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# RESEARCH ARTICLE

## COMPARATIVE INDOOR AND OUTDOOR AEROSOL POLLUTION STUDY OF SENSITIVE ZONES OF BHOPAL CITY, INDIA

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**ABSTRACT**

Aerosol has recently become an issue of increasing importance in pollution studies due to its noticeable effects on global environment as well as on human health. Aerosol pollution has many sources, most of which are associated with urban development, industrial development, road, air and rail transport etc. Aerosol pollution study is novel research carried out first time in Bhopal city. Aerosols of the size 10 micron & 2.5 micron are being considered as main parameter for this study.Total twelve monitoring sites were identified in Bhopal city as sensitive zones for study. The average result concluded that the aerosol pollution (PM2.5, PM10) level were found exceeding the Indian National Ambient Air Quality Standards limits in indoor & outdoor atmosphere of selected malls and hospitals than the indoor & outdoor atmosphere of selected schools. Among all selected monitoring locations in Bhopal city, environmental status of aerosol pollution is least at Raja Bhoj airport.



## INTRODUCTION

The climatic and environmental status of aerosols are the critical issues in global science community because aerosols, derived from variety of natural and man-made (or anthropogenic) emission sources, are well known to affect the air quality, human health and radiation budget (Pöschl 2005). This is because of inadequate measurements of aerosols, their microphysical and optical properties and poor understanding of their role in the Earth's radiation budget. Aerosols influence the Earth's climate directly by scattering and absorbing the solar and terrestrial radiations and indirectly by modifying the cloud macro- and micro-physical properties (Schwartz et al.1995). Aerosols are generated both naturally and as a result of human activities. Dust, mostly in the form of fine mineral particles, is the most prevalent natural source of aerosols. Anthropogenic aerosols make up about 10 percent of the amount of aerosols in our atmosphere. Primary emissions are aerosol sources that directly project aerosol particles into the air. Dust, volcanic ash, and black carbon from various types of burning are all examples of primary emissions. Secondary emission refers to substances that are not aerosols when they are originally emitted, but later undergo some chemical reaction in the atmosphere that transforms them into aerosols. Pollutant gases such as sulfur dioxide and nitric oxide are two gases that are often transformed into aerosols by secondary emissions. Chemical reactions in the atmosphere convert these gases into liquid or solid aerosols. Tiny particles of black carbon, or soot, are a major component of smoke produced by many kinds of burning. Internal combustion engines in cars, trucks, and construction vehicles also emit plenty of black carbon. Diesel engines are especially prolific producers of this type of aerosol. Human activities also increase the amount of mineral dust aerosol generation. Desertification, the removal of plants that help prevent wind erosion of soil and large construction sites are the major anthropogenic sources of dust aerosols. Sulfur oxides and nitrogen oxides, which are emitted by fossil fuel combustion and a variety of industrial processes, can generate secondary emissions of aerosols as a result of chemical reactions in the atmosphere. Indoor air quality is a major determinant of personal exposure to pollutants because people spend a substantial time indoors. Particulate matters suspended in the air are generally considered to be one of the principal indoor risk factors. There have been a number findings of many previous of studies that measure the exposure of different groups of population to particulate matter as a function of occupation, location and socio-economic background (Balakrishnan *et al.,* 2004; Balakrishnan *et al.,* 2002; Moenkkoenen *et al.,* 2005; Varghese *et al.,* 2005; Sahu *et al.,* 2011; Padhi *et al.,* 2008). Furthermore, knowledge of particulate emissions from indoor sources is increasing in

