DU Journal of Undergraduate Research and Innovation
Volume 3, Issue 2, pp 71-81

Gauging the Nature and Magnitude of Particulate Matter (PM) Concentrations in Bengaluru, the IT Capital of India

Charu K. Gupta[1], Jatinder Pal Singh, Priya Chopra, V. Bhasker Raj and Arijit Chowdhuri[2]

[1]Environmental Monitoring and Assessment Laboratory (EMAL)

[2]Sensing Materials and Devices Laboratory (SMDL)

Acharya Narendra Dev College (University of Delhi), Kalkaji, New Delhi-110 019

arijitchowdhuri@andc.du.ac.in

ABSTRACT

Developing nations are in the midst of rapid industrialization where environmental concerns are many a time neglected in the larger scheme of things. World Health Organization (WHO) has earmarked the level of air pollution in any country as a benchmark of sustainable development in that country. In view of the WHO air quality threshold standards, air pollution contaminant concentration levels assume importance especially in developing metropolitan cities like Bengaluru (IT capital of India), with burgeoning traffic and workforce which is identified as the silicon valley of India. In the current investigation airborne particulate matter (PM) concentration levels are measured in 10 (ten) traffic hot-spots in Bengaluru over two months to understand the extent of airborne PM encountered by a common man on a daily basis. It is pertinent to note that two types of PM namely – $PM_{2.5}$ (small particles) and PM_{10} (coarse particles) majorly affect the health of humans to the greatest extent. Measured PM levels indicate that places with high number of idling vehicles have high levels of both $PM_{2.5}$ and PM_{10} whereas residential apartments with ongoing construction have elevated levels of only $PM_{2.5}$. Presence of dense foliage and water bodies in the vicinity are seen to alleviate PM concentration levels. However, observed values of PM concentration levels are seen to breach WHO and Indian National Ambient Air Quality Standards (NAAQS) certified threshold values and indicate an urgent need to project the nature and magnitude of airborne PM pollution in all affected cities of India that may help develop strategies to mitigate the same.

Keywords: Air Quality Monitor, Ambient Air Pollution, Mitigation, Particulate matter.

INTRODUCTION

Over the last few decades developing countries have experienced a severe degradation in air quality which has been readily attributed to rapid industrialisation and urbanisation. Due to aforementioned endeavours airborne pollutants arising from diverse origins in the immediate environment are reported to be causing irreversible damage to all living beings and the environment they live in. The pollutants responsible for the deterioration in air quality act as major health hazards by seriously influencing mortality rates and serious illnesses. (1) Their potent nature is ascribed to the fact that their origin is much faster than their rates of absorption or dispersion by the atmosphere or other natural processes. Rapid (unplanned) industrialization, emissions from high density of vehicles (lack of rapid transport for masses), burgeoning waste generation (high population density), biomass burning in rural households along with emanation of various types of suspensions from unpaved roads are some of the typical sources of pollution that ambient air in developing nations. (2) In India, China, Bolivia etc. pollution levels are so severe that ambient air pollution (AAP) component in the urban environment surpasses even the total atmospheric pollution monitored in that country. Elevated concentrations of pollutants is mainly attributed to high population density and anthropogenic activities carried out in cities compared to less developed rural areas (3). It is a matter of coincidence that some of the industries that contribute to heightened pollution somehow always relate to usage of superior technology and that facilitate anthropogenic activities including energy generation, petrochemical production, fertilisers, pesticides etc.

