Journal of Advanced Research in Alternative Energy, Environment and Ecology
Volume 5, Issue 1&2 - 2018, Pg. No. 29-32
Peer Reviewed Journal
Research Article

Air Pollution in NCR

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Abstract

Since the past two decades, air pollution has become a global public health issue and identified as a major environmental health hazard. Due to rapid development, society is facing serious challenges such as: climate change, global warming, ozone hole, acid rain and smog. Increasing energy demand and growing per capita energy consumption has led to such serious challenges. Their notoriety is evidence for the growing concern about the human impacts on climate. Recently, the onset of winter in every year Delhi and National capital Region (NCR) of India witnessed hazy and dusty condition or smog, which prolonged for many days (October to November). In present investigation, on the basis of air quality monitored by various Government organizations for the years 2009 – 2015, the occurrence of smog in Delhi is studied and fog is categorized as mixture of Classical and Photochemical Smog. In present investigation the overall scientific aspects driving the research are as: important processes controlling levels of smog and surface exchange, impacts of smog on human health and the environment and important processes controlling the interaction between climate and air pollution.

Introduction

Delhi has earned the unenviable distinction of becoming the most polluted city on Earth last year. The airborne particles and toxic chemicals that make up the smog and contributes to air pollution in NCR had reached the record level on November 8, 2017 when some monitoring stations reported an Air Quality Index of 999, way above the upper limit of the worst category, Hazardous. (An extra-sensitive air quality instrument at the US embassy got a reading of 1,010).

'Great Smog' was deadly air pollution event in history of London between December 5-9, 1952, around 4,000 people died of illnesses linked to respiratory problems such as bronchitis and pneumonia, and the smog's effects caused another 8,000 deaths over the next several months [1]. Great smog showed first time that it could be deadly. Term smog is derived from the words smoke and fog. There are several variants of smog but at least two distinct types of smog are recognized in literature: Classical (London-type) smog or sulfurous smog [1] and Photochemical smog [2] (Los Angeles-type). Sulfurous smog results from a high concentration of sulfur oxides in the air and is caused by the use of sulfur-bearing fossil fuels, particularly coal. London-type smog occurs in the regions where, emission of the sulfur-containing compounds is high (due to burning of coal to generate heat and energy) and air contains high liquid water contents or fog. Burning of coal produces sulfur dioxide, soot and other gases and particulates, which are commonly called smoke. It leads to the production of high concentrations of sulfuric acid in fog droplets. The classical smog is recognized by the human since along. Here the primary pollutants are SO_2, soot particles and secondary pollutants are H_2SO_4, sulfate aerosol. It predominantly occurs in early morning hours when temperature is low and relative humidity is high or foggy.

Photochemical (Los Angeles-type) smog was first recognized during mid-1940s. It predominantly occurs in noon-evening hours and the required temperature is (> 75°F) and relative humidity is low and usually hot and dry environment. This type of smog occurs in the regions of high emissions of automobiles, large concentrations of reactive hydrocarbons (RH) (from automobile exhaust or from other natural or anthropogenic sources) and plenty of sunlight (high level of UV radiation). Photochemical smog typically develops in summer (when solar radiation is strongest) in stagnant conditions promoted by temperature inversions and weak winds. Photochemical smog is a ubiquitous urban problem and often blankets large populated regions such as the eastern United States and Western Europe and Asia for extended periods in summer.

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How to cite this article: Kumari K. Air Pollution in NCR. *J Adv Res Alt Energ Env Eco* 2018; 5(1&2): 29-32.

Photochemical smog produce due to the chemical reactions of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, which leaves airborne particles and ground-level ozone . This is noxious mixture of air pollutants such as Aldehydes, Nitrogen oxides, particularly nitric oxide and nitrogen dioxide, Peroxyacetyl nitrates, Tropospheric ozone, Volatile organic compounds.

Atmospheric aerosol particles, also known as suspended particulate matters (SPM) are microscopic solid or liquid matter suspended in Earth›s atmosphere. Aerosol particles scatter sunlight and are responsible for the whitish haze associated with smog. The size of the particle is a main issue for the determinant in the respiratory tract of human and animal. Particles whose diameter lies between 10µm to 2.5µm are termed as 'coarse particles' (PM_{10}) can reach up to deepest part of the lungs such as the bronchioles or alveoli. The particles with diameter less than 2.5µm are called as 'fine particles' ($PM_{2.5}$) are considered most harmful to health tend to penetrate into the gas exchange regions of the lung (alveolus). Size of 'ultra-fine' particles ($PM_{1.0}$) with diameters less than 1.0 micrometer are mainly produced when precursor gases condense in the atmosphere. Major components of fine aerosols are sulfate, nitrate, organic carbon, and elemental carbon. These are important agents for climate change and are also suspected to be particularly hazardous for human health.

