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URBAN AMBIENT AIR QUALITY IN KOLKATA: AN ASSESSMENT OF DIFFERENT POLLUTING SOURCES

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Keywords	*Abstract*
Air Quality, Kolkata, Vehicular Emission, Industrial Emission, Road Dust.	Kolkata, a metropolitan city in West Bengal has been designated as one of the most polluted cities in the world in terms of ambient air quality. The deteriorated air quality in Kolkata is the outcome of several factors where the vehicular emission has found to be the leading contributor (51.4 per cent) to air pollution followed by industrial emission (24.5 per cent) and dust particles (21.1 per cent) respectively. The limited road spaces, heavy concentration of private motor vehicles, concentration of large number of old vehicles and significant growth of vehicular population are some of the major causes of vehicular emission and resulted pollution in Kolkata. An assessment of vehicular emission have revealed that buses (65 per cent) are the leading contributor of particulate matter which includes large buses with 48.2 per cent and small busses with 17.2 per cent emissions respectively. The major source of emissions of CO and HC are 3 wheelers with 44 per cent and 69 per cent share respectively. Buses are the single largest emitter of oxides of nitrogen accounting for nearly 73 per cent of the fleet emissions. The power generating plants are the biggest industrial source of NO_x and SO_2 emissions with 32,232 and 9,964 metric tons per year releasing into the atmosphere. These are also comprises the single largest contributor to NO_x and SO_2 with 94.2 per cent and 80.5 per cent emissions respectively. Foundry leads to the emission of

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	RPM with 49.4 per cent which was the highest single emitter of RPM followed by brick kilns, power plant coal and battery manufacturing with 17.9 per cent, 14.2 per cent and 11.9 per cent share of emissions respectively. The RPM emission from paved road dust is 45,881 tons per year which is 85 per cent of the total area source of RPM emissions. The other least significant source of air pollution includes open burning of fossil fuel, domestic cooking in slum areas and emission from diesel running trains.

1.1 Introduction

The word urban is the manifestation of cities and towns. Cities are both social and physical structures. It ranges from the structural characteristic of large build up areas, functional characteristics in terms of economic activities and cultural attributes such as centres for learning, scholarship, artistic achievement and religious activity etc. Life in the city is an amalgam of social encounters and physical experiences (Douglas, 1983). Urban areas are considered to be the world's primary sources of air pollution and hazardous waste generation. Currently the world's urban complexes, which occupy less than 5 per cent of the earth's land area, produce as much as 80 per cent of the CO_2 pollution (Ghosh and Maji, 2011). In India, the situation is particularly problematic. More than 90 per cent of the national monitoring stations have recorded particulate concentrations exceeding the WHO permissible limit (The Energy and Research Institute, 2003). There are many anthropogenic activities continuously happening in the name of development in India where the environmental pollution can broadly be attributed to rapid industrialization, energy production, urbanization, commercialization and increase in the number of motorized vehicles (Maitra, 1993). The anthropogenic activities and changing lad use pattern may also destroy the existing micro-climate and create great complexities to the city dwellers (Kumar and Singh, 2003). The large metropolitan cities like Mumbai, Kolkata, Chennai and Delhi present a very depressing picture as the environment in these places becoming worsen day by day (Maiti et al., 2005). The present study has been conducted by taking case study of Kolkata, the capital city of West Bengal. Spread roughly north-south along the east bank of the River Hugli, Kolkata sits within the lower Ganga Delta of Eastern India. The city lies about 86 miles away from the sea and 18-20 feet above the mean sea level (Imperial Gazetteer of India, 1984). Its latitudinal and longitudinal extent is 22˚56′N and 88˚36′E respectively.

1.2 Present Status of Air Quality in Kolkata

West Bengal Pollution Control Board (WBPCB) monitored air quality in the district of Kolkata at 17 stations. Air qualities at these stations were monitored during April 2010- December 2011 for four criteria pollutants namely Suspended Particulate Matters (SPM), Respirable Particulate Matter (RPM), Sulphur Dioxide (SO_2) and Nitrogen Dioxide (NO_2). Following the national air monitoring protocol, these stations operate on two days a week for 24 hours in each day of monitoring to get representative air quality information (West Bengal Pollution Control Board, 2011).