Besides other sources of air pollution, mushrooming traffic due to both commercial and private vehicles is one of the single biggest factor influencing urban air quality in developing countries. Vehicular transport emissions include contributions from various gaseous pollutants including different types of nitrous oxides (NOx), carbon monoxide (CO) and methane (CH_4 – main component of compressed natural gas CNG) while SO_x emissions have been controlled through use of better fuel quality. However, presence of particulate matter (PM) in the vehicular emissions over the last few years has severely affected the general environment. Inefficient fuel burning, un-tuned engines of vehicles, overloaded commercial transport and adulterated fuel are some of the root causes of PM emission from vehicles in developing countries. PM is widely reported to affect human health in a myriad ways and is mainly classified according to well established aerodynamic diameters with categories including PM_{10} (coarse), $PM_{2.5}$ (small), $PM_{0.5}$ (fine) and $PM_{0.1}$ (ultrafine) (4-6). Besides vehicular emissions some other sources of traffic related to PM include remnants from wear & tear of brake pads, erosion of rubber tyres besides roadside dust (7-10). One source of fine PM is incomplete combustion of fuel, arising in both moving as well as and stationary vehicles besides sources such as heavy industries, thermal power plants, hotels/restaurants/malls, and biomass burning in rural areas. PM is composed of a complex mixture of inorganic and organic substances suspended in air which mainly consists of liquid and solid particles. Inorganic ions (calcium, sodium, magnesium, potassium) mainly make up PM besides nitrates, sulphates, ammonium and elemental carbon. In addition polycyclic aromatic hydrocarbons (PAH) as also microbial compounds and allergens are also found in PM (5). It is a matter of grave concern that PM pollution affects people worldwide, but low- and middle-income countries disproportionately experience this burden (11). Fine PM affects health even at very low concentrations-even though no threshold has been identified below which no damage to health is observed. Particulate matter is a well identified cause of chronic obstructive pulmonary diseases (COPD), lung cancer, cardio-vascular diseases and other acute and chronic illness. Published reports indicate 11% of deaths resulting from COPD, 16% deaths due to lung cancer and 20% of deaths due to strokes and heart disease.

Composition of PM in ambient air varies widely and is dependent on the source of emission, size of particles, geographical location, atmospheric chemical transformation and meteorology. Further, PM is labelled as primary if emitted directly into the air and classified as secondary if converted from gaseous precursors released from anthropogenic and natural sources.

A given characteristic of the PM is that smaller the particle, deeper it penetrates before finally getting deposited in the respiratory tract. Normally, cilia and the mucus membranes effectively filter out PM_{10} through sneezing and coughing. However smaller particles successfully reach lung alveoli before escaping into the blood stream causing significant health problems (12-14).

According to World Health Organization (15), an unprecedented migration of human population to urban areas in the last few decades will result in 6.4 billion people living in cities by 2050. This rapid expansion in urbanization necessitates development of infrastructure at an enormous scale and at a rapid pace where environmental concerns are expected to be sacrificed in the name of development (16). Available literature indicates that incomplete combustion process results in generation of more toxic PM resulting in aggravation of health problems compared to non-combustible process (17). India also possess some unique sources of airborne pollution like funeral pyres, fireworks and biomass burning (18) besides incense sticks, mosquito coils etc.

Currently, Bengaluru an IT hub and also the third most populous city of India is in the throes of a spiralling increase in vehicle numbers, uncontrolled construction boom, demolition and other anthropogenic activities typically identified with a growing metropolis and which is proving to be a tremendous strain on its existing infrastructure which in a way is creating alarming levels of PM in air. Bengaluru is much sought after city mainly because of availability of newly created job opportunities in the IT Industry. With free flow of working class population in Bengaluru, a corresponding enhancement in the number of vehicles is observed, so much so that roughly 5 lakh vehicles get registered every year and total number of vehicles is around 67 lakh (as of March 2017, Economic Times). This number does not include vehicles which come and leave the city on a daily basis and are not registered with Bengaluru transport authority.

Since restriction of interstate workforce migration is not practiced in India, there is an urgent need to monitor air pollution and specifically airborne PM concentrations in real-time. The present investigation involves real-time measurement of airborne PM pollution concentration levels in Bengaluru so that targeted research, advanced monitoring strategies and inter-comparisons can be carried out. The present study envisages assessment of PM exposure so that strategies to mitigate the same can be worked out at the national level.

METHODOLOGY

In the present investigation, airborne PM concentration levels for PM10 and PM2.5 were measured at ten different locations for two months, August and September 2016. The PM concentration levels were measured using an Air Quality Monitor (AQM) - DYLOS 1700, USA which measures air quality using a LASER particle counter. The AQM allows air quality measurement in 2 particle size ranges (> 0.5 μm and > 2.5 μm). The AQM DYLOS 1700 is able to show real-time small (> 0.5 μm) and large (> 2.5 μm) particle concentrations on a screen and its working details have been published earlier (19). The 10 (ten) traffic hotspots across the city that were selected to measure PM concentration levels for an average exposure at peak-traffic rush hour for two months are well known bottlenecks where, vehicles are prone to create a jam. At traffic intersections , vehicles frequently stop with idling engines during red light and speed up rapidly during green light. It is well known that sudden acceleration and deceleration (velocity fluctuation) of vehicles leads to higher emission rates (20). The 10 locations are enumerated below in Table 1 and some of them are shown in Google map (Figure 1) as coloured dots.