Smog in Delhi

Delhi is the one of the most polluted [3] city in the world and according to one estimate, air pollution causes the death of about 10,500 people in Delhi every year [4]. During 2013–14, peak levels of fine particulate matter (PM) in Delhi increased by about 44%, primarily due to high vehicular and industrial emissions, construction work and crop burning in adjoining states. Delhi has the highest level of the airborne particulate matter $PM_{2.5}$, (153 micrograms). Rising air pollution level has significantly increased lung-related ailments (especially asthma and lung cancer) among Delhi's children and women. The dense smog in Delhi during winter season results in major air and surface traffic disruptions every year. Considering the serious impacts caused by smog, the effective management to meet out such conditions becomes inevitable. Therefore, to monitor and control of various air pollutants, Central Pollution Control Board (CPCB) had launched a nationwide program National Air Quality Monitoring Programme (NAMP) [5]. Moreover, under the NAMP, three major pollutants viz. sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM_{10}) have been identified for regular monitoring at almost all the locations of Delhi. Other parameters like particulate matter ($PM_{2.5}$), carbon monoxide (CO), ammonia (NH_3), lead (Pb), ozone (O_3), benzene (C_6H_6), arsenic (As), and nickel (Ni) are also monitored at selected locations and are slowly being added to the monitoring networks under NAMP. Air quality monitoring in Delhi is carried out through a number of air quality monitoring stations situated across the territory. The monitoring is undertaken by various organizations viz. Central Pollution Control Board (CPCB), Delhi Pollution Control Committee (DPCC), and System of Air Quality and Weather Forecasting and Research (SAFAR) of Indian Institute of Tropical Meteorology (IITM), Pune.

Air quality for three major contents of smog (SO_2, NO_2, and PM) is determined to understand the trend of pollution in Delhi during recent years [5]. On the basis of annual average concentration of pollutants, air quality trend has been seen for the years 2009 – 2015 along with the comparison with existing national ambient air quality standards (NAAQS), 2009. Regarding the three pollutants viz. SO_2, NO_2, and PM_{10}, the concentration of NO_2 and PM_{10} are far exceeding the prescribed standard limits. The concentration of SO_2 is within the standard limits. However, as far as NO_2 is concerned, continuous rise in concentration was observed in 2009 – 2015. Moreover, the problem of particulate matter (PM_{10}) is more critical. Since 2009, approximately 258–335% rise has been observed in PM_{10} concentration compared to the standards. Further the concentration of volatile organic compounds (VOC) significantly increased during smog.

Chemistry of Photochemical Smog

This type of smog requires neither smoke nor fog, has its origin in the nitrogen oxides and hydrocarbon vapors emitted by automobiles and other sources [6-8]. Photochemical smog forms primarily as a result of interactions among nitrogen oxides ($NO_x = NO + NO_2$), reactive hydrocarbons (RH), and sunlight. Primary pollutants NO_x and reactive organic vapors RH are emitted from automobiles and create secondary pollutants i.e., ozone, peroxyacetyl nitrate (PAN), smog *etc*. Ozone produced in stratosphere is known as good ozone and shield the planet from harmful ultraviolet radiations of Sun. Here, ground level or «bad ozone" is produced in troposphere, dangerous to human health when detected in our atmosphere and at ground level.

First, RHs are chemically transformed to radicals, denoted by $R^{\cdot}$. The organic radical $R^{\cdot}$, can be composed of many atoms and have a complex molecular structure.

$$RH + OH = R^{\cdot} + H_2O \quad (1)$$

$$R^{\cdot} + O_2 + M = RO_2^{\cdot} + M \quad (2)$$

Then these organic radicals react with nitric oxide (NO) to form nitrogen dioxide (NO_2).

$$RO_2^{\cdot} + NO = RO^{\cdot} + NO_2 \quad (3)$$

The photochemical reaction breaks NO_2 back to NO and

O at wavelength $\lambda < 0.42$ µm

$$NO_2 + hv = NO + O \quad (4)$$

Atomic oxygen produces ozone O_3, which is of primary concern in photochemical smog.

$$O + O_2 + M = O_3 + M \quad (5)$$

Thus, the overall process of smog formation can be summarized as

$$RH + HO + NO + hv = O_3 + NO_2 + HC \quad (6)$$

Hundreds of different compounds may be produced by the reactions of RH. One of the most important is peroxyacetyl nitrate (PAN). Thus, secondary hydrocarbons are important components of photochemical smog. Hence in photochemical smog, emission of NO, CO, RH occurs in initial stage then due to presence of sunlight O_3, NO_2, PAN (and other hydrocarbons), haze (aerosols) are formed in the final stage.

