Air Pollution Status of Lucknow City, Associated Environmental and Health Impacts: A Review

Siddhant Rajput[1], Kamal Nabh Tripathi[2], Anupam Mehrotra[3]
[1]Dept of Civil Engineering
[2] Assistant Professor, Dept of Civil Engineering
[3] Head of Department, Dept of Civil Engineering
[1, 2, 3] Babu Banarsi Das University, Lucknow (U.P.), India

Abstract- *The rapid development in urban India has resulted in enormous increase in number of vehicles. Many of the cities has multiplied its numbers in terms of motor vehicles in last few decades. Rapid urbanization and high growth of automobiles (motor vehicles) lays a serious effect on human life and the environment in last few years. Motor vehicles are one of the significant source of urban air pollution and important contributors of anthropogenic gases. Transport sector contributes a major sector, contributing approximate 90% of total emission. Lucknow is a fast growing city where day by day boundaries are extended. Researches from the city have studied various aspect of air pollution during last one and half decade and identified particulate matter ($PM_{2.5}$ and PM_{10}) as the main pollutant. The objective of this review paper is to analyze the air pollution status of city, associated with environmental and health impact and possible control measures presented in studies on Lucknow through available literature. Mainly the pollutants which exceeds national ambient air quality standard (NAAQS) limits are $PM_{2.5}$ and PM_{10} i.e. particulate matter whereas the other two harmful pollutant i.e. oxides of sulphur and oxides of nitrogen are within the permissible limit. Winter season was recorded the most polluted due to lack of dispersion of pollutants and minimum in the monsoon season as pollutants get washed away by rain. The exposure of these pollutants leads to cardiovascular and respiratory diseases, neurological impairments and even mortality and morbidity. Some reports also mention the impact of pollutants on chlorophyll content of plants. Air pollution level at control sites (village or low traffic density areas) was lower than the other urban sites of city.*

Keywords- Air pollution, cardiovascular, control measures, ambient air quality.

I. INTRODUCTION

The growing population and urbanization leads to increase in traffic volume with higher level of energy consumption that has resulted an increment in pollution load in the major areas of Lucknow city (PCB, 2017). Air pollution is considered to be the main source of environmental as well as heath risk and is estimated to cause approximately 2911670 premature deaths per year (WHO 2012).

The air quality has been therefore, an issue of social concern in backdrop of various developmental activities. Though the measurement of air quality is complicated, there are a few pollutants which regulators keep a watchful eye during regular monitoring. The most highlighted pollutant are particulate matter (PM), nitrogen di oxide (NO_2) and sulphur di oxide (SO_2). The most affecting pollutants in Lucknow city is particulate matter (CSIR-IITR, 2017).

Air pollutants emitted from vehicles are responsible for boom anxiety, discomfort, and increase in air borne diseases, irritation and deterioration of heritage building. Many scholars and researchers conducted out studies in Lucknow city with respect to four major pollutants including trace metals etc. in ambient air.

Considering the worsening traffic growth and emissions and their impact on human health and urban air quality there is a need for a regulatory framework for the management of traffic, air quality and emission at local level, regional and national scales (Costabile et al.,2008).

II. STUDY AREA

Lucknow is the capital city of Uttar Pradesh which is rich in heritage and advancement in technologies which has the population of 3.328 million and area of 310 Sq.km and its geographical location is 26º52’ N latitude to 80º56’ E longitude; 128 m above mean sea level.

It is one of the most rapid growing cities in all the sectors therefore resulting in high density of traffic volume which ultimately results in increase in concentration of pollutants .and these activities of the city is responsible for depreciated ambient air quality. Industrial operation, construction practices, poor traffic management, uneven roads adds on to poor quality on environmental risk. Automobiles are the primary source of air pollution. In India transportation sector emits an estimated about 261 tonnes of CO_2, of which 94.5% is contributed by road transport (Dayal 2011). Total vehicle population in Lucknow city is estimated to be 19,78,345 which consumes petrol and diesel near about 193,345 KL and 230, 626 KL respectively (CSIR-IITR, 2017). Following table shows the increment of vehicles in the Lucknow city as per RTO Lucknow, 2017.