Table I List of places in Bengaluru where PM concentration levels ($PM_{2.5}$ and PM_{10}) are measured

S. No.	**Place**	**S. No.**	**Place**
1.	Bommanahalli Crossing	6.	Marathalli
2.	Silk Board Crossing	7.	HAL
3.	Agara	8.	Ulsoor
4.	Bellandur	9.	Salarpuria Apartments
5.	RMZ Ecospace	10.	Cubbon Park

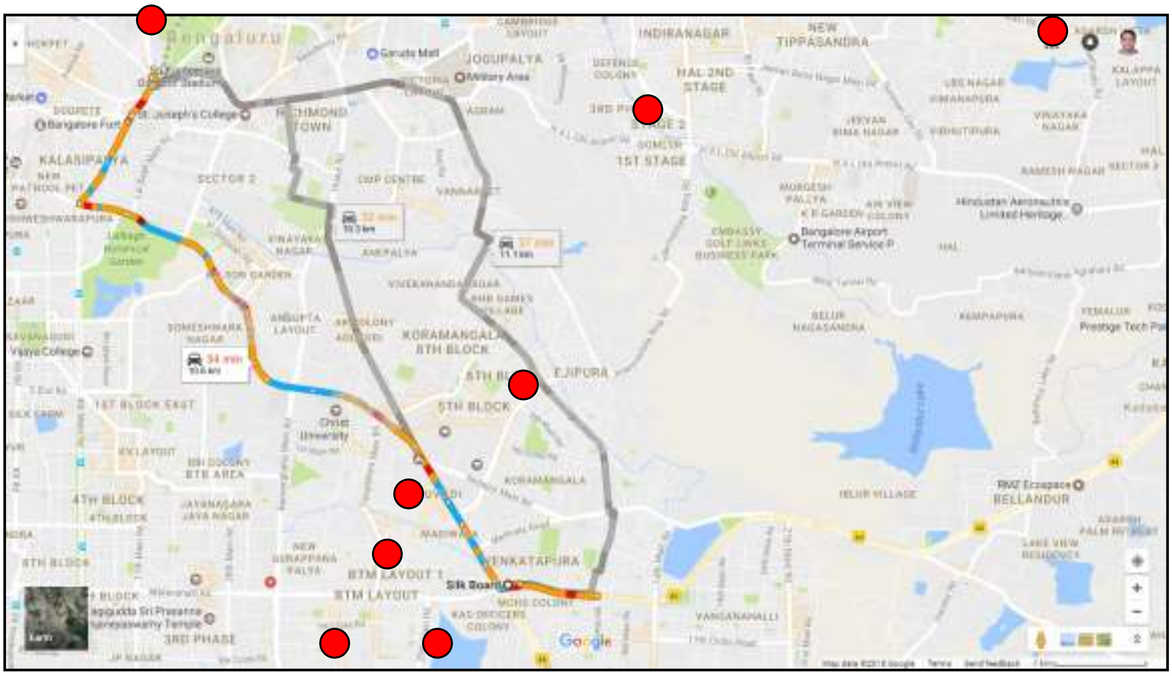

Figure-1 Places in Bengaluru notorious for traffic jams at rush-hour (8.00 – 10.00 a.m.) wherein PM concentration levels are measured.

Bomannahalli traffic intersection is one of the busiest traffic signal on Hosur road, which is literally a nightmare for commuters. Close by is the Silk board crossing, which is also in vicinity of BTM and HSR Layouts, both booming residential areas in South Bengaluru dotted with restaurants and located conveniently near office towers amidst a web of highways. Agara is situated on the busy outer ring-road and is a well known destination because of two very famous temples. Further down on the ring-road is the Bellandur area which is currently in news because of the toxic fumes emanating from the Bellandur lake.

RMZ Ecospace is one of the hubs of IT offices, which is visited by over 2 lakh employees, everyday via a very narrow by lane of the ring-road and where traffic is heavy for major part of the day. Further down on the ring road is Marathalli, which too is one of the congested areas enroute to the very commercial Whitefield area. HAL is relatively less polluted and congested as it is one of the oldest areas without much scope of expansion and moreover, has huge tree canopies. Ulsoor and Cubbon park are close to the famous Mahatma Gandhi road. Ulsoor has a heavy footfall everyday because of the presence of a lake. Cubbon park is the green lung of the city, which has been considered for comparison. Salarpuria Greenage apartments on Hosur road are a typical case of ongoing construction adding to particulate matter in the ambient.

