Ambient Air Quality Monitoring and Management in Moradabad

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Abstract

The present study deals with the assessment of ambient air quality with respect to Total Suspended Particulates (TSP), Respirable Suspended Particulate Matter (PM_{10}), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2) considered over a period of two years from Sep 2010 to Aug. 2012. Air quality index are used for local and regional air quality management in many cities of the world. The air quality index has been determined at three different sites i.e. PTC (SI), Buddh Bazar (SII) and Mughalpura (SIII) of Moradabad city. The experimental results obtained from the different air quality categories according to national ambient air quality standard at different site as PTC (SI) though looks a clean area, falls under moderate pollution category with 68.78 index value. This may be due to fossil fuel combustion at the outskirts of the parade grounds and burning of dry leaves inside the area. Buddh Bazar (SII) which is a commercial area falls under high air pollution category with 99.48 index value. This site near railway station is extremely congested resulting in slow movement of vehicles, long waits at the signals and a large number of vehicles running during the day and night time. Mughalpura (SIII) is an industrial area, falls under the very high pollution category with 120.99 index value, may be due to the industrial activities i.e. mainly brasswares. Five heavy metals i.e. Cu, Zn, Fe, Cd and Pb were also observed at all the sites. Among the metals highest concentration of Zn was recorded at almost all the sites whereas Cu, Zn and Fe was found higher at industrial site, may be attributed to melting of Brass sillies to prepare the different Brassware items.

Keywords: AQI, Heavy Metals, Air Quality Management

1. Introduction

Exposure to air pollution is the main environmental threat to human health and vegetation. Various chemicals are being emitted into the air from both, natural and anthropogenic sources. In spite of the introduction of cleaner technologies in industry, energy production and transport, air pollution remains a major health risk.

Particulate matter pollution is nowadays one of the most concerning problems in urban cities, not only because of the adverse health effects, but also for the reducing atmospheric visibility and affect to the state of conversion of various cultural heritages [1]. A number of epidemiological studies [2-4] have demonstrated that acute and chronic health effects are related to the inhalable PM_{10} exposure in the urban environment may be due to the carriers of acidic or toxic species, and some data also seem to indicate possible seasonal effects of the particulate matter on human health. Scientists have argued that PM_{10} could be substituted as a better standard cut-off point or more effective indicator for fine particles rather than $PM_{2.5}$ [5] because human respiratory systems are highly associated with PM_{10} levels [6, 2]. Besides particulate matter, literature also suggests that there is a strong relationship between higher concentration of SO_2 and NO_2 and several health effects [7], like cardiovascular diseases [8, 9], respiratory health effects such as asthma and bronchitis [10], reproductive and developmental effects such as increased risk of preterm birth [11].

Among all other pollutants, air borne trace elements are a major threat to the human health [12]. Normally toxic trace elements are found to be associated with the finer particle size rather than coarser ones [13]. Heavy metals present in suspended PM are considered to be a health hazard since they are readily absorbed by the lung tissues. Toxicological in vitro and in vivo studies have shown that metals are harmful components of PM as they can cause different cardiovascular and lung diseases [14].

The AQI (Air Quality Index) for the pollutants is an index to indicate and to monitor trends of the medium and long term back- ground pollution levels that are typically higher in urban areas than in rural setting and this is largely due to the

concentration of human activities that occur in cities [15]. Already Environmental Protection Agency (EPA) is using the AQI for the following five major pollutants regulated by clean air viz. ground level ozone, particulate matter, carbon monoxide, sulphur dioxide and nitrogen dioxide. For each of these pollutants EPA has set National Ambient Air Quality Standards (NAAQS) to protest against harmful health effects.

The present study was undertaken to estimate the level of criteria pollutants and trace metal accumulation (Cu, Zn, Fe, Cd and Pb) in atmospheric environment of Moradabad city for the period of two years. The air quality index is estimated for respective areas, i.e. residential, commercial and industrial. A detailed environmental management plan for Moradabad city is also discussed herewith.

2. Material and Methods
2.1. Study Area

Moradabad is the Brasscity of India, situated in northern India with a population of 889,810 (Census, 2011) and lies

between 28^0 15' Latitude and 74^0 49 Longitude at 76.19 m above sea level. Monitoring of SPM, PM_{10}, SO_2 and NO_2 was done simultaneously in the ambient air at three different locations of Moradabad city. As seen in Fig. 1. sampling locations in Moradabad include Police Training Centre (PTC, SI) Buddh Bazar (SII) and Mughalpura (SIII) representing residential, commercial and industrial area respectively.