Table 1.Vehicular population in city (RTO, Lucknow)

S.No.	Type of vehicles	No .Of registered vehicle as on 31 march 2016-17
1	Multi Articulated	3556
2	Four wheeler	26225
3	Three wheeler	3408
4	Buses	3324
5	Taxi	10003
6	Light Motor Vehicles	7606
7	Two wheelers	1582255
8	Car	27485
9	Jeep	35592
10	Tractor	24919
11	Trailors	1721
12	Others	4877

III. AIR POLLUTION STATUS AND ITS IMPACT

The ambient air quality studies of Lucknow reported in literature since the last many years have been summarized in this section. The researches have studied about various parameters which is responsible for creating nuisance in environment and can cause various ill effects on human and plant health. Survey at seven locations in residential, commercial and industrial areas of Lucknow during 1999-2000, showed that particulate concentration and their metallic content tend to fluctuate with the change in meteorological conditions. In this study levels of PM_{10} was 230.9, 216.5, 261.5, 241.1μg/m^3 during winter, summer, pre and post monsoon respectively and the corresponding values for SPM were 565.4, 522.3, 918.4 and 551.9 μg/m^3 respectively. All the value were higher than the prescribed NAAQS. Particulate fraction PM10 assessed for heavy metals showed the presence of Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn in all the seasons. The results of the study indicate marked variations in the metal contents from different locations and differ significantly in different seasons. As per the authors opinion the higher particulates can be attributed to the greater density of small diesel driven vehicles plying through routes nearby sampling location (winter) μg/m^3 respectively, exceeding NAAQS (A. Pradhan et.al.2004), (Sharma et.al.2015).

A study in Low/High Traffic Density (LTD/HTD) sites in urban Lucknow in 2001- 02, during summer revealed PM10 levels at LTD site as 73.0 and at two HTD sites as 100.4 and 96.4 μg/m^3 and the corresponding values of SPM to be 137.5 (at LTD), 159.6 and 153.4 μg/m^3 (at HTD). However, in winter season observed PM10 levels were 165.2, 288.7 and 264.3 μg/m^3 at one LTD and two HTD sites respectively. Similarly SPM levels were 222.6, 361.9 and 332.8 μg/m^3 at respective sites. Particulates exceeded NAAQS limits in winter only, while SO_2 and NOx were within the limits in both the seasons. The authors also studied PAHs attached to particulates, revealing the presence of all the examined types (both auto exhaust/ biomass emission specific PAHs) in the sampled air. The mean values of sum PAHs at HTD sites and LTD sites were (24.76 ng/m^3) and (9.44 ng/m^3) during summer and (106.08 ng/m^3) and (26.64 ng/m^3) during winter respectively. The mean values at both the sites were much greater than the guide value of 1 ng/m^3 set for PAH by the World Health Organization (WHO). The mean PAHs value was approximately three to four times higher in winter than summer and almost similar trend was observed between HTD and LTD. The author further emphasized that a substantially higher percentage of population is exposed to PAHs and faces the risk of short-term clinical symptoms related to cardiovascular, respiratory, ear and eye systems that are attributable to PAH exposure. As per study the estimated cost of health damage in the PAH exposed population (1.64million) on an average is Rs.900 million per annum for Lucknow (Kumar S., et.al. 2003).

During post monsoon (October, 2001) the average SPM in residential, commercial and industrial areas; 342.0, 547.5, 541.7 μg/m^3 was higher than the NAAQS limits, while SO_2 (23.06-36.5 μg/m^3) and NOx (26.54-43.0 μg/m^3) was less than the standards. The study has identified vehicular traffic as the root cause of air pollution with contributions from industries and other scattered burning activities (Salve P.R, et. al 2003).

The average concentration of PM_{10} during winters of 2002, 2003 and 2004 was 196.5, 266.8 and 166.3 μg/m^3 in residential, 258.2, 321.7, 211.2 μg/m^3 in commercial and 205.0, 231.5, 198.5 μg/m^3 in industrial area respectively, were above their respective NAAQS of 100 μg/m^3 for residential/ commercial, rural and other areas and 150 μg/m^3 for industrial areas. The Pb concentration in this study ranged 0.07-0.89 μg/m^3. Introduction of CNG buses for public transport in place of diesel-operated three wheelers on the trunk route resulted in lower PM_{10} levels in 2004(Kisku G.C. et. Al 2013).