For assessing the air quality, CPCB has introduced a method called Exceedence Factor (the ratio of annual mean concentration of a pollutant with that of a respective standard). The air quality has been

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categorized into four broad categories with applying the formula of Exceedence Factor (EF). These four categories of pollution level are Low, Moderate, High and Critical (CPCB, 2012).

The Exceedence Factor (EF) is calculated as follows:

$$\textbf{Exceedence Factor} = \frac{\textbf{Observed annual mean concentration of criteria pollutant}}{\textbf{Annual standard for the respective pollutant and area class}}$$

The four air quality categories are:

- Critical pollution (C): when EF is > 1.5;
- High pollution (H): when the EF is between 1.0 - <1.5;
- Moderate pollution (M): when the EF between 0.5 - <1.0; and
- Low pollution (L): when the EF is < 0.5.

The analysis of the criteria pollutants with respect to National Ambient Air Quality Standards (NAAQS) during 2010-2011 revealed that out of the total 17 monitoring stations from where data has been gathered, SO_2 mainly showed low concentration in all the locations. With respect to the parameter NO_2, 12 locations came under the high category and rest of the 5 in critical category of pollution level. Similarly for RPM (PM_{10}), 10 locations came under high category and remaining 7 locations came under the critical level of air pollution.

1.3 Possible Sources of Air Pollution in Kolkata

Out of several factors that cause air pollution in Kolkata, one of the main factors is transportation (Mondol et al. 2000; Ghose et al. 2004) where the abundance of poorly maintained vehicles, use of petrol fuel and poor controlling is making transportation the major air polluting sector (Mukherjee and Mukherjee 1998; Kazimuddin and Banarjee, 2000). Besides, there are three thermal power plants operating in and around Kolkata and some small scale industries which also affects the air quality (Ghose, 2009). An analysis of different sources of air pollution in Kolkata has revealed that the motor vehicles are the leading contributor to air pollution (51.4 per cent) which is followed by industry (24.5 per cent) and dust particles (21.1 per cent) respectively (**Fig. 1**).

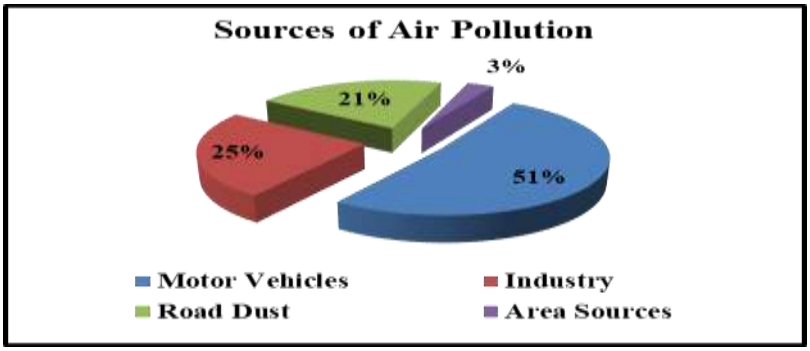

Figure 1: Sources of Air Pollution in Kolkata

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1.4.1 Vehicular Sources of Air Pollution

Vehicular emission constitutes more than half (51.4 per cent) of the total emission summary of the air pollution. In Kolkata, a large number of vehicles are plying daily with only 6 per cent available road space, causing congestion which reduces the average vehicular speed and also resulted into heavy vehicular emission (West Bengal Pollution Control Board, 2010). The number of vehicles has a growth of about 2.00 times which numbers to 1.20 million in 2011 from 0.73 million in 1996 (Government of West Bengal, 2012). The vehicular population in Kolkata has increased at an annual growth rate of 4 per cent. Private cars have increased from 0.26 million in 2000 to 0.65 million in 2011 which indicates 2.5 times increase (Bhaduri, 2013). The heavy concentration of private motor vehicles in metropolitan cities has been one of the key reasons for congestion, increased travel times, pollution and accidents. In terms of available surface road length Kolkata has least coverage about 1,416 km, whereas the vehicular density is one of the highest nearing 823/km (Government of West Bengal, 2013).

