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Haze Formation During Winter in Delhi

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Abstract

Surging anthropogenic emissions are increasing the aerosol concentration in the atmosphere in Delhi. During winter season temporal variability is at its peak which makes atmosphere rich in toxic particles and noxious emissions. Due to atmospheric inversion pollutants get trapped in the cold air and reduce the amount of solar radiation reaching the earth's surface. Dust storm events make this problem more critical in the Indo-Gangetic Basin (IGB, which incidentally is also a host to the highest population density in India). Bio-mass burning, vehicular emissions, stationary fossil fuel combustion, rubbish burning, in-situ particle formation and wind-blown dust, all contribute to hazy conditions and visibility degradation. Visibility levels can be used as a broad-based proxy for particulate air pollution. This review discusses the contributing factors and resulting problems associated with haze formation in Delhi during winter. Recommendations for further necessary study to understand the haze and its management are made.

Keywords: Aerosol; Haze; Combustion; Volatile organic aerosol; Bio-mass burning

1. Introduction

Haze is a common feature of industrial and rural regions around the world. The rapid urbanization and industrialization has intensified the environmental stress, causing rise in atmospheric concentration levels of air pollutants. Megacity Delhi is located in semiarid climate zone in North India (28.38 N, 77.12 E), with population of more than 16 million and extreme climate with range of normal temperature in summer from 25 to 48°C. Delhi, as one of the most polluted cities in the world in terms of high level of particulate matter (PM) of size less than or equal to 2.5μm (PM 2.5) is facing an alarmingly high level of haze episodes (Rizwan et al., 2013). In September 2011, the World Health Organization reported that Delhi has exceeded the PM limit by 10 times.

It has been reported that per day around 3000 metric tons of air pollutants are emitted in Delhi. Among this, the major contribution i.e.

67% is by vehicular pollution followed by 12% of coal-thermal power plants. Contribution of Municipal Solid Waste (MSW) burning, in total oxides of nitrogen (NOx) load and PM 2.5 were found to be 0.2% and 3.0% respectively (Sunil *et al.,* in press; MOE and F, 2011).

Kumar et al in their studies reported that the daily average PM 2.5 concentrations at different locations in Delhi are quite high compared to the standard of national ambient air quality standards (NAAQS) (Kumar *et al.,* 2017).

The temporal variability is prominent during winter and the concentrations of particulate matter, NO_2 (nitrogen dioxide), O_3 (ozone), CO (carbon monoxide), CO_2 (carbon dioxide), SO_2 (sulphur dioxide), volatile organic compounds (VOC) are increasing mainly due to vehicular emission, greenhouse gas, industrial exhaust, burning of fossil-fuel. Overall, air becomes fully charged with particles and toxic emissions which do not disperse due to atmospheric inversion.

In winters the main challenge for the air quality of Delhi is haze pollution due to anthropogenic emitted particles in addition to dust storm events. All these are able to produce hazy conditions and reducing the sight range.

Haze, an air pollution phenomenon, causes low visibility due to high airborne particulate matter (PM), and drastically affects the air quality (Zhao *et al.,* 2013; Sun *et al.,* 2006; Okada *et al.,* 2001; Chen *et al.*, 2003; Yadav *et al.*, 2003; Lee *et al.,* 2006; Huang *et al.,* 2011; Huang *et al.,* 2014; Ji *et al.,* 2014; Tao *et al.,* 2014; Wang *et al.,* 2014; Zhang *et al.,* 2014a, 2014b; Zheng *et al.,* 2015; Rongrong *et al.,* in press).

Haze lessens the atmospheric visibility to less than 10 km due to smoke, suspended particles, vapour, volatile organic compounds, secondary organic aerosols, organic and inorganic particles found in the atmosphere (Zhang *et al.,* 2013; Behra *et al.*, 2010).