Moradabad is famous worldwide for brassware. It is the largest producing and exporting centre of Brass items. In and around the city there are about 7137 small and large industries are located and about 36,915 workers are working in these industries (Industries Directory 2012). The vehicular population in the city is increasing day by day. About 44039 vehicles were recorded in Moradabad up to March 2012 (RTO, Moradabad). The brassware industries and the increasing number of vehicles are degrading the air quality of Moradabad city.
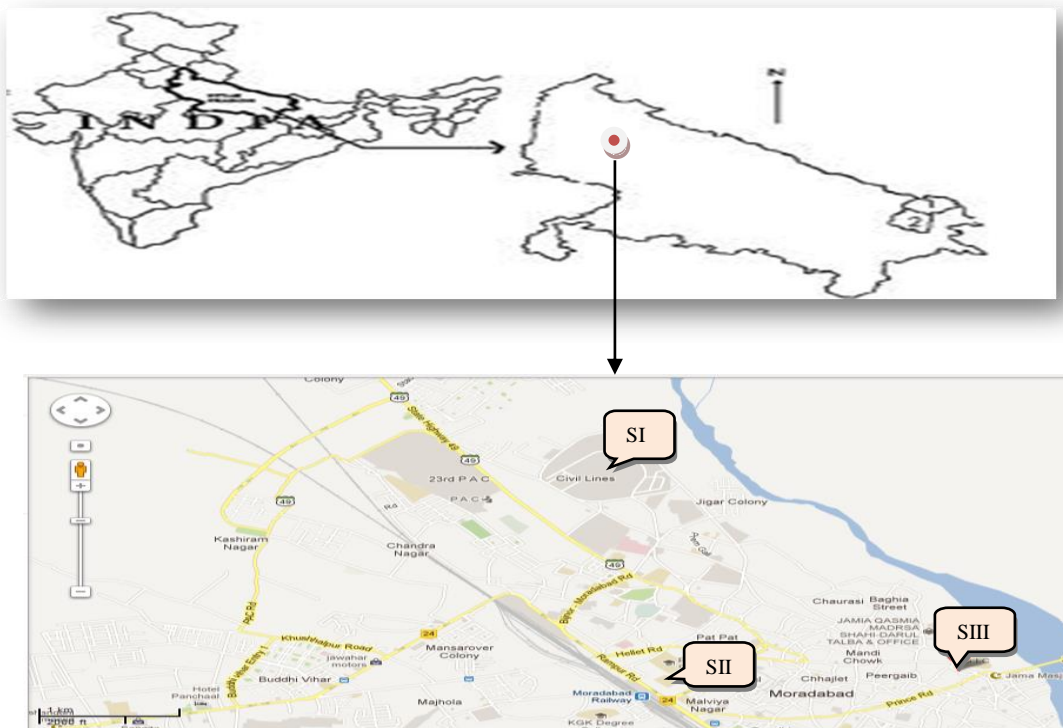

Fig. 1. Map of the sampling site

2.2. Sampling and Analysis

Monitoring of SPM and PM_{10} was carried out using Respirable Dust Sampler (Model-460NL, Envirotech, New Delhi) at a flow rate of 1.0-1.2m3/min for two samples per week on Whatman glass fiber filter paper – GF/A for 24 hrs. (Three shift, i.e. 8 hrs). The difference in initial and final weight of the filter paper gave the total quantity of RSPM collected over the 24 hours period. The values of PM_{10} were reported in μg/m³.

react with para rosaniline and methysulphonic acid. The absorbance of the solution was measured at a wavelength of

Mass concentration of SPM was calculated by adding the concentration of RSPM and NRPM (as the air with suspended particulates enters the cyclone, coarse non-respirable dust is separated from the air stream by centrifugal forces. The suspended particulate matter falls through the cyclone's conical hopper and is collected in the cyclonic-cup).