Fuel Consumption and Age Distribution of Vehicular Fleet in KMA

Diesel related emissions both particulate matter and nitrogen oxides are of serious concerns in the city. In Kolkata, nearly 65 per cent of all vehicles and nearly 99 per cent of all commercial vehicles are diesel-run (Centre for Science and Environment, 2011). Large diesel buses account for nearly one half of the vehicular particulate matter in Kolkata. Nearly 65 per cent of the vehicles in the city are more than 15 years of age. It is evident that an old diesel bus could emit 12 times more pollution than a new bus (Centre for Science and Environment, 2011). About one-quarter of the large trucks are over 30 years old and over one third of these are 20 years old. About 6 per cent of the passenger cars are over 30 years old and 16 per cent are more than 20 years old, suggesting that there is very little turnover in the vehicle fleet (**Table 1**).

Table 1: Kolkata Vehicles Fleet Age Distribution

Vehicles Types	**Age Distribution of Vehicles (Percentage)**			
	Age > 30 years	**Age 20-30 years**	**Age 10-19 years**	**Age <10 years**
2 Wheelers	0.8	4.9	13.5	80.7
3 Wheelers	11.9	71.7	13.6	2.8
Large Bases	4.4	25.7	38.7	31.2
Large Trucks	28.4	6.6	11.6	53.5
Passengers Cars	5.6	11.0	33.4	50.0
Small Buses	1.2	3.6	5.2	90.1
Small Trucks	11.4	4.7	46.4	37.5

Source: WBPCB, 2005.

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Assessment of Vehicular Emissions

For assessing the vehicular emissions, an estimation of air pollution emissions from Kolkata motor vehicles were conducted by West Bengal Pollution Control Board in 2005. The summary of mobile source emissions of RPM, CO, HC and NOx in metric tons per year emitted by Kolkata vehicle fleet (tailpipe emissions only) thus evaluated have revealed that the largest contributor to particulate matter emissions from mobile sources are buses which collectively account more than 65 per cent. These are includes large buses with 48.2 per cent and small busses with 17.2 per cent emissions respectively. The major source of emissions of CO and HC are 3 wheelers with 44 per cent and 69 per cent share respectively. Buses are the single largest emitter of oxides of nitrogen accounting for nearly 73 per cent of the fleet emissions (**Fig. 2**). It has been found that the large buses and the 3 wheelers are the major sources of vehicular pollution as the emission emitted by these are having maximum share among the various sources of vehicular pollution.

1.4.2 Industrial Sources of Air Pollution

Industries are the second largest source of air pollution in Kolkata which constitute near about 25 per cent of the total emission summary. The industrial sources include coal-fired power plants, brick kiln operation and a number of small scale industries including rubber product factories, foundries, battery manufacturing, restaurants, dying and bleaching operation, bakeries and paper product (West Bengal Pollution Control Board, 2005). The releases of gasses from the industries and its mixing with the ambient air directly pollute the environment and make it unhealthy for breathing (**Plate 1**).