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social built public places such as schools, hospitals, malls and airport. The most important indoor pollution sources include cooking, kerosene heating and wood burning while sources such as cleaning, dusting and vacuuming, showering, electric motors, movement of people and gas-to-particle conversion have also been has been described before (Sjaastad *et al.,* 2008; Abt *et al.,* 2000, 2000b). In addition, concentration measurements have been carried out for various public activities while number concentration emissions have been reported from clothes dryer, office equipment and vacuuming (Hussein *et al.,* 2005). The outdoor aerosol particles can origin from both natural and anthropogenic processes. Combustion processes, industrial processes and the traffic are the main anthropogenic sources of particles in typical urban environment. Diesel motors produce 10 times more particles than conventional gasoline motors and the produced particles belong to the dangerous particles with a very small diameter (Kinney 2000). The primary interest in these measurements is to monitor the mass concentrations of aerosol in ambient air as a direct indicator of the potential hazard to human health. This is also the most commonly found atmospheric aerosol data in the literature on ambient air. Currently the regulatory standards for aerosol such as $PM_{10}$ and $PM_{2.5}$ in ambient environments in India are 100 and 60 $\mu g/m^3$ respectively. Earlier most of researchers have studied air pollution status and correlated it with environmental, human and plants health impacts.

## MATERIALS AND METHODS

### Study Area

Bhopal city is the capital of Madhya Pradesh which is very well connected to all the corners of the country situated in the central part of India. It lies between N-latitude 23.007° & 23.020° and E- longitude 77.019° & 77.031°. The city encompasses an area of 463 sq. km with 85 municipal wards. Bhopal is also known as the Lake City for its various natural as well as artificial lakes and is one of the greenest cities in India. The population of Bhopal Municipal Corporation as per census 2011 is 23, 71, 061. The climate is characterized by a hot summer and well distributed rainfall during the southwest monsoon season. There are three well defined seasons namely winter, summer and monsoon. Bhopal is one of the most developed city and home to various markets, parks, schools, hospitals and malls etc. Twelve monitoring sites include four schools, four malls, three hospitals and airport in Bhopal city for indoor and outdoor were selected for present study. Details of all monitoring locations are depicted in Table 1 and Fig 1.


**Figure 1. Selected locations for aerosol monitoring in Bhopal city**

### Analysis

In this study, especially aerosol (PM2.5, PM10), air toxic gases such as NOx, $SO_2$ and heavy metals were analyzed. Ambient air is drawn through a size-selective inlet of the dust sampler Envirotech APM-460 BL and APM 540 equipments. The collected samples were analyzed for various parameters using standard methods prescribed by Central Pollution Control Board, India and originally described by American Public Health Association (1977). Aerosol that is PM10 and PM2.5 were analyzed by gravimetric method. Aerosol particles are drawn through preweighed glass fibre filter paper at a flow rate of 0.5 $m^3$/min on 8-hourly basis for 24 hours. Gaseous pollutant NOx was analyzed by Jacob & Hochheiser method. $SO_2$ were analyzed by West & Geake method. Heavy metals were analyzed by atomic absorption spectroscopy.

## RESULT AND DISCUSSION

Atmospheric aerosols also known as particulates or particulate matter (PM) are tiny pieces of solid or liquid matter associated with the Earth's atmosphere. Sources of particulate matter can be man made or natural. They can adversely affect human health and also have impacts on climate and precipitation. Subtypes of atmospheric particle matter include suspended particulate matter, respirable suspended particle (diameter of 10 micron or less), fine particles (diameter of 2.5 micron or less), ultrafine particles and soot. Obtained data of aerosol size 10 micron & 2.5 micron in sensitive zones of Bhopal showed that their concentration and metallic content tend to fluctuate with the change in meteorological conditions.

**Table 1. Selected Locations for Aerosol Monitoring**

| S.No | Code | Monitoring Locations |
|---|---|---|
| 1 | A1 | Indoor and outdoor at Govt. Subhash H. Sec. Excellence School, Shivaji Nagar, Bhopal |
| 2 | A2 | Indoor and outdoor at Army Public School, Dronanchal Nuri Hills, Karond Bypass Road Bhopal |
| 3 | A3 | Indoor and outdoor at Kendriya Vidyalaya No 3,Shriramsharnam Colony, Hoshangabad Road, Bhopal |
| 4 | A4 | Indoor and outdoor at Kamla Nahru Govt Girl, H. Sec School, T.T Nagar Bhopal |
| 5 | A5 | Indoor and outdoor at Jai Prakash District Hospital, 1250, Tulsi Nagar, Bhopal |
| 6 | A6 | Indoor and outdoor at Bhopal Memorial Hospital And Research Centre, Bhanpur, Bhopal |
| 7 | A7 | Indoor and outdoor at Hamidia Hospital, Hamidia Road, Bhopal |
| 8 | A8 | Indoor and outdoor at DB City Mall , Arera Hills, Bhopal |
| 9 | A9 | Indoor and outdoor at Mirgnayani Emporium, Sultania Road Bhopal |
| 10 | A10 | Indoor and outdoor at Peoples Mall, Bhanpur, Ayodhya Bypass Road, Bhopal |
| 11 | A11 | Indoor and outdoor at Aashima Mall Pvt Ltd, Hoshangabad Road, Bhopal |
| 12 | A12 | Indoor and outdoor at Raja Bhoj Airport, Gandhi Nagar, Bhopal |