The concentration of PM_{10} at 10 locations in city was recorded in the range of 107.6-237.8 μg/m^3 in summer (May, 2005) in Lucknow. It was 146.9 and 178.4 μg/m^3 in residential and commercial areas where as 107.6 μg/m^3 in one industrial area. The relative difference (%) of PM_{10} with NAAQS i.e. the exceedence factor ranged from 0.7 in industrial to 2.4 in commercial area. Author also reported that the mean concentration of Fe (1242.10 ng/m^3) was maximum and Cd (6.36 ng/m^3) minimum in the city. The concentration of PM_{10} in air was found higher almost double than NAAQS. For high concentration of PM_{10} in air trace metals Fe, Mn and Mg were found responsible. The adverse health effects of PM_{10} related to Fe, Mn and Mg may be the reason for frequent hospital visitors. Author commented that the considerable abatement at root levels in the sources of these metals may reduce the concentration of PM_{10} and thus the air quality as well as the health of the city dwellers will certainly improve (Sharma k., et. Al 2006).

A pre monsoon survey (2008) data for PM_{10} at seven locations ranged from 188.3-199.2 (residential), 198.0-216.2 (commercial), 167.8 μg/m3 in industrial area, whereas SO2 and NOx ranged from 17.4-33.8 and 27.5-42.8 μg/m^3 respectively. The observed PM_{10} exceeded NAAQS limit while gases were within the limit. Rain water characterization in the study reported that pH level of rain water was in acidic range but greater than 5.6. It means that rain does not fall in the category of acid rain, however the rain water quality indicates the impact of air pollution (Mishra A., et. al 2012).

In a study conducted at four locations of the city during 2007–09, the average value of PM_{10} and $PM_{2.5}$ was 168.1 (1.7 times) and 87.3 (1.5 times) μg/m3 higher than their respective NAAQS limits of 100 and 60 μg/m3. Amongst the metals associated with PM10, maximum Fe and minimum Cd was observed. Concentration of Pb, 40.6 was less than 1000 ng/m3, while Ni, 35.1 exceeded 20 ng/m3 limits prescribed by NAAQS-2009. The maximum values of metals were observed during winter. The average level of Benzo (a)pyrene (51.96 ng/m^3) was about 50 times higher than the standard value of 1 ng/m3 (NAAQS-2009, India: annual average). Author suggested that the higher prevalence of diseases viz.; asthma, tuberculosis, pneumoconiosis, chronic bronchitis and lung cancer among Lucknow population can be linked to the high concentration of fine particulates, toxic metals and PAHs found in urban atmosphere (D. Patel et. al. 2013).

In this study conducted at eight locations of the Lucknow city and Sitapur city, in which six locations selected monitoring location of Lucknow and two location of Sitapur city. The value of Reparable Suspended Particulate Matter was in the range of 145.15 to 85.23μg/m^3 in Lucknow city and 98.40 to 89.70μg/m^3 in Sitapur city. The concentration of SO2 was in the range of 17.61 to 11.23μg/m^3 in Lucknow city and 18.60 to 18.21μg/m^3 in Sitapur city. The concentration of NOx was in the range of 25.11 to 15.11μg/m^3 in Lucknow city and 24.80 to 24.17μg/m^3 in Sitapur city. The concentration of the Reparable Suspended Particulate Matter was above the NAAQS limits in Lucknow city and Sitapur and the concentration of the SO_2 and NOx was within the NAAQS limits in Lucknow city and Sitapur (G.S. Gupta et.al. 2014).

Shukla A. et al., observed high levels of SPM (1088.6 μg/m^3) during day time (8:00-20:00 hrs) at five locations (residential, commercial and heavy traffic zone) of old city part of Lucknow exceeding NAAQS (1994) limit (200 μg/m^3). The high particulate level may be due to dense population and slow moving traffic in these areas. Although SO2 (23-53 μg/m^3) and NOx (52.6-73.7 μg/m^3) were less than the limits (80 μg/m^3) but higher than the levels at other parts of the city. Authors also estimated high Air Quality Index (AQI) that may cause asthma and other bronchial diseases in people living in these areas (Mishra et. al 2010).