Plate 1: Industrial Emissions at Garden Reach in Kolkata

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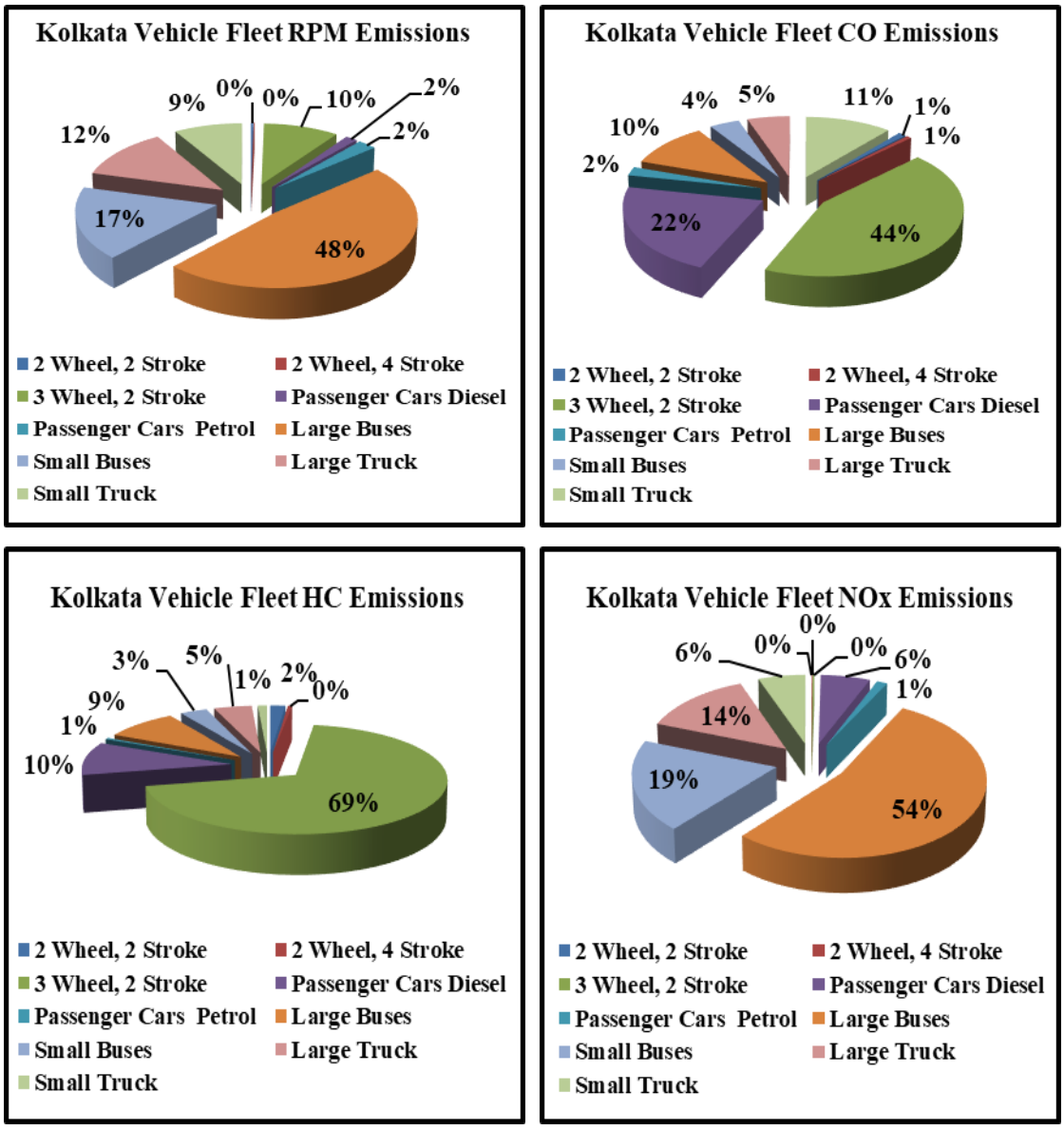

Source: WBPCB, 2005.

Figure 2: Vehicular Sources of Emissions

It is found that the Kolkata Leather Complex with 500 units under its production is an important industrial sector in Kolkata (West Bengal Pollution Control Board, 2006). Besides that, the paper and paper products and leather based industries are very much prominent in Kolkata with 206 and 181 units under their operation. Woollen, silk and artificial thread based clothes industries with 100 units in operation have also constitutes a major share in the industrial set up of the area along with readymade garments and embroidery with 59 units under its operation (**Table 2**).

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Table 2: Micro and Small Enterprises and Artisan Units in Kolkata

NIC Code No.	Type of Industries	Number of Units
14	Cotton Textile	2
14	Woollen, Silk & Artificial Thread Based Clothes	100
14	Readymade Garments & Embroidery	59
16	Wooden/ Wooden Based Furniture	1
17	Paper and Paper Products	206
15	Leather Based	181
20	Chemical/ Chemical Based	9
22	Rubber, Plastic & Petro Based	3
25	Metal Based (Steel Fab.)	13
27 & 29	Electrical Machinery &Transport Equipment	8
95	Repairing & Services	1

Source: MSME, 2012.

Industrial Categorization and Grossly Polluting Industries in Kolkata

Depending upon the pollution potential, the WBPCB has classified the industrial units in three different categories: Red, Orange, and Green. The 'Red' category units have maximum pollution potential, the 'Orange' category units have moderate pollution potential and the 'Green' units have the least pollution potential (West Bengal Pollution Control Board, 2006). It has identified 334 grossly polluting units under its regular surveillance. Among the grossly polluting industries in Kolkata, secondary lead smelting comprises the highest number with 17 units under its operation. other polluting industries are includes electro plating with 5 units, asbestos with 3 units and pharmaceutical, soft drink manufacturing and foundry with 2 units each under their operation respectively (**Table 3**).