Before 1970s it was commonly believed that tropospheric ozone was basically transported downward from the stratosphere and eventually destroyed at the earth's surface [9-10]. Ozone production in heavily polluted summer-smog was recognized by many researcher [11-12]. In the 1970s it was discovered that ozone is produced and destroyed in the troposphere during the oxidation of methane and carbon monoxide (CO) catalyzed by free radicals and nitrogen oxides, NO_x=NO+NO_2 [6-8,13]. In Radical chemistry, formerly ozone production was considered to be important in the stratosphere but later it was found to be strongly involved in tropospheric chemistry as well, and ozone was identified as the main precursor of the important hydroxyl radical (OH) [14]. OH is the dominant sink for methane, carbon monoxide and many other organic substances in the atmosphere and is therefore often called the detergent of the atmosphere".

Thus, the role of ozone in the atmosphere is manifold. It is an effective greenhouse gas, and largely controls the oxidizing power of the atmosphere. Additionally, ozone is a toxic gas which can have detrimental effects on human health and crops. The controlling factor in determining ozone production or loss in large parts of the troposphere is the abundance of NO_x, which is largely emitted by human activity.

Visibility and smog

Aerosols or SPM present in smog also have important irradiative effects in the atmosphere. Particles are efficient scatter of light due to their size which is of the order of wave length of visible light. SPM modify the direction of radiation beams without absorbing radiation. Scattering of sunlight by SPM is the principal mechanism limiting visibility in the atmosphere, as it prevents us from distinguishing an object from the background. Air molecules are inefficient scatterers because their sizes are orders of magnitude smaller than the wavelengths of visible radiation (0.4 to 0.7 micrometers). Further in humid environment, SPM absorb water, which causes them to swell and increases their cross-sectional area for scattering, creating haze. Without aerosol pollution our visual range would typically be about 200 miles, but haze can reduce visibility significantly.

Results and Discussion

Regarding the characteristics of smog - at Delhi the concentration of SO_2 is within the standard limits, evidently it can't be classified as sulphrous smog but the presence of aerosol and smoke, high ambient particulate concentration results in hazy conditions, leads towards the conditions of classical smog. Hazy condition of Delhi is due to burning of millions of tonnes agricultural stubble by farmers in northern India in every October, before the onset of winter. An estimated 35 million tonnes are set afire in Punjab and Haryana alone to make room for the winter crop. Delhi area had no smoke, but after development of certain geographical disturbances caused movement of smoke towards Delhi. As per the Report of IIT Kanpur, analysis of the black trajectory in satellite image suggest that the crop residue burning and other biomass emissions may be transported to the capital from the sources upwind of Delhi [15]. Hence, the exceeding concentration of NO_2 and PM_{10} had characterized the Delhi smog as photochemical type. Due to disadvantage of specific geographical location of Delhi, the trapped air brings pollutants from neighboring areas but doesn't take them away, in three months of November, December and January. According to experts, the specific geography of NCR results in the advection or large-scale horizontal movement of air from the surrounding areas, into the in the atmosphere of the NCR causes sometimes significantly more polluted than the city centre itself. As a land-locked megacity, there are limited avenues for the flushing of polluted air out of the city, or its replacement with air from relatively unpolluted marine regions, which means that atmospheric transport from all directions, is likely to add to inner-city pollution.

Photochemical smog is therefore considered to be a problem due to indiscriminate industrialization and transportation in Delhi. It is present in all modern cities, but it is more common in cities with sunny, warm, dry climates and a large number of motor vehicles like Delhi. Because it travels with the wind, it can affect sparsely populated areas as well. Smog may have different characteristics at different locations, owing to the various reasons such as: sources of primary pollutants; timing of emissions; distribution of sources; prevailing winds; regional topology; geographical character; season of the year; urban demographics.

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Date of Submission: 2018-04-02
Date of Acceptance: 2018-05-06