Source apportionment of particulate matter and its probable consequences in urban area of Lucknow

ABSTRACT

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ABSTRACT

During the last decades, rapid urbanization, uncontrolled traffic growth, reduced forest cover and the sudden expansion of the number of vehicles have rapidly deteriorated the air quality of developing and developed countries. According to the World Health Organization report, 37 cities in India are among the 100 cities in the world with the particulate pollution, while Delhi, Raipur, Gwalior and Lucknow are among the top 10. Particulate matter (PM) is a complex mixture of organic and inorganic species in which high levels of polyaromatic hydrocarbons (PAHs) and trace metals can cause severe mortality and morbidity worldwide. In addition, several epidemiological studies revealed that trace metals associated with PM are contributing significantly to adverse health effects, even at low concentrations. Vehicular emission, re-suspension of road dust and residential heating are the main sources of PM_{10} in residential areas, whereas, incomplete combustion of petroleum product, biomass burning, solid waste burning and emission from DG sets are the major source of $PM_{2.5}$. To identify potential sources of these pollutants a receptor model viz. Enrichment Factor and principal component analysis has been used, further risk assessment due to exposure of particulate matter, trace metals and Organochlorine pesticides was also estimated. More precisely the present study has been done with following objectives.

- To study the variation in ambient air quality with respect to particulate matter.
- To characterize the particulate matter with respect to Urban and Rural area.
- To estimate the Organochlorine pesticides with respect to particulate matter at Rural and Urban area.
- Source apportionment of PM_{10} & $PM_{2.5}$ using Principal component analysis in urban area of Lucknow
- To study the human health risk assessment due to exposure to particulate matter, trace metals and pesticides.
- To study the prioritization of air pollution management/control options and preparation of action plan for the study area.

Throughout the research period, I have used different instruments and methodology to characterize the particulate matter. Continuous monitoring of particulate matter (PM_{10} & $PM_{2.5}$) was performed using respirable dust sampler (Model-APM 460 BL Envirotech, New Delhi, India) and fine particle sampler (Model- FPM-550, Envirotech, New Delhi, India). PM_{10} & $PM_{2.5}$ was collected onto glass fiber filters (GF/C, Whatman Cole-Parmer India Pvt. Ltd. Mumbai, Maharashtra, India) of 8 ×10 inch and 47 mm diameter respectively. However, the concentration of trace metals (Cu, Zn, Pb, Cd, Co, Cr, Ni Ca, Mg, Mn and Fe) was estimated by an atomic absorption spectrophotometer (AA 240 FS, Varian, Agilent Technologies Pvt Ltd. Australia). Morphological and elemental characterization of airborne particles were carried out using Scanning Electron Microscope (JSM 6490LV, JEOL, Japan) coupled with Energy Dispersive Spectroscopy (Oxford INCA x-act, UK) having resolution of 3.0 nm. To analyse morphological characteristics, such as particle count, total area, average size, perimeter, circularity, aspect ratio, roundness; equivalent spherical diameter (ESD), surface area and volume, representative SEM images have been analyzed using Image-J software. Functional group and mineralogy of particulate matter was measured between 4000 and 400 cm^{-1} at a resolution of 0.09 cm^{-1} using Fourier Transform Infra-Red Spectroscopy (FTIR, Nicolet TM 6700, Make, Thermo Scientific, USA). Finally 11 airborne Organochlorine pesticide (α -HCH, β-HCH, γ-HCH, δ-HCH), α-endosulfan, β-endosulfan, aldrin, p,p-DDE, p,p-DDD, p,p-DDT and o'p' DDT) were extracted through Soxhlet apparatus with n-hexane. The OCPs in the extracts were analysed with Gas Chromatograph (Varian CP-3800) equipped with a Ni63 ECD (electron capture detector). The selected OCPs were identified by comparing the retention time of the corresponding OCP standards. Risk assessment due to the exposure of particulate matter, airborne trace metals and Organochlorine pesticides was also estimated in the present study. Although, the identification of potential sources of particulate matter and its constituents was investigated by using the principal component analysis and enrichment factor.

The annual mean concentration ($\mu g/m^3$) of particulate matter (PM_{10} and $PM_{2.5}$) was found to be almost three times higher than annual standards (PM_{10}; 60, $PM_{2.5}$; 40), prescribed in National Ambient Air Quality Standards 1.2 times to the 24 h standards (PM_{10}; 150, $PM_{2.5}$; 35) prescribed by United State Environmental Protection Agency and approximately 9-10 times to the annual standards (PM_{10}; 20, $PM_{2.5}$; 10) prescribed by World Health Organization. With respect to ambient air quality winter season may be considered as worsen as .compared with other season. The mass fraction ratio of $PM_{2.5}$-PM_{10} was significantly higher during winter season indicating formation of secondary pollutants due to interaction between various primary combustion sources viz. biomass burning, waste incineration, petrol, diesel, CNG and residential heating during winter season. The meteorological factors, namely temperature, RH and wind speed influenced the atmospheric pollutants. Temperature and concentrations of PM had shown negative correlation; whereas RH exhibited positive correlation with finer fraction of PM. The concentration (ng/m^3) of trace metals (Cu, Zn, Pb, Cd, Co, Cr, Ni Ca, Mg, Mn and Fe) present in both size fractions and its seasonal variation was studied. Average concentration of trace metals were found in the decreasing order of Fe> Ca> Zn> Pb> Mg> Cu> Cd> Co> Mn> Ni> Cr. The highest concentration of trace metals was found at Nishatganj followed by BBAU and Mohanlalganj. It was observed that concentration of trace metals was found to be highest in winter followed by summer and monsoon. Based on the total metal concentration (PM10 & PM2.5), sampling locations can be arranged in the following order: Nishatganj> BBAU> Mohanlalganj. Among all trace metals, the level of Cd, Cu, Fe, Pb present in the coarser fraction of particles (PM_{10}) was lower than the standard limit prescribed by the US national ambient air quality standards.