Physical interaction of light with pollution particles (smoke, dust, vapours, soot particles) and atmospheric gases, increases the absorption and scattering of atmospheric gases/aerosols. This accelerates and intensifies the process of fog and smog formation in the urban areas especially in Delhi, which is one of the highly polluted industrialized mega city in south Asia. Whenever there is a hindrance in dispersion of suspended particles, they get accumulated and concentrated, forming a low-hanging veil that impairs visibility. All this contributes to occurrence of large-scale pollution haze imposing severe risk to both aerial and surface navigation and also leading to disruption of the climate and water cycle (Figure 1 and 2) (Singh, 2017; Mitter, 2017).

Problem of urban haze during winters in India is the combined effect of presence of primary aerosol particles (dust, emanated soot due to construction, combustion, and industrial processes), formation of secondary inorganic ions and hygroscopic growth of secondary aerosol in the atmosphere owing to several psychophysical processes. These organic and carbon particulate matter slowly permeates the whole region. In Delhi, sources of PM 2.5 and PM 10 are abundant and heterogeneous. Table 1 shows major pollution contributors in Delhi (Shewta, 2016).

Figure 1. Heavy haze formation observed on a winter afternoon at New Delhi

Figure 2. Crippling traffic due to winter smog in Asian Mega City, New Delhi

Table 1. Major sources of pollution in Delhi and their percentage contribution

S No	Source	PM2.5	PM10
1	Brick Kilns	13%	9%
2	Construction	4%	6%
3	Diesel gen Set	5%	3%
4	Domestic	11%	7%
5	Industries	13%	9%
6	Power plant	9%	13%
7	Road dust	9%	31%
9	Waste burning	6%	4%

This changes from season to season and from day to night, for example, emission of PM will be higher during the winter due to burning of biomass for heating purposes than summers (Sahu *et al.,* 2011; Sharma *et al.,* 2016; Xuefang *et al.,* 2013).

Biomass burning contributes a lot in terms of particulate matter and atmospheric gases which have intense effects on atmospheric chemistry (Verma *et al.,* 2008; Alves *et al.,* 2010).

2. Literature Analysis

Biomass burning (anthropogenic aerosol) in the nearby regions which contribute around 26% of PM 2.5 (Kirpa *et al.,* 2012) coupled with the desert dust aerosols from the Great Indian Desert lead to a high level of aerosol loadings. Secondary inorganic aerosol (including water-soluble inorganic species such as ammonium, sulfates, nitrates) is also rising predominantly due to oxidation of SO_2 and NOx. These emanations are mainly associated with fossil fuel combustion, biomass combustion, organic aerosols from industrial emissions, biological sources, refrigerate discharge, landfill emissions, paints and organic/inorganic solvents.

According to Varshney *et al.,* (2008) the annual anthropogenic VOC emissions for India have been estimated to be 21 million metric tons (m.t.) where the majority of emissions i.e. 60% originated from combustion of biomass, nearly 20% due to oil production and distribution followed by 12% of transport and 7% of open burning of agricultural residues (Sharma *et al.,* 2015). All these factors generously contribute to enhance the scattering characteristics of aerosols.

Recently, Journal of Science of the Total Environment (Li *et al.,* 2014) stated that in New Delhi higher strong emissions of fatty acids, fatty alcohols, n-alkanes, phthalates, etc. is due to open burning of plastics and other solid wastes. Important sources of carbonaceous aerosols are biomass burning, and rapid growth in usage of motor vehicles (6.89% in New Delhi, 2014-2015).

Radiocarbon measurement of aerosols proved that biomass burning or biogenic sources contributed 79% to water-soluble organic carbon, despite of various other fossil air pollution sources (Fang *et al.,* 2015). Winter time total solid particulates (TSP) indicates that crustal material is the most abundant component of ambient particles in New Delhi accounting for 48% of particle masses, 23% organic matter and 12% secondary inorganic ions (sulfate, nitrate plus ammonium). In New Delhi, during winters, the overall average concentration of PM 2.5 is 375 $\mu g/m^3$ against the acceptable level of 60 µg/m3. PM 2.5 expose people to very high health risks (Ostro *et al.,* 2006; Pop *et al.,* 2006). These fine particles (1/30th average width of human hair) get lodged deep in the lungs. Roughly one out of three people in the world is at a higher risk of experiencing PM 2.5 related health effects. It is estimated that more than three million deaths occur globally every year due to air pollution, mainly by particulate matter (Dholakia *et al.,* 2013; Heal *et al.,* 2012; WHO, 2016).