The analysis of SO_2 and NO_2 was done by Bureau of Indian Standard (BIS) methods [16, 17]. A known quantity was passed through the impinger containing known volume of absorbing solution: SO_2 is absorbed in absorbing solution, sodium tetrachloromercurate dichlorsulphitomercurate complex is formed which made to

560 nm on spectrophotometer (Systronics 166). Whereas, Nitrogen oxides (NOx) as nitrogen dioxide was observed in

absorbing solution, sodium hydroxide which formed a stable solution of sodium nitrite. The nitrite ion produced was determined colorimetrically at a wavelength 540 nm by reacting the exposed absorbing reagent with phosphoric acid, sulphanilamide and N (1- naphthyl) ethylenediamine dihydrochloride.

2.3. Heavy Metal / Elemental Analysis

For heavy metal analysis, a portion of the fiber filter paper covered by particulates was digested by nitric acid and perchloric acid at 140^0C hot plate. Residues were then re-dissolved by 0.1m hydrochloric acid and a blank was also prepared using the same area of unexposed glass fiber filter paper and by treating the same procedure. These were cooled, filtered and made to 50 ml by distilled water. Concentrations of heavy metals were analyzed by Inductively Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES; Spectro Analytical Instruments, West Midlands, UK) from samples collected for each site.

2.4. Statistical Analysis

Summary statistics were used to obtain the means and standard deviations for the criteria pollutants and trace metals. One–way analysis of variance (ANOVA) was applied to detect the significant difference between metals and within metals (p ≤0.01).

3. Results and Discussion

3.1. Air Quality Status and Trend

The air quality data of selected parameters from three different monitoring stations have been analyzed to determine the status and trend in the ambient air during the period of September 2010 to August 2012. It has been found that annual average concentrations of PM_{10} and Total Suspended Particulate Matter are found to exceed the National Standards (NAAQS) while the annual average of sulphur dioxide and nitrogen dioxide were found to be within the national standards [19]. The Central Pollution Control Board (CPCB), New Delhi has presented a maximum permissible limit for each air pollutant for specific areas.

3.1.1. Particulate Matter (PM_{10} and TSP)

There is now growing concern all over the world about particulate matter of size 10 micron and 2.5 micron (PM_{10} and $_{2.5}$) or less. The WHO has classified these as thoracic particles because they are respirable and because of their small size get lodged deep down in the lower respiratory track. These particles exacerbate cardiac and respiratory problems among the primary pollutants [18]. Results show that the annual mean concentrations of PM_{10} at different sites in Moradabad city, i.e. PTC (residential area, SI), Buddh Bazar (commercial area, SII) and Mughalpura (industrial area, SIII) were 130.91 µg/m³, 178.04 µg/m³, 181.45 µg/m³ respectively which are more than the permissible limit of NAAQS [19].

The monthly mean concentrations of PM_{10} ranged between 45-290 µg/m³ during the period of Sep. 2010-Aug. 2012. The highest monthly mean concentration was observed at Mughalpura in the month of January 2011, while the lowest concentration was found at PTC in the month of September

2010. All the mean monthly values were found to exceed the national standard at each site except at PTC (SI) in the month of September (Fig. 2a).

The annual concentrations of TSP at all the sites were found 141.91 µg/m³ (SI), 299.95 µg/m³ (SII), 327 µg/m³ (SII) respectively. At all the respective sites the annual concentrations crossed the prescribed annual limit [19]. The monthly mean concentrations of Total Suspended Particulates ranged between 88-431 µg/m³. The maximum concentration was recorded at Mughalpura in December 2010, while the lowest concentration was found at PTC in August 2011. At commercial (SII) and industrial (SIII) sites, all the mean monthly values exceeded the prescribed the NAAQS while at residential (SI) site some values were within the prescribed limit (Fig. 2b).

According to Fig. 2a and 2b, the concentrations of particulate pollutants were found to be highest in winter season and lowest in monsoon season. The foggy hazy conditions are said to have been caused by persistent particulate emissions from air pollution sources in association with a proglonged dry period in stable meteorological conditions [20]. This creates an unfaurable conditions for efficient transportation and dispersion of surface pollutants in the region.
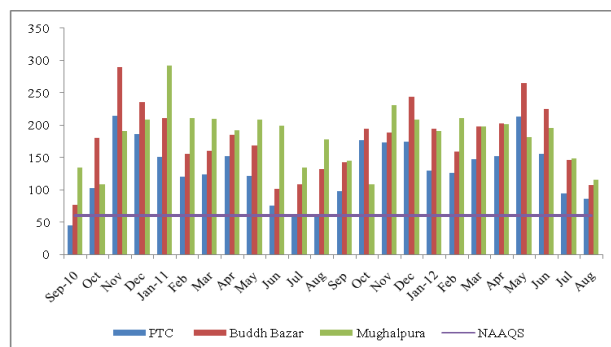