Mir A. Q. et al. in a study to establish correlation between number and types of plying vehicles with effect on plants found significant lowering of the chlorophyll, carotenoid and protein content in all the plant species at the four sites with high traffic density in comparison to the control site. The observations clearly reveal a conspicuous difference on the amount of the changes, in the content of three parameters at the highest traffic density (Charbagh) in comparison to Nakhas (minimum traffic load). However, even Nakhas with minimum traffic load exhibited marked differences from the plants growing at the control site, showing a direct correlation with the number of automobiles. At Charbagh, the significant differences can also be attributed because of the very high number of heavy automobiles, i.e., diesel driven vehicle, as the diesel contains four times more sulphur content as compared to petrol and SO_2 happens to be main phytotoxicant (Mir A.Q. et. al 2018).

In a study (winter 2011) Babasaheb Bhimrao Ambedkar University (BBAU) campus with low traffic (410 vehicles /hour) was considered as control against Sikunderbagh crossing high traffic density area (6632 vehicles/hour). At control site, recorded air pollution levels for PM_{10}, SPM, SO_2, NOx and O_3 were 106.5, 200.6, 11.82, 13.10 and 50.87μg/m^3 respectively (six hour sampling between 9:00 AM to 3:00 PM). The corresponding values of pollutants were 397.9, 738.8, 38.95, 55.39 and 64.75 μg/m3at high traffic density site that are remarkably higher than control site. The impact of vehicle density and air pollution levels indicate clear evidence of significance reduction in biomass of its varieties Trishna and PRC-1 due to use of herbicide. The cumulative impact of herbicide (2,4-D sodium salt) and air pollution plays an important role to significantly enhance the production of secondary metabolites that are directly involved in various physiological process and growth of the plant and are indicators of a plant's resistance towards abiotic stress.(Singh A. et. al 2013).

During post monsoon (September - October), 2015 we have monitored air pollutants such as PM_{10}, $PM_{2.5}$, Superfine and Ultrafine particles, SO_2, NOx and trace metals for assessment of ambient air quality. The RSPM (PM_{10}) level at all the monitoring locations of residential, commercial and industrial areas were higher than the NAAQS. The mean levels of Fine particles ($PM_{2.5}$) at all the standard of these particles. The concentration of gaseous pollutants, SO_2 and NOx were below the prescribed NAAQS (80 μg/m^3) at all the locations but showed slightly mixed trend. Monitoring locations of residential, commercial and industrial areas were higher than the NAAQS. The total mass concentration of superfine and ultrafine particles were found to be higher in the commercial as well as in the in residential areas and almost double the control/rural values which indicate the release of the smaller particles in urban area due vehicular pollution or anthropogenic activities. It is remarkable that total concentration of these particles were found to be near/ equal to permissible limit of $PM_{2.5}$ (60μg/m^3). Overall results indicate that PM_{10} and $PM_{2.5}$ and associated metals are one of the major causes for deterioration of ambient air quality. Unlimited growth of number of vehicles, their technological development and release of invisible tailpipe pollutant emissions are serious debatable issues even for the policy makers. Use of different types of fuels namely petrol, diesel, LPG and CNG make the environment more complex regarding the air quality and their synergistic effects on the human health.(CSIR- IITR 2015 post monsoon).

This study was carried out during the month of September-October, 2017 (Diwali period not considered) to investigate the status of air quality by monitoring and assessment of some selected air pollutants namely Respirable Particulate Matter (RSPM or PM_{10}), Fine Particulate Matter ($PM_{2.5}$), Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2) and noise level at 9 representative locations, categorized as residential (four), commercial (four) and industrial (one) areas in Lucknow city. The results revealed the 24 hours concentration of PM_{10} to be in the range of 99.5 to 358.4 μg/m^3 with an average of 196.6 μg/m^3, whereas 24 hours $PM_{2.5}$ level were found to be in the range 50.5 to 166.4 μg/m^3 with an average of 101.5 μg/m^3. The average values of PM_{10} and $PM_{2.5}$, irrespective of the locations were found to be above the permissible limit (PM_{10} =100 and $PM_{2.5}$ = 60 μg/m^3) prescribed by MoEF. Twenty four hours concentration of SO_2 and NO_2 were found in the range of 6.8 to 20.7 and 20.3 to 91.5μg/m^3 with an average concentration of 13.8 and 50.5μg/m^3 respectively and all the values were below the permissible limits (80 μg/m^3). Trace metals Ni and Pb were found to be associated with PM_{10}. Twenty four hours concentration of Ni was found to be in the range of 4.18 to 57.71 with an average of 22.26ng/m^3. The average Ni concentration was found to be above the permissible limit of annual average (20ng/m^3). In case of Pb, 24 hours concentration in PM_{10} was found to be in the range of 105.41 to 516.38 with an average of 199.87ng/m^3 which was within the permissible limit (1000ng/m^3). (CSIR-IITR 2017 post monsoon).