Table 3: Grossly Polluting Industries in Kolkata

Sl. No.	Type of Industries	Number of Units	Sl. No.	Type of Industries	Number of Units
1	Secondary Lead Smelting	17	13	Zinc Melting	1
2	Bakery & Biscuit Manufacture	1	14	Engineering	1

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3	Pharmaceuticals	2	15	Chemical Units	1
4	Soft Drink Manufacture	2	16	Distillery	1
5	Electro Plating Units	5	17	Dyes and Dye Intermediates	1
6	Asbestos	3	18	Rubber Goods	1
7	Foundry	2	19	Paper & Pulp	1
8	Soap & Detergent Manufacture	1	20	Chlor-Alkali	1
9	Bulk Drug Smelting	1	21	Vanaspati Manufacturer	1
10	Wagon Manufacturer	2	22	Match Manufacturer	1
11	Basic Drug Units	1	23	Lead Smelting	1
12	Dry Cell Manufacturer	1			

Source: WBPCB, 2010.

Assessing industrial Emissions

For assessing the emissions from these dispersed sources, a field survey was conducted by WBPCB in 2005 covering 26 small scale industries namely bakeries, lead smelters, acid lead battery plants, iron foundries, rubber products manufacturing, dyeing and bleaching operation, restaurants, ceramics and paper product manufacturing. The results have revealed that the power plant coal comprises the single largest contributor to NO_x and SO_2 with 94.2 per cent and 80.5 per cent emissions respectively. Foundry leads to the emission of RPM with 49.4 per cent which was the highest single emitter of RPM followed by brick kilns, power plant coal and battery manufacturing with 17.9 per cent, 14.2 per cent and 11.9 per cent share of emissions respectively (**Table 4**).

Table 4: Industrial Source Emissions Summary

Source Types	**Emissions (Metric Tons Per Year)**			**Emissions (Percentage)**		
	RPM	**NOx**	**SO_2**	**RPM**	**NOx**	**SO_2**
Power Plants- Coal	934	32,232	9,964	14.2	94.2	80.5
Brick Kilns	1,177	N/A	N/A	17.9	N/A	N/A
Bakeries	200	10	0	3.0	0.02	0
Ceramics	17	44	4	0.3	0.1	0.03
Dry & Bleaching	19	10	155	0.3	0.02	1.3

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Restaurants	117	44	5	1.8	0.1	0.04
Battery Mfg.	784	547	970	11.9	1.6	7.8
Paper Product	65	285	1,083	1.0	0.8	8.7
Rubber Product	16	4	59	0.2	0.01	0.5
Foundry	3,244	1,031	139	49.4	3.0	1.1
Totals	**6,571**	**34,208**	**12,378**	**100.0**	**100.0**	**100.0**

Source: WBPCB, 2005.

Table 5: Other Sources of RPM Emissions

Source Type	Emissions (TPY)	Emissions (Percentage)
Road Dust	45,881	88.8
Diesel Trains	163	0.3
Slum Cooking	1,211	2.4
Open Burning	4,388	8.5
Totals	**51,643**	**100.0**

Source: WBPCB, 2005.

1.4.3 Other Sources of Air Pollution in Kolkata

In Kolkata, the ever increasing population and their activities accentuate air pollution emissions from different sources including paved and unpaved road dust, residential and street-side cooking, small scale commercial operations, trash burning, and many other (**Table 5**). These sources are dispersed throughout the KMA, often have no specific location and are of temporary in nature. Cumulatively, these sources significantly contribute to air pollution emissions within the KMA.

1.4 Conclusion

The study thus conducted to identify the factors being responsible for the deterioration of air quality in Kolkata has revealed that the single largest source of air pollution is the vehicular emission. The vehicular source of emission is due to the unavailability of proper road spaces and the disproportionate vehicles plying on it. It is found that the buses are the largest emitters of RPM and NO_2 where the large buses are having their biggest share along with the small buses and three wheelers. One of the biggest reasons of vehicular emission in Kolkata is the presence of old vehicles in large number and their consumption of excessive fuel resulted into more emission. Another biggest source of air pollution is

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the industrial emissions where the thermal power plants are found to be the largest emitters of NOx and SO_2 followed by the foundry which is the major source of industrial RPM emission. Dust particles and fossil fuels used in slums are some of the area sources found to have a little share in RPM emissions into the ambient air.

AUTHOR(S) CONTRIBUTION

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CONFLICTS OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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