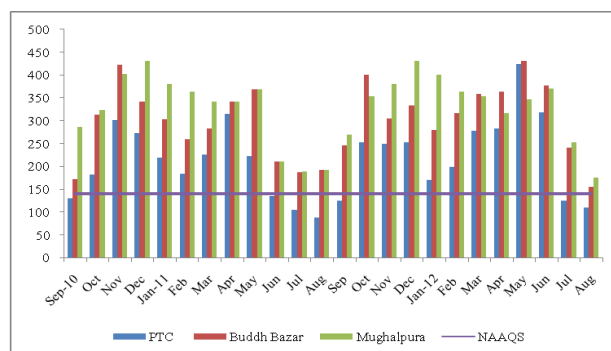**Fig. 2a. Status and trend of PM_{10} (µg/m³) at three sites of Moradabad**

Fig. 2b. Status and trend of TSP (µg/m³) at three sites of Moradabad city

3.1.2. Gaseous Pollutants (SO_2 and NO_2)

Results for the gaseous concentrations were presented in Fig. 3a and 3b. The annual mean concentration of sulphur dioxide for three respective site, i.e. SI (residential), SII (commercial)

and SIII (industrial), were found $10.75\mu g/m^3$, $12.91\mu g/m^3$, $19.87\mu g/m^3$ respectively. The annual concentration of SO_2 at all the representative sites are not more than the prescribed limit of NAAQS, i.e. 50 $\mu g/m^3$. The monthly mean concentrations of SO_2 ranged between 5 – 25 $\mu g/m^3$ during the study period. The highest monthly mean concentration was recorded at Mughalpura in January 2011, while the minimum mean concentration was found at PTC in the month of September 2010. High level of SO_2 are particularly dangerous in the presence of PM, because it slowly absorbs on fine atmospheric particles and can be transported very deep into the lungs causing damage to the lung tissues. The monthly mean concentrations at all the sites, i.e. residential, commercial and industrial, were within the recommended standard of NAAQS (Fig. 3a).

NO_2, which is generated maximaly due to the vehicles, was recorded annualy 18.83, 25.28 and $30.54\mu g/m^3$ at PTC (SI), Buddh Bazar (SII) and Mughalpura (SIII) respectively.

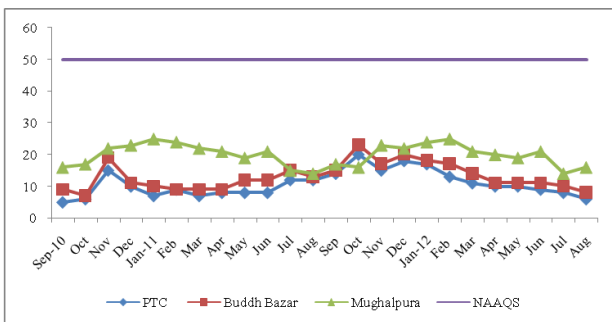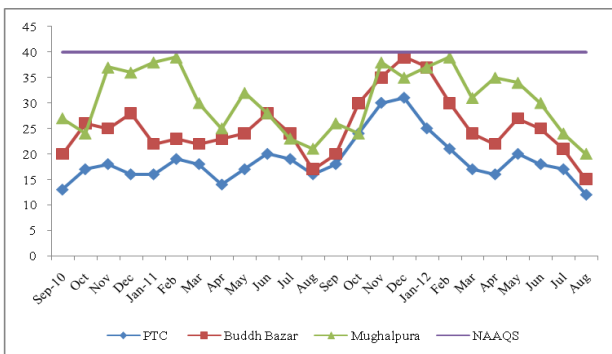**Fig. 3a. Status and trend of SO_2 ($\mu g/m^3$) at three sites of Moradabad city**

Fig. 3b. Status and trend of NO_2 ($\mu g/m^3$) at three sites of Moradabad city

These values did not exceed the prescribed limit [19]. According to the Fig. 3b the monthly mean concentration ranged between 12 - $39\mu g/m^3$. The minimum concentration was recorded in the month of August 2012 in residential area, while the maximum concentration was found in the month of December 2011 in commercial area of the city. Buddh Bazar, a commercial site have a very congested and busy roads with an intensive transport activities, while the Police Training Centre (PTC), a residential site has an open space and greenery all around. The values of NO_2 do not exceed the NAAQS. Maximum values are recorded in winter season, while the minimum concentration was recorded in monsoon. High values of gaseous pollutants in peak months of winter season may be attributed to inversion effect [21].