**Table 2. Indoor and Outdoor Aerosol Pollution Status at Monitoring Locations in Bhopal City**

| S.N | Monitoring location | PM2.5* (µg/m$^3$) | | PM10* (µg/m$^3$) | | $NO_X$* (µg/m$^3$) | | $SO_2$* (µg/m$^3$) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Indoor | Outdoor | Indoor | Outdoor | Indoor | Outdoor | Indoor | Outdoor |
| 1 | Subhash School | 92 | 128 | 173 | 197 | 14.7 | 29.2 | BDL | BDL |
| 2 | Army School | 76 | 115 | 113 | 185 | 14.2 | 25.3 | BDL | BDL |
| 3 | K V 3 School | 84 | 96 | 128 | 182 | 15.1 | 21.5 | BDL | BDL |
| 4 | Kamla Nehru School | 105 | 139 | 180 | 210 | 28.7 | 32.3 | BDL | BDL |
| 5 | J P Hospital | 90 | 128 | 165 | 186 | 23.4 | 28.1 | BDL | BDL |
| 6 | BMHRC | 85 | 145 | 174 | 217 | 28.4 | 33.2 | BDL | BDL |
| 7 | Hamidia Hospital | 130 | 170 | 210 | 284 | 29 | 32.9 | BDL | BDL |
| 8 | DB Mall | 87 | 120 | 127 | 167 | 25.2 | 24.2 | BDL | BDL |
| 9 | Mrignaini Emporium | 142 | 179 | 206 | 452 | 30.6 | 36.2 | BDL | BDL |
| 10 | Peoples Mall | 92 | 117 | 169 | 295 | 20.8 | 27.2 | BDL | BDL |
| 11 | Aashima Mall | 129 | 138 | 182 | 378 | 20.1 | 37.9 | BDL | BDL |
| 12 | Raja Bhoj Airport | 26 | 67 | 91 | 130 | BDL | 11.2 | BDL | BDL |