RESULTS

The spots where PM concentrations are measured are tabulated in Table 2 along with real-time values of $PM_{2.5}$ and PM_{10}.

Table II Average PM concentration levels during peak-traffic rush hour (8.00 – 10.00 a.m.) measured over two months at 10 most busy locations in Bengaluru

S. No.	Place	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)
1.	Bommanahalli Crossing	453	71
2.	Silk Board Crossing	479	174
3.	Agara	181	30
4.	Bellandur	150	42
5.	RMZ Ecospace	180	42
6.	Marathalli	150	29
7.	HAL	135	15
8.	Ulsoor	135	14
9.	Salarpuria Apartments	300	29
10.	Cubbon Park	66	07

The study indicates that ambient air pollution levels, particularly airborne PM concentrations at the 10 traffic intersections of Bengaluru city are potentially quite high and therefore a cause of major public health concern. The average $PM_{2.5}$ concentrations seen at the Silk Board Crossing and the Bomanhalli traffic intersection are way above the permissible limits prescribed by the World Health Organization and also National Ambient Air Quality Standards (NAAQS).

WHO in its Air Quality Guidelines (21), has prescribed the given safe standards as follow:

$PM_{2.5}$: 10 µg/m^3 annual mean; 25 µg/m^3 24-hour mean

PM_{10}: 20 µg/m^3 annual mean; 50 µg/m^3 24-hour mean

Considering the 24 hour mean prescribed by WHO, most areas exhibit a much higher concentration of $PM_{2.5}$, varying between 3 -19 times more than the prescribed limit, though the values for PM_{10} are not that scary. Data for NAAQS, INDIA 2009 are different from those of WHO, being almost close to being double the values. Going by NAAQS Standards of our own country it is distressing to note that PM levels are far higher than safe limits. The Indian standards being:

$PM_{2.5}$: 40 µg/m^3 annual mean; 60 µg/m^3 24-hour mean and

PM_{10}: 60 µg/m^3 annual mean; 100 µg/m^3 24-hour mean.

It is interesting to note from Table 2 that wherever the number of idling vehicles is high (Bommanahalli and Silk Board crossings) one observes elevated levels of both $PM_{2.5}$ and PM_{10}. However, in places with ongoing construction work (Salarpuria apartments) only high $PM_{2.5}$ levels are noted. Further, places located in the vicinity of lakes (Ulsoor, Bellandur) exhibit lower levels of PM especially larger PM_{10} particulates. This inhibition in values is attributed to presence of water bodies and heavy foliage together deter presence of airborne PM as can also be seen in the case of Cubbon Park.

As already discussed, PM2.5 is considered more harmful than PM10, especially at such alarming concentrations because of its greater penetration in the airways which is a matter of grave concern. PM between 5 - 10 µm get preferentially lodged in the tracheal bronchioles, whereas those lying between 1 - 5 µm can potentially move deeper into the alveoli and bronchioles causing major health problems. Exposure to PM is known to lead to increased hospital admissions, emergency room visits, and respiratory symptoms, chronic asthma, exacerbation of chronic respiratory & cardiovascular diseases, decreased lung function, airway irritation, coughing and difficulty in breathing (12). Scientific studies further suggest that continued contact with elevated PM concentration levels leads to deaths of infants or low birth weight and pre-term deliveries.

Exposure to $PM_{2.5}$ is estimated to reduce the life expectancy of the population by about 8.6 months on an average (13). More than one thousand epidemiological studies have drawn a significant association between PM exposure and risk of lung cancer (14).

DISCUSSION

Reliable estimates of magnitude of exposure to airborne PM and exposure-assessment studies are needed to work out proactive mitigation strategies at the institutional and ministerial. Tackling air pollution is only possible through implementation, monitoring and evaluating schemes based on reliable real-time information (11). Air pollution is a global environmental burden with the urban PM being one of the most dangerous air pollutants with adverse effects on human health.

Enhanced exposure to air pollution has been connected with a) low quality of life at high health care costs, b) decreased lifespan, c) environmentally linked diseases and d) inequitable distribution of pollution amongst low-income groups (22).

