable carcinogenic risk indicated much higher than the acceptable limits of 1×10^{-6}, according to the EPA Cancer Risk Guidelines (EPA, 2011). But dermal carcinogenic risk showed much below than the acceptable limits.

2.2. Human health risk travel by Auto-rickshaw

Table 4 reveals that the level of non-carcinogenic risk (total HQ) was estimated to be 93.19×10^{-3} for Auto-rickshaw and inhalable carcinogen risk (total inhalable risk) to be 2.32×10^{-4} for Auto-rickshaw. This study explores dermal carcinogenic risk (total dermal risk) of 4.75×10^{-10} for Auto-rickshaw. From the result, it can be asserted that the non-carcinogenic risk indicated by both individual HQ and total HQ remain below acceptable levels (acceptable level for HQ = 1). Inhalable carcinogenic risk indicated much higher than the acceptable limits of 1×10^{-6}, as suggested by EPA Cancer Risk Guidelines (EPA, 2011). But dermal carcinogenic risk appears much below than the acceptable limits.

Table 4. Human health risk (travel by Auto-rickshaw)

Pollutant	**Hazardous Quotient (HQ)**	**Inhalation Carcinogenic risk**	**Dermal Carcinogenic risk**
Pb	8.08×10^{-3}		
Fe	4.59×10^{-3}		
Zn	5.98×10^{-3}		
Mn	44.18×10^{-3}		
Cu	12.91×10^{-3}		
Co	17.45×10^{-3}		
Ni		6.25×10^{-5}	1.25×10^{-10}
Cd		2.27×10^{-5}	5.54×10^{-11}
Cr		1.47×10^{-4}	2.95×10^{-10}
	$\sum = 93.19 \times 10^{-3}$	**$\sum = 2.32 \times 10^{-4}$**	**$\sum = 4.75 \times 10^{-10}$**

2.3. Human health risk travel by Bike (Two Wheelers)

As shown in Table 5, the level of non-carcinogenic risk (total HQ) were estimated to be 126×10^{-3} for Bike (Two Wheelers) and inhalable carcinogen risk (total inhalable risk) to 4.46×10^{-4} for Bike.

Table 5. Human health risk (travel by Bike)

pollutant	**Hazardous Quotient (HQ)**	**Inhalation Carcinogenic risk**	**Dermal Carcinogenic risk**

Pb	23.43×10^{-3}		
Fe	5.52×10^{-3}		
Zn	6.96×10^{-3}		
Mn	53.84×10^{-3}		
Cu	13.41×10^{-3}		
Co	23.00×10^{-3}		
Ni		7.35×10^{-5}	1.47×10^{-10}
Cd		2.86×10^{-5}	5.73×10^{-11}
Cr		3.65×10^{-4}	7.30×10^{-10}
	$\sum = 126 \times 10^{-3}$	**$\sum = 4.46 \times 10^{-4}$**	**$\sum = 9.34 \times 10^{-10}$**

This paper also tries to find dermal carcinogenic risk (total dermal risk) to be 9.34×10^{-10} for Bike. The non-carcinogenic risk indicated by both individual HQ and total HQ appear below acceptable levels (acceptable level for HQ = 1). On the other hand, inhalable carcinogenic risk indicated much higher than the acceptable limits of 1×10^{-6}, according to the EPA Cancer Risk Guidelines (EPA, 2011). But dermal carcinogenic risk shows much below than the acceptable limits.

Conclusion

Total aerosol concentrations at all the mode of transportation (Bus, Bike and Auto-rickshaw) are found to be well below the standards prescribed by OSHA (5000 µgm $^{-3}$). The maximum concentration of RSPM is observed in Bike and minimum in Auto-rickshaw. Fe is found to be the dominant metal in all mode of transportation followed by Zn, Co, Ni and Mn. Risk assessments of particulate bounded elements can be deduced that the non-carcinogenic risk indicated by both individual HQ and total HQ below acceptable levels (acceptable level for HQ = 1). On the other hand, inhalable carcinogenic risk indicates much higher than the acceptable limits of 1×10^{-6}. But dermal carcinogenic risk shows much below than the acceptable limits.

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