Remark : * Annual average value, BDL = Below detection limit

**Table 3. Concentration of Metals at All monitoring locations in Bhopal City**

| S.N. | Locations | | Zn | Fe | Cu | Mn | Cr | Ni | Pb | Co | Cd |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Selected School sites in Bhopal City | | | | | | | | | | |
| 1. | Govt. Subhash School | indoor | 0.214 | 0.098 | 0.005 | ND | ND | ND | 0.001 | ND | ND |
| | | outdoor | 0.411 | 0.079 | 0.001 | ND | ND | ND | 0.002 | ND | ND |
| 2. | Army Public School | indoor | 0.005 | 0.163 | 0.001 | 0.002 | ND | ND | 0.004 | ND | ND |
| | | outdoor | 0.001 | 0.184 | 0.002 | 0.001 | ND | ND | 0.001 | ND | ND |
| 3. | Kendriya Vidyalaya No 3 | indoor | 0.138 | 0.001 | 0.001 | 0.001 | ND | ND | 0.002 | ND | ND |
| | | outdoor | 0.331 | 0.001 | 0.005 | 0.001 | ND | ND | 0.001 | ND | ND |
| 4. | Kamla Nahru School | indoor | 0.22 | 0.053 | 0.001 | 0.001 | ND | ND | 0.001 | ND | ND |
| | | outdoor | 0.223 | 0.032 | 0.001 | 0.001 | ND | ND | 0.001 | ND | ND |
| | Selected Hospital sites in Bhopal City | | | | | | | | | | |
| 5. | Jai Prakash District Hospital | indoor | 0.375 | 0.076 | 0.005 | 0.002 | ND | ND | 0.001 | ND | ND |
| | | outdoor | 0.562 | 0.091 | 0.003 | 0.002 | ND | ND | 0.001 | ND | ND |
| 6. | Bhopal memorial Hospital & | indoor | 0.418 | 0.121 | 0.002 | 0.001 | ND | ND | 0.001 | ND | ND |
| | Research Centre | outdoor | 0.523 | 0.194 | 0.005 | 0.005 | ND | ND | 0.001 | ND | ND |
| 7. | Hamidia Hospital | indoor | 0.283 | 0.296 | 0.181 | 0.006 | ND | ND | 0.001 | ND | ND |
| | | outdoor | 0.324 | 0.136 | 0.078 | 0.001 | ND | ND | 0.001 | ND | ND |
| | Selected Mall sites in Bhopal City | | | | | | | | | | |
| 8. | DB City Mall | indoor | 0.382 | 0.162 | 0.002 | 0.002 | ND | ND | 0.001 | ND | ND |
| | | outdoor | 1.573 | 0.182 | 0.002 | 0.004 | ND | ND | 0.001 | ND | ND |
| 9. | Mirgnayani Emporium | indoor | 0.003 | 0.027 | 0.002 | 0.001 | ND | ND | 0.001 | ND | ND |
| | | outdoor | 0.207 | 0.016 | 0.001 | 0.102 | ND | ND | 0.001 | ND | ND |
| 10. | Peoples Mall | indoor | 0.012 | 0.022 | 0.001 | 0.001 | ND | ND | 0.001 | ND | ND |
| | | outdoor | 0.347 | 0.092 | 0.002 | 0.004 | ND | ND | 0.001 | ND | ND |
| 11. | Aashima Mall | indoor | 0.216 | 0.029 | 0.003 | 0.001 | ND | ND | 0.001 | ND | ND |
| | | outdoor | 0.347 | 0.078 | 0.005 | 0.002 | ND | ND | 0.001 | ND | ND |