According to US EPA (4), fine PM pollution leads to a) early death or chronic health threats b) heart diseases (attacks and strokes) c) asthma / COPD getting worse d) cancer development and e) reproductive harm.

In India, more than 50% of people reside in areas where $PM_{2.5}$ level exceeds the annual mean (40 µg/m^3) and only less than 0.01% of population lives in areas that meet the WHO $PM_{2.5}$ guideline of 10 µg/m^3 (23, 24, 25).

Pant and others (26) have reported an annual PM_{10} and $PM_{2.5}$ concentrations of 222 ± 142 µg/m^3 and 130 ± 103 µg/m^3 for New Delhi and even lower concentrations for Chennai, where annual PM_{10} and $PM_{2.5}$ concentrations range between 49.7 and 212.6 µg/m3 and 28.3-105.5µg/m3. Abba et al. (27) have reported a concentration range of PM2.5 in Mumbai between 69 ± 20µg/m3 at a background location to 95 ± 36µg/m3 at industrial locations. Comparing the levels in all the above mentioned Metros in India, Bengaluru takes the lead in being the most polluted with PM2.5 ranging between 66 and 479 ± 20µg/m3 and PM10 ranging between 29 – 174 ± 20µg/m3. As already discussed, major percentage of this particle pollution comes from the vehicular traffic followed by construction, demolition and building activities. IT with other associated industries in Bengaluru has fuelled rapid population growth which has resulted in an increase in the number of vehicles to about 1.5 million, with an annual growth rate of 7 - 10%. Guttikunda and Mohan, (28) have reported an increase (~ 7 times) in the vehicular numbers in India between 1990-2010. They have further, suggested an increase of 4 - 5 times by 2030.

In Bengaluru, one notices that most of the roads operate above their capacity and the volume, leading to major traffic snarls all day long leading to increased emissions. Travel speed drops to 08 kmph during the peak hours. Apart from the emissions, the road dust from paved and unpaved roads as well as bare grounds is also a major contributor to the PM content. Dust deposited on roads can be re-suspended by wind force or other anthropogenic activities and may contribute upto 30% of urban PM (7). Movement of vehicles on unpaved roads results in dust particles getting lifted and dropped from the wheels of the vehicles. Magnitude of dust emissions are influenced by a) conditions of road (silt, material, surface and moisture content) b) speed and volume of traffic and c) weight of the vehicle (8).

The fact that Bengaluru is the asthma capital of India can largely be attributed to its weather and primarily to the ever increasing air pollution. As per records available with the Road Transport Authority, an average of 1500 vehicles is being registered on a daily basis. With continuous shrinking of the green lungs in the city, it is leading to increased instances of asthma within the populace. The most vulnerable part of the population with regards to asthma and other respiratory diseases are the children and the elderly. This is for the simple reason that their bronchioles are smaller in size and hence get obstructed easily. Until and unless, we make concerted efforts to improve the roads, lower the density of vehicles plying, switch to cleaner fuels, plant more trees etc, the situation appears very grim in terms of hospital admissions, mortality and lifelong diseases.

With such grave consequences of particle pollution, this report is an endeavour to make common man and the authorities to take stringent, cognitive and immediate measures to improve the situation. Today the exposure is more in the ambient air but slowly with surging levels even indoors will not be safe.

CONCLUSIONS

Air pollution is considered as a marker of sustainable development by World Health Organization (WHO). In the current investigation observed values of $PM_{2.5}$ concentration levels are seen to breach WHO and NAAQS certified thresholds with alarming alacrity while PM_{10} concentration levels either surpass or maybe just below the margin at all the 09 (nine) traffic hotspots in Bengaluru. The only exception is the Cubbon Park which incidentally is a heavily forested green island in the middle of the city. PM concentration levels measured in Bengaluru indicate the requirement to develop standardized methods for PM monitoring in real-time by putting into practice targeted research, advanced monitoring strategies and inter-comparisons. There is an urgent need to project the nature and magnitude of airborne PM pollution in all affected cities of India while developing strategies to mitigate the same.

ACKNOWLEDGEMENTS

The authors CKG and AC are thankful to Department of Science and Technology, Govt. of India for the award of Indo-Slovenia bilateral project (INT/SLOVENIA/P-09/2014). The authors also extend their gratitude to Principal, Acharya Narendra Dev College (University of Delhi) for help with laboratory infrastructure.

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