3.2. Status of elemental concentration in ambient air

Elements are the main constitution of PM that are toxic to human health, as well as plants and other species. The results for the elements are presented in Table 1 and 2. Among all the elements (Cu, Zn, Fe, Cd and Pb) Zn contributed the maximum concentration with an average of 11.96 $\mu g/m^3$ followed by Fe 9.6 $\mu g/m^3$, Cu 7.60 $\mu g/m^3$, Pb 1.94 $\mu g/m^3$, Cd 0.10 $\mu g/m^3$. The highest mean concentration of Zn (21.24±8.02 $\mu g/m^3$), Fe (18.4±1.83 $\mu g/m^3$), and Cu (15.12±9.16 $\mu g/m^3$) was found at site III while the concentration of Pb (2.72±1.22 $\mu g/m^3$) and Cd (0.2±0.21 $\mu g/m^3$) was recorded at Site II (Table 1).

A number of brass industries are located in Mughalpura, the industrial area of the city, which are specialized in melting, casting, cutting, grinding, scraping, polishing, etc. During the process of melting and casting, a large amount of metal fumes are emitted, which may act as a sensitizer and cause allergies i.e. Asthma, Dermatitis, Bronchitis and Cancer etc [22, 23]. In these industries, Brass (60% Cu and 40%Zn) and German silver (55% Cu, 35% Zn and 10% Ni) are the main alloys used for moulding purposes in making brassware items and other utensils in Moradabad.

It has been estimated that vehicular pollution is the primary cause of air pollution in the urban areas (60%), followed by industries (20-30%) in India [24, 25]. The vehicular population in Moradabad city has increased many folds. The major source of human lead accumulation in developing countries was found to be airborne lead and 90 percent of which comes from leaded gasoline [26]. Cadmium, one of the most dangerous pollutants for organism, is mainly derived from combustion of accumulators and carburetors of vehicles [27]. Vehicular traffic, which is a great source of the fine particulates, is often enriched in potentially toxic trace elements in the urban environment [28-30].

Table 1. Elemental status ($\mu g/m^3$) in PM_{10} collected at three sites in Moradabad

	PTC (SI)				Buddh Bazar (SII)				Mughalpura (SIII)			
	Min	**Max**	**Avg**	**SD**	**Min**	**Max**	**Avg**	**SD**	**Min**	**Max**	**Avg**	**SD**
Cu	1.47	3.87	2.1	0.84	3.65	8.54	5.6	1.48	4.9	40.92	15.12	9.16
Zn	0.8	2.8	2.5	0.72	5.02	21.09	12.2	4.76	8.97	21.94	21.24	8.02
Fe	1.71	8.87	3.9	1.9	2.15	9.04	6.55	2.18	15.33	36.8	18.4	1.83
Cd	0.0001	0.01	0.001	0.002	0.008	0.4	0.2	0.21	0.001	0.5	0.101	0.15
Pb	0.56	1.23	1.01	0.36	1.72	5.9	2.72	1.22	1.13	4.03	2.1	0.77

r values shows in bold are significant at p≤0.01

Table 2 Correlation coefficient matrix (r) for selected elements in PM$_{10}$ of three different sites

	Cu	Zn	Fe	Cd	Pb
Cu	1				
Zn	**0.7089**	1			
Fe	**0.6791**	**0.6923**	1		
Cd	0.0876	0.3704	0.0426	1	
Pb	0.1865	0.4161	0.2244	**0.5493**	1

The correlation coefficient between five metals i.e. Cu, Zn, Fe, Cd and Pb has been presented in Table 2. A strong correlation

was found between Cu-Zn (r=0.7089), Cu-Fe (r=0.6791), Zn-Fe (r=0.6923), Cd-Pb (r=0.5493).

Based on the correlation study it may be concluded that the three metals viz. Zn, Fe and Cu (Table 2) might be originated from similar sources [31], probably by the industrial emission or other anthropogenic activities.

A significant correlation was found between Cd-Pb (r=0.5493). These values are significant at p≤0.001 level. These elements are believed to be originated from automobile emissions together with industrial emissions, especially the metallurgical / electroplating units located in the industrial area of the city [32-33].