In summer 2012 levels of PM $_{2.5}$, PM_{10}, SO_2 and NOx were 85.6, 218.4, 15.9 and 33.5 μg/m^3 respectively in three residential and one commercial sites of city. SO_2 and NOx were within the limit while both the particulate fraction exceeded NAAQS 2009. Iron (162.9 and 1813.9 ng/m^3) was maximum in $PM_{2.5}$ and PM_{10} while Cu (12.45 ng/m^3) in $PM_{2.5}$ and Co (23.78 ng/m^3) in PM_{10} fractions was found minimum. The results indicated that urban airquality is adversely affected due to emission and accumulation of $PM_{2.5}$, PM_{10}, SO_2, NOx and trace metals. Vehicular emission, industrial operation, combustion of waste, construction activity and resuspended road dust were identified as the sources of heavy metals in the study area (Chaudhary P., et. al 2013).

The estimated AQI using the method developed by Ziauddin et al. indicated that the commercial area was heavily polluted whereas residential areas were moderately polluted in the city. In a study, during summer 2012, at four residential, one industrial and one commercial area, the average levels of PM_{10}, SO_2 and NOx were 111.52, 13.66 and 22.28μg/m3 respectively. The concentration of PM_{10} exceeded the NAAQS limit (100 μg/m^3) while gases were within the limit (80μg/m^3). The higher PM10values were due to local construction activity and the results indicate that PM_{10} is one of the major cause for deterioration of ambient air quality. Results of the study carried out during the summer season (March-June 2012) revealed that the average levels of PM_{10} and $PM_{2.5}$ were above the permissible limits laid by WHO at densely populated area (189 and 76 μg/m^3) and on roadside sites was (226 and 91 μg/m^3) respectively. Survey results also showed that 46% of urban people suffered from acute respiratory infections like bronchial asthma, headache, depression and dizziness and these people were mostly from roadside colonies. In general positive correlation was observed in indoor and outdoor air quality in homes. Amongst the sites PM_{10} levels in well planned area was comparatively low to that of unplanned and densely populated and roadside areas. Indoor observed level of $PM_{2.5}$ and PM_{10} in the study ranged from 42-82 and 78-182 µg/m3. The estimated Air Quality Index (AQI) of unplanned and densely populated and roadside areas was in unhealthy zone (209- 302) whereas that in well planned area it was unhealthy for sensitive group (150-200) (Fatima N., et. al 2014).

IV. DISCUSSION

Pollution in Indian cities is increasing on alarming rate. Above studies shows that particulate matter were higher than national ambient air quality standard (NAAQS) and gaseous pollutants were within limits. In above studies PM_{10} and SPM in the city were observed in the range of 100.4 – 499.4µg/m^3 and 200.6 – 1088.8µg/m^3; higher than their respective limits (100µg/m^3 NAAQS 2017 and 200 µg/m^3 NAAQS 1994), except in few studies. Few studies show that $PM_{2.5}$ in the range of 76.0- 212.4 µg/m^3 which is observed above the NAAQS limits of 60 µg/m^3.

The post monsoon season witnesses a number of changes in ambient air quality such as the dipping of night time air temperatures resulting in the formation of an inversion layer that traps pollutants near the ground level. India being primarily an agrarian economy, the months of September and October are marked by preparations for the Rabi or winter season crop. Such preparations often include burning of agriculture residue from the previous cropping season producing a huge amount of smoke, dust and particulate matter which reaches adjoining cities. This is also the time when the Diwali festival or the “festival of lights” is celebrated with huge pomp and show in the entire country. Burning of fire crackers during this festival also adds to the already deteriorating air quality. Therefore, this season observes high pollutant concentrations in most of the North Indian cities.