However, characterizations of individual airborne particles using SEM-EDS revealed that amorphous, spherical and carbonaceous particles was observed viz. organic particles with inorganic inclusion, soot, tar balls, and aluminosilicates. Various shape descriptor viz. aspect ratio, circulatory, ESD and surface area have provided the physiochemical characteristics of the particles. In present study the average aspect ratio of airborne particles was found to be in the range of 1.84-1.96. On the other hand, average circulatory was found to be less than one, which indicates that most of the particles are not perfectly spherical. However, the roundness of airborne particles inferred that particles were nearly spherical to irregular in shape. For a non-spherical particle, ranges of equivalent diameter have been used and can be expressed as equivalent spherical diameter (ESD) which is found to be greater than 0.93 at all sampling sites in Lucknow indicating the severity of particulate pollution. Because according to an expert panel on air quality standards a value of ESD greater than 0.93 is known as a respiratory fraction. Based on the analysis of SEM image; it was revealed that an increase in number of particles simultaneously increases the surface area and provides more space for microscopic airborne toxic elements to adhere rapidly. It can also increase their interaction with lung tissues and can cause greater damage to respiratory organs.

FTIR analysis confirmed the presence of miscellaneous functional groups viz. SO4−2, HSO_{-4}, H_2O, SiO_4^{-4}, SiO_2, NO^{-3}, SiO_4, NH_{4+}, C-H, R-OH, R-O-N-O and C=O in a coarser fraction of particulate matter. While, asbestos, quartz, cerussite, organic carbon and montmorillonite, whereas, feldspar, calcite, kaolinite, smectite, Palygorskite and clay were also identified by comparing the FTIR spectra with previous studies. Crystallinity index of silica was found in disordered state which is one of the prime agents of respiratory diseases in the urban atmosphere. Further, 11 Organochlorine pesticides viz. hexachlorocyclohexane (α-HCH, β-HCH, γ-HCH, δ-HCH), dichlorodiphenyltrichloroethane (p,p-DDE, p,p-DDD, p,p-DDT, o'p' DDT), Endosulfan (α-endosulfan, β-endosulfan), and aldrin were measured in PM10 fraction and their concentration was found to be in the order of Aldrin> ΣHCH> Endosulfan> ΣDDT. The highest concentration (pg/m^3) of OCPs were found in Mohanlalganj (39275.08±5321.60) followed by Nishatganj (25081.78±823.24) and BBAU (20462.25±1042.02), which revealed that the rural areas were relatively more contaminated. During monsoon season the highest levels of OCPs were found in rural area probably due to application of insecticides and weedicides on crop and during application these pesticides volatilize into ambient environment to enhance the levels of OCPs. Source apportionment carried out applying PCA by Varimax rotated factor matrix method, identified three major sources viz. vehicular emission (45%) followed by crustal re-suspension (30%) and small scale industrial emission (15%) respectively in coarse size fraction, however, in the case of fine particle vehicular pollution (65%) dominated over industrial emission (15%) and crustal suspension (10%). PCA analysis revealed that vehicular pollution is the major identified source of PM10 & PM2.5 in urban areas of Lucknow. Human health risk assessment associated with direct inhalation of particulate matter was also estimated which is based on the air quality index. The average air quality index ranged from 258-366 at different sampling locations, which is considered to be unhealthy for people residing in Lucknow. The trends of AQI was found to in the order of Nishatganj > BBAU > Mohanlalganj. In Nishatganj, the highest average AQI was observed in winter (366) followed by summer (334) and monsoon (331) may be due to a higher proportion of $PM_{2.5}$-PM_{10} indicating the predominance of anthropogenic particles.

The mortality rate due to inhalation of fine particle was found to be highest at Nishatganj (24.3%) during the winter season; while the minimum was observed at Mohanlalganj in summer season (2.75%). The mortality rate was twice as high as the previously reported mortality rate of 10.7% indicates the severity of air pollution in urban areas of Lucknow. To evaluate the carcinogenic and non-carcinogenic risk associated with airborne trace metals, hazard quotient (HQ) for three exposure routes have been estimated. Among all three locations hazard quotient via inhalation exposure for Co at Nishatganj and Mohanlalganj (1.63 and 1.06) were higher than the safe level (1) for both children and adults. The values of the inhalation risk index for adults and children (2.7 and 1.8) were higher than the safe level (1), indicating cumulative non-carcinogenic risks. Among three locations, it was found that the carcinogenic (CR) risks associated with the trace elements present in the coarser fraction were lower than the acceptable level (1.0E-04) in adult and children via three exposure pathways in Nishatganj and Mohanlalganj. Among three age groups, maximum DIE was found to be in the order of Infants>Children>Adults. The DIE and cancer risk for adults associated with OCPs were found in the order of Aldrin > α-HCH> β-Endosulfan> pp-DDE> α-Endosulfan >pp-DDT> β-HCH> δ-HCH >γ-HCH>op-DDT>pp-DDD. It has been observed that infants were highly susceptible to OCPs and the highest carcinogenic ratio was found to be 9.00E-08; which is well below the standard level i.e.1.00E-06 that can cause carcinogenicity. To prioritize the air pollution air pollution tolerance of plant species has been studied in the proximity of Talkatora Industrial Estate. Among 25 plant species *F. bengalensis*, *F. religiosa*, *E. globus*, *A. indica juss*, *H. brasiliensis*, *S. cumini*, *M. oleifera* were found to be tolerant, and can be incorporated into a greenbelt design to assist the air pollution management practices in industrial areas