Table 3 Air Quality Index and air quality category for three different sites of Moradabad city

Parameters / Sites	Quality Rating					
	SO$_2$	NO$_2$	PM$_{10}$	TSP	AQI	Category
PTC (SI)	22	47	218	101	68.78	Moderate Air Pollution
Buddh Bazar (SII)	24	63	297	214	99.48	High Air Pollution
Mughalpura (SIII)	40	76	302	234	120.9	Very High Air Pollution

3.3. Air Quality Assessment / Index

The ambient Air Quality Index is an index for reporting the day to day air quality. It gives details about the cleanliness of ambient air to what extent ambient air is polluted. Indices of air pollution or air quality have been used for about 30 years. The following computation was used to derive the Air Quality Index of the sites under consideration.

$AQI = \frac{1}{4}[TSP/_sTSP + PM_{10}/_sPM_{10} + SO_2/_sSO_2 + NO_2/_sNO2] \times 100$

Where $_sTSP$, $_sPM_{10}$, $_sSO_2$, $_sNO_2$ represent the ambient air quality standard as prescribed by the CPCB for the respective pollutants and TSP, PM$_{10}$, SO$_2$, NO$_2$ are the actual value of the pollutants.

The AQI scale was divided into six categories, each category describes the range of air quality and its associated potential health effect. From 0-25= clean air, 26-50= slight air pollution, 51-75= moderate air, 76-100= high air pollution, 101-125= very high air pollution, >125= severe air pollution. PTC with index value 68.78 μg/m^3 was categories under the moderate air pollution category. Buddh Bazar with index value 99.48 was found in the high pollution category while the Mughalpura with index value 120.9 was found in the category of very high air pollution (Table 3).

The results of air quality monitoring show that the pollution concentrations were highly variable at different sampling sites and depend on the active mobile and stationary pollutant emitting sources and its influence by the meteorological factors.

3.4. Air Quality Management

The objective of environmental management plan is first to estimate the quantum of the emission of major pollutants, i.e. SO$_2$, NO$_2$, PM$_{10}$, TSP and Heavy Metals emitted from different sources and then to make recommendations on technological interventions for air pollution.

During this long term monitoring, the problem of air pollution is predominantly due to small/medium scale industries and vehicles. As the heavy industries are being shifted in outer areas, there are still a number of Brassware melting units in dense residential localities such as Mughalpura, causing respiratory illnesses. Emission from each small unit varies differently depending upon the fuel type used and metals melted. Thus each industry requires particular / specific attention towards air pollution control management.

Apart from industries, burning of e-waste further intensifies the air pollution problem of the city. E-waste (management and handling) rules 2012 that became effective last year is inadequate and does not clear much on the export and its import. E- waste is brought illegally in city from Delhi threw road. Pollution Control Board and city's Administration should cope up this problem at utmost priority.

As the number of vehicles have an exponential increase during recent years. Benzene, Toluene and VOC should also be in listed in NAMP Programme of Moradabad.
A rich Green Belt should be developed around the industries and should be of particularly mixed type plantation to support the biodiversity in Moradabad. The prevailing air pollution

conditions should be identified. In order to select the plant suitable for pollution abatement, the appropriate selection is guided by their performance / response to pollution and also upon their economic /aesthetic value. Furthermore, the selected plant species should preferably be indigenous, fast growing, requiring minimal maintenance and self-rejuvenating.

Almost socio-economic activities i.e. construction of road, houses, industries, transport contribute to environmental degradation including air. These things provide a good life to residents of the city but at the same time these are responsible to degrade the quality of environment. Of course, now the city has to adopt the action plan based upon the air quality data trends and have also to become conscious of their environment.

4. Conclusion

This study concludes that the concentration of PM recorded at three different sites is more than the prescribed limit while gases are found within the prescribed limit recommended by the CPCB, MoEF. Air Quality Index reported in three different sites fall in the polluted category. The estimated airborne metal concentrations in PM_{10} were reported high and might be effected by three major sources i.e. industrial activities, traffic and illegal e-waste burning. These toxic emissions are associated with adverse health effect to the inhabitants as well as to the plants of the city. To develop strategy for air quality management of Moradabad city the first and foremost task is source identification, intensive monitoring data collection and diligent analyses.

Acknowledgments

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