The concentration of all the pollutants in city was in general more during winter followed by summer and least in monsoon season as pollutants get washed away. The stable atmospheric conditions hamper the vertical and horizontal turbulence for proper mixing of pollutants with upper air makes the air mass more stagnant. As a result, minimum atmospheric dispersion throughout the planetary boundary layer is observed in the study area. Fog formation during early winter early winter morning dampens the air and increases in density, which results in accumulation of pollutants near the ground breathing zone concentration.

The lack of precipitation during winter months reduces the potential for wet deposition and associated cleansing mechanisms. Conversely, during monsoons, low pollutant concentrations can be ascribed to precipitation driven washout (especially for SO2 and NO2). Monsoon rains have the most dramatic effect in lowering the gaseous pollutant levels in the atmosphere. Despite low solubility of oxides of nitrogen in water, rains in the monsoon season effectively reduce their concentrations in the air.

Increasing air pollution in the Lucknow city is due to the rapid growth in population which got proportional with the growth in automobiles. The city has shown a phenomenal growth with respect to area over the years. i.e. 143sqKm in 2001 to 310sqKm in 2017. According to India oil corporation(IOC), Bharat petroleum corporation (BPCL), Hindustan petroleum corporation (HPCL) consumption/ sale of petrol and diesel was 1,93,345 and 2,30,626 KL as on 31-03- 2017. It is observed that petroleum sale has increased by 11.36% whereas sale of diesel has increased by 26.38%. Also the city shows 6.10 % increase in the vehicle population according to RTO department of Lucknow. Along with the vehicular traffic many commercial, industrial and other activities contributing towards the air pollution in the city.

V. HEALTH EFFECT

At elevated levels, all the pollutants including metals have adverse effects on human and environmental health. Accumulation of pollutants in the human body through inhalation of air is an important route. Individuals with heart diseases, lung diseases such as COPD, pregnant women, elderly people and infants are more susceptible to environmental pollution. Results of the present study revealed that higher level of particulate matter (PM_{10}) especially the finer particles $PM_{2.5}$ at all the monitoring locations have serious health impacts on human being and responsible for several cardiovascular and respiratory diseases such as asthma, bronchitis, accelerated aging of the lung cells etc., reproductive abnormalities, increased risk of preterm birth and even mortality and morbidity rate. It is reported that the total daily mortality increases by approximately 1% for every 10 µg/m^3 increase in PM_{10} concentration. Human exposure to particulate air pollution has been identified as a risk factor for human mortality and morbidity and many countries have revised the limits for PM_{10} as previously defined and set up new quantitative standards for $PM_{2.5}$. Nevertheless, PM threshold levels, to which exposure does not lead to adverse effects on human health, have not yet been clearly identified and hence there is a substantial inter individual variability in exposure and in the response. Therefore, it is difficult to establish a standard or a guideline value that will lead to complete protection of every individual against all possible adverse health effects of particulate matter. The effect of PM depends on the mass and number concentration, shape and size and the composition and concentration of other inorganic and organic pollutants associated with it. Metals Ni, Pb and As can cause cancer through inhalation of fine particles. PM_{10} represents the particle mass that enters the respiratory tract and, moreover, it includes both the coarse (particle size between 2.5 and 10 μm) and fine particles (measuring less than 2.5 μm, $PM_{2.5}$) that are considered to contribute to the health effects observed in urban environments. Ultrafine particles (UFPs), i.e. particles smaller than 0.1μm in diameter, have recently attracted significant scientific and medical attention (WHO, 2005). While there is considerable toxicological evidence of potential detrimental effects of UFPs on human health, the existing body of epidemiological evidence is insufficient to reach a conclusion on the exposure–response relationship of UFPs. Therefore no recommendations can be provided as to guideline concentrations of UFPs at this point in time.

In the present study, the concentration of SO_2 and NO_2 were found to be below permissible limit ($80\mu g/m^3$) of NAAQS (MoEF 2009), but there are several reports that gaseous pollutants are related with respiratory diseases and reproductive and developmental effect even at low concentration. Vehicular traffic and NO_2 are associated with significantly higher risk of lung cancer.