Unit in ng/m$^3$; ND = Not Detectable

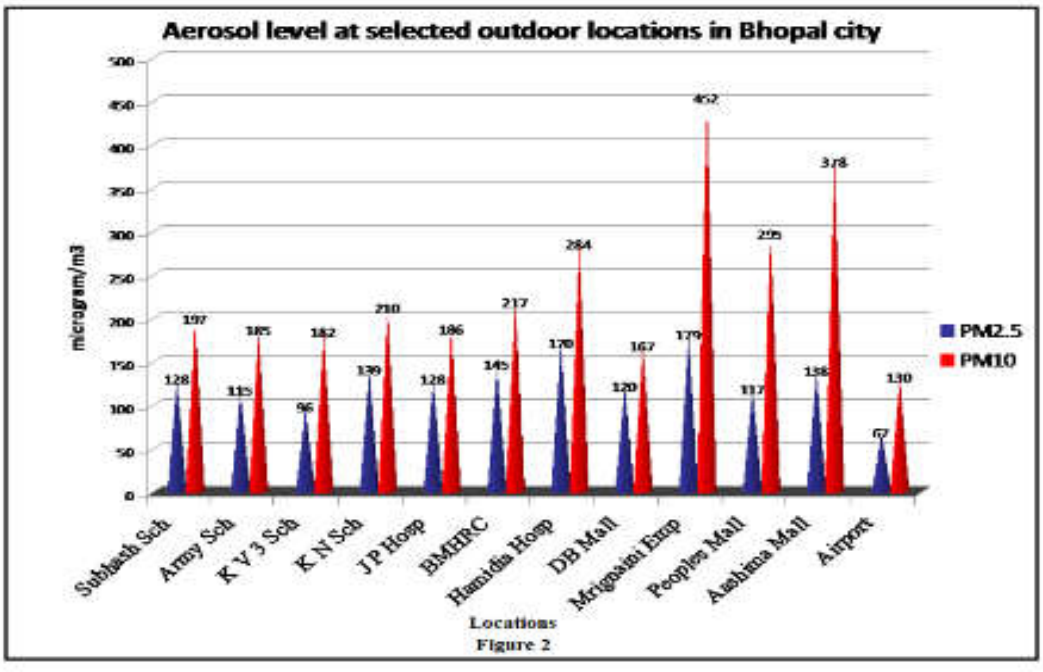


**Figure 2. Aerosol level at selected outdoor locations in Bhopal city**

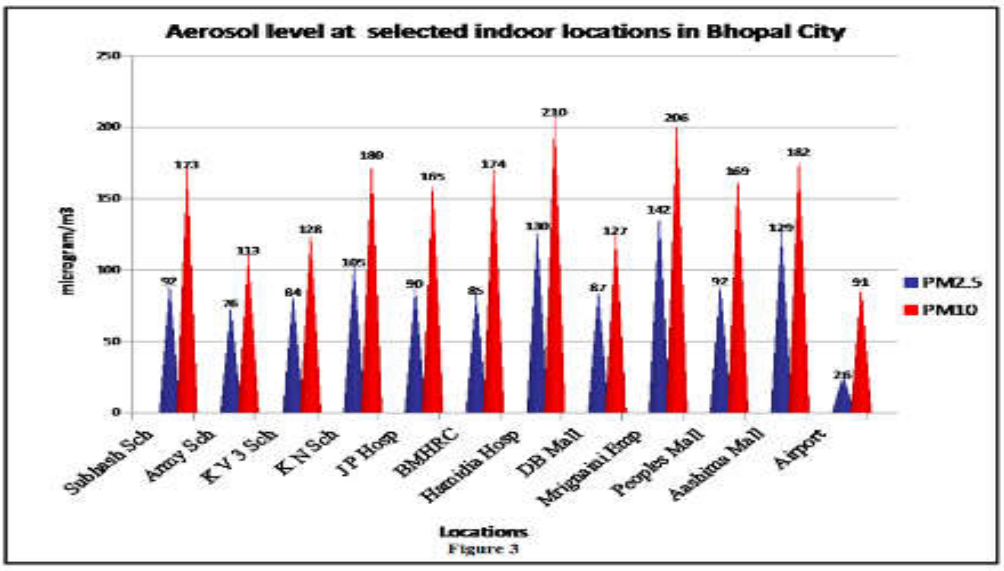


**Figure 3. Aerosol level at selected indoor locations in Bhopal city**

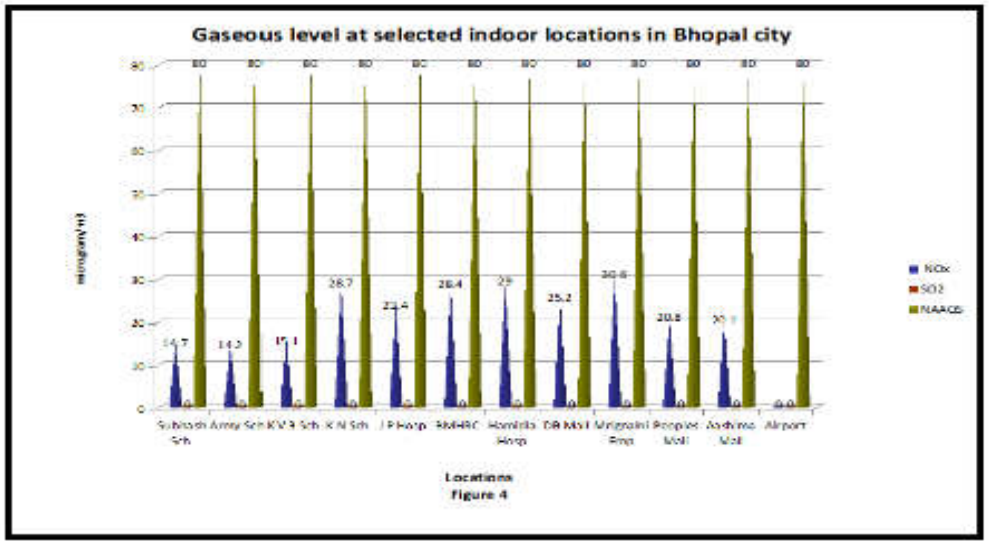


**Figure 4. Gaseous level at selected indoor locations in Bhopal city**

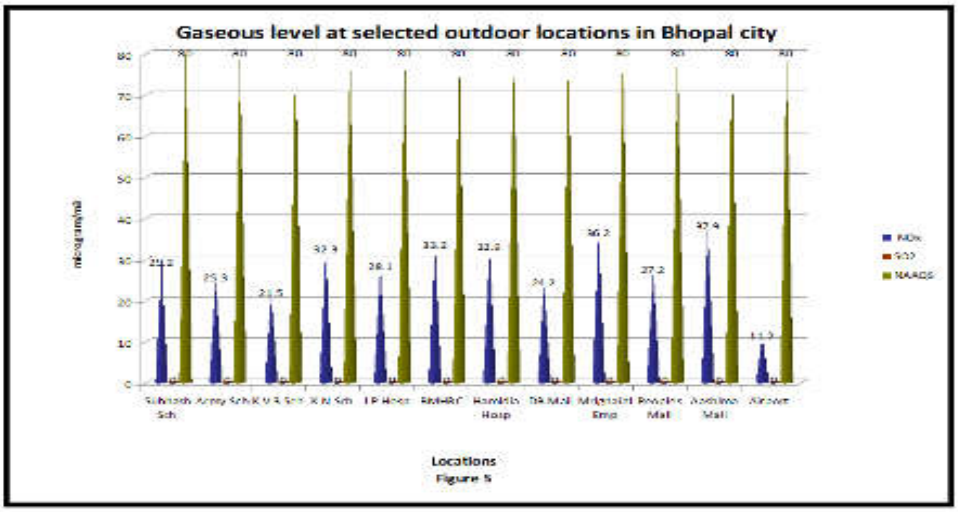


**Figure 5. Gaseous level at selected outdoor locations in Bhopal city**

Airborne toxic metals are found mainly in particulate matter dispersed in air. Metals are commonly found in atmospheric particles.

The dispersion and accumulation of particulate matter in any location is mainly affected by the existing sources, meteorological conditions and local topography.

The aerosol pollution ($PM_{2.5}$, $PM_{10}$) levels were exceeding the NAAQS limits in indoor & outdoor atmosphere at all the selected locations. However aerosol level is high in indoor & outdoor locations of malls and hospitals as compared to indoor & outdoor locations of selected schools. The Analysis result of study is shown in Table 2 and Fig 2- 5. In present Study, the average value of $PM_{2.5}$ was found at inside the building of all selected monitoring locations between 26 - 142 $\mu g/m^3$ and outside the building of all selected monitoring locations between 67- 179 $\mu g/m^3$. The average value of $PM_{10}$ was found at inside the building of all selected monitoring locations 91-210 $\mu g/m^3$ and outside the building of all monitoring locations 130 - 452 $\mu g/m^3$. The comparative study of airborne toxic metals concentration at all selected locations in Bhopal city shown in Table 3. The observed order of the analyzed metals in the aerosol are as Zn>Fe>Cu>Mn>Pb and Cr, Cd, Co, Ni are not found at inside and outside building of all selected monitoring locations in Bhopal City.

**Conclusion**

Data revealed that particulate aerosol concentration and their metallic content tend to fluctuate with the change in meteorological conditions i.e. lower concentration in winter season and higher concentration in summer season. Alarming vehicular and population growth rate, frequent traffic jams and overall poor infrastructure has lead to a significant rise in the aerosol such as PM10, and PM2.5 level. The ascending order of aerosol pollution level in sensitive zones in Bhopal city is Malls > Hospitals > Schools >Airport. Although vehicles and industries are the two most important contributors to aerosol level in outdoor atmosphere, comparative less level in indoor atmosphere at selected monitoring locations. Other pollution sources, such as roadside dust, trans-boundary migrations, solid waste and local sources are also reasons for aerosol pollution in ambient atmosphere of sensitive zones of Bhopal city, India.

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