Satellite images and data of several investigators for the period of December to February reveal the presence of persistent aerosol haze layers over northern India along the southern edge of Himalayan region and above the Indo-Gangetic plain extending across Bangladesh onto the Bay of Bengal. The

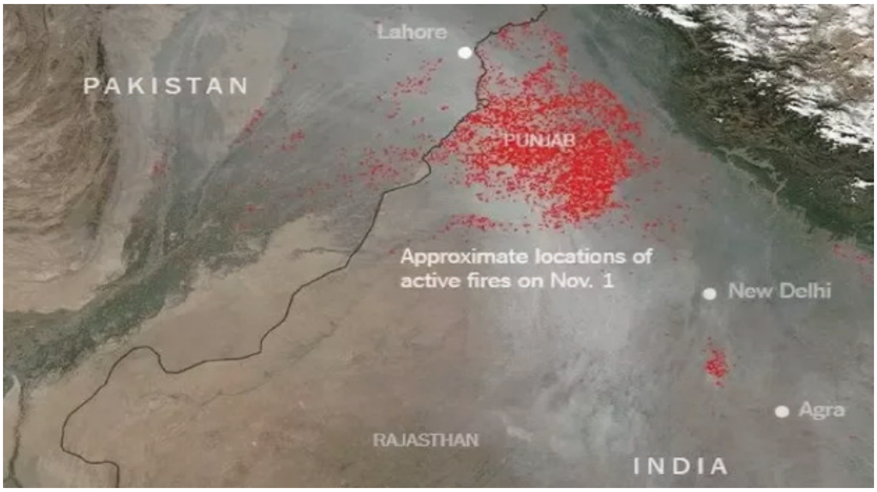

Figure 4. NASA image showing red (fire) spots near and around Delhi in November 2012

problem is more critical in the Indo-Gangetic Basin (IGB), where frequent fog formation leading to very low visibility is aided by high aerosol concentration (Tiwari *et al.,* 2011). Images released in 2012 by the United States NASA (National Aeronautics and Space Administration) (figure 4) suggest a thick blanket of aerosols and fire spots mainly over northern Indian states including Delhi during winter time. The large area covered with red dots in figure 4 suggest fire due to crop/biomass burning.

In Kanpur, another major city in Gangetic basin, contribution of secondary organic aerosols (SOA) is about 17% of total PM 2.5 (Behra *et al.,* 2010). This suggests that VOCs emission need to be controlled, both in and outside New Delhi, as it can lead to formation of SOA from VOC sources at a distance farther from the receptor.

3. Conclusion

In India the expected emission of VOCs is about 22.5 million metric tons by 2025, stressing the urgent need of developing effective VOC emission control approach in the near future. To understand the impact of smoke, aerosols emitted after the biomass burning on the local and regional climate system, identification of different categories of biomass burning and their contributions in several modes especially weather wise is essential. Since increase in PM mass concentration increases the adverse effects of PM on human health it has become more and more important to find out the sources of PM and the development of effective PM emission reduction strategies. The motto should be to first catch the problem at source point by using clean and green fuels.

In industries more emphasis should be laid on the green methodology and energy efficient processes. Since air pollution is not bound by geographical boundaries strict rules and regulation are the need of the hour on the emission of gases from the industries and vehicles, and stringent control on backyard bio mass burning.

Apart from regulatory measures, usage of smokeless fuels, proper maintenance of roads and vehicles, optimization of technology for the development of low emission and energy efficient vehicles, advancement and adaptation of electric vehicle technology, properly planned and systematic management of traffic are few points to be considered.

To provide more lung space government and people should promote more and more green plantation in and around the susceptible regions.

For the mitigation of haze formation more research studies are necessary to characterize physical properties, chemical compositions, and secondary formation processes of urban non-fossil emissions. As SOA sources are still unknown and their formation include complex chemistry, multiphase processing they deserve concrete investigation and research.

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