VI. CONCLUSION

Lucknow has witnessed significant growth during the last one and half decades and recorded similar trends of air pollution to other cities located in northern Indo Gangetic plains of India. Lucknow has a complex mix of air pollution like any other urban centers. The present review, based on the studies conducted in Lucknow, identified particulate matter as the main air pollutant in the city. Most of the time particulate fractions ($PM_{2.5}$, PM_{10}, SPM) exceeded the NAAQS limits. Gaseous pollutants sulphur dioxide and nitrogen dioxide although remained within the NAAQS limits, but were high enough to cause substantial damage to human and plant health.

The pollution levels in the city have increased in time and space. High traffic densities and abnormal meteorological factors adversely influenced the ambient air quality of Lucknow. Degraded air quality has adverse effects on building, materials, human health and plants. Air pollutants exposure may lead to the substantial burden of disease and premature death. Number and mass concentration, shape, size, composition of particulates and presence of co-pollutants determines their detrimental effects.

The estimated high values of excess cancer risk for metals associated with PM10 and PM2.5 in a study suggest the potential risk to cancer. Fine particulates less than 2.5 micron are the carriers of metals and are loaded with reactive species including PAHs which can pierce the alveoli and diffuse into the blood system, transported to other organs and may cause systemic poisoning. Lucknow reported high air pollution in high traffic density zones than the control sites with low traffic density. Plants in general are exposed to ambient air pollution but roadside plants are exposed to extreme level of air pollutants.

VII. RECOMMENDATION

India needs to generate regular information on the ambient concentration levels of repairable particulates and take important steps to control their emissions. There is an urgent need to adopt suitable ways for air quality control to improve urban air quality. Exposure to air pollutants is largely beyond the control of individuals and requires action by public authorities at the national, regional and local levels. City's proposed master plans of 2031 have envisaged expansion of the city up to proposed new ring road of about a length of 150 km. The estimated population of city would be about 65 lakh by 2031 as per master plan. Development in the outskirts of the city will put pressure on its central zone. While there will be a real estate boom on the one hand, there will be a growth in slum conditions on the other. The increase in transport demand, particularly in central zone, will result in increased air pollution in the city. Environmental aspects are needed to be considered while planning the expansion and development of the city. Sufficient open space in the form of parks, multilane roads able to accommodate the growing traffic load, flyovers on busy crossings, multilevel parking, phasing out of very old vehicles could be some of the steps to stop further deterioration of the cities air quality. Lucknow has witnessed some improvement in this regard. The latest development is the introduction of metro rail connecting airport and railway station through north-south and east-west corridor to the different parts of the city. The metro stations will be connected to adjoining areas by local public transport. Availability of swift public transport would reduce personal vehicles on roads and intern air pollution load, due to this major contributor in city pollution.

These are some recommendation for improvement of the ambient air quality:

- Major roads of the city should be widened as far as possible.
- Suitable modification on crossings for smooth traffic flow.
- Encroachment to be removed for smooth flow of traffic.
- Footpath for pedestrians should be restored.
- Provision of parking facilities by private operators on vacant private land.
- Increase in the parking charges on hourly basis to discourage the use of personal vehicles in congested areas.
- Subsidized public mass transport (Metro, Monorail etc.) must be strengthened to minimize use of personal vehicles.
- Improvement in traffic management.
- Public awareness programme of air pollution and its health effects, reduction of automobile pollution by proper maintenance of vehicles, driving skills.
- Systematically develop residential complex at the periphery of the city with all facilities to reduce crowd from central areas of the city.
- Provision of bus stands on all the outgoing highways to reduce traffic load inside the city.
- Removal of garbage dumps along the roads. Ban on burning of dry leaves, tyres or any other type of solid waste and arrangement for its proper disposal.
- Plantation of trees wherever possible in parks, open spaces and road side areas.
- Installation of more CNG filling stations across the city.
- Encouragement for battery operated or hybrid vehicles.
- Promoting solar energy as an alternate to D.G. sets.
- Heavy dust removal system be installed at major traffic point which may be operated during peak hours.

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