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Role of Aerosols in Climate Change and Cloud Formation Emitted from Coal Based Power Plant

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Abstract

Present study showed that aerosols from coal based thermal power plants can directly obstruct the light by scattering and thereby affect the energy budget of the earth surface and can influence the climatic change. The concentrations of particulate matter (PM), SO_2 and NO_X range from 165–263, 566–679, 287–453 mg /Nm^3 respectively. The percentage of O_2 and CO_2 are ranged from 11.4–19.2 and 10.0–13.8% whiles the concentration of CO and hydrocarbon ranged from 71–159 and 310–514 ppm. The concentrations of pollutants were more (PM: 263 mg/Nm^3; SO_2: 679 mg/Nm^3; NO_X: 453 mg/Nm^3; CO_2: 13.8 mg/Nm^3; CO: 159 mg/Nm^3) in unit-I as compared to the other units. The concentration of certain chemical compounds was higher in coal fly ash as compared to coal. Though it's a multifarious phenomenon but definitely the oxides of sulphur and nitrogen are two major players in climate change, global warming and cloud formation.

Keywords

Thermal Power Plant; Aerosol; Gaseous Pollutants; Climate Change; Cloud Formation

Introduction

Coal is India's primary source of energy. About 143 coal based thermal power plants are continuously consuming 523.52 million tons of coal for the power generation during 2013-14 [1]. Coal based thermal power plant generates lot of black carbon and often loft it high into the atmosphere as emitted from tall stack (~275 m) [2]. These power plants are not only releasing aerosols but also flue gases in huge amount. Aerosols are fine particles (usually solids or tiny liquid droplets) of 10 nm to 100 µm that remain suspended in the atmosphere [3]. Tiny particles of black carbon or soot are major components of the flue gases. These are sufficiently small and light enough that they do not quickly fall out of the air under the influence of gravity, Aerosols, Cloud Nucleation and Global Dimming, Windows to the Universe [4, 5]. Aerosols can be classified into 3 groups; (i) by their source or method of formation, (ii) by their chemical properties and (iii) by the way they interact with sunlight. Pollutant

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gases such as sulfur dioxide (SO_2) and oxides of nitrogen (NO_X) which are emitted by coal combustion and a variety of industrial processes are transformed to secondary aerosols [6]. SO_2 and NO_X gases are the prevalent sources of secondary emissions of aerosols [7]. Chemical reactions convert these gases into solid aerosols or liquid droplets. During this process, SO_2 combines with water vapour and transform into sulfuric acid droplets (a liquid aerosol that cause acid rain). Sulfuric acid in turn combines with gaseous ammonia (NH_3) to form a solid ammonium salt, ammonium sulfate [$(NH_4)_2SO_4$] [8].

There were many catastrophic episodes that occurred because of air pollution and stable meteorological conditions. Very famous London smog was happened during 1st week of December 1952 which killed more than 4500 people within a short period. Along with the usual industrial emissions of coal smoke and soot, increasing burning of coal for home heating added to smoke levels pouring from chimneys. The weather conditions were favorable for smog (smoke with fog) formation and characterized by calm wind which unable to disperse smoke vertically or horizontally.

In last decade of past century, a peculiar cloud cover was observed which is known as Indian Ocean brown cloud or Asian brown cloud. It is a layer of air pollution that recurrently covers parts of South Asia, namely the Northern Indian Ocean, India and Pakistan. The Asian brown cloud, the thick haze caused by pollution that hangs over Southern Asia, is rapidly melting Himalayan glaciers and could precipitate an environmental disaster that could affect billions of people of China, Tibet, India and Pakistan. The Asian brown cloud is created by a range of airborne particles and pollutants from discharge of automobiles, biomass burning and industrial processes with incomplete burning. The cloud is formed during November-December to April (winter season) when there is obscure rainfall to precipitate the atmospheric air pollutants. This phenomenon was first observed in late 1990s as part of the Indian Ocean Experiment (INDOEX), in which coordinated air pollution measurements were taken from satellites, aircraft, ships, surface stations and balloons.

Aerosols alter albedo, changing the amount of solar energy that reaches the earth's surface and the amount that is absorbed at various levels within the atmosphere [9]. Altitude, temperature and humidity will determine the types of cloud formed in various locations [10]. Less well known is the critical role aerosols play in cloud formation, serving as cloud condensation nuclei or "cloud seeds". The abundance, shape, size and chemical properties of these aerosols influence the types of clouds generated and the rates at which they form. Clouds with smaller droplet have a higher albedo, while clouds with larger droplet are more prone to producing precipitation [11]. The specific objective of this paper are to qualitative and quantitative determination of aerosol/ gaseous pollutants released from a coal based thermal power plant and to discuss the possible role of these aerosols in climate change and cloud formation.

2.0 Materials and Methods

Samples were collected from coal based thermal power plant of National Thermal Power Corporation (NTPC) Ltd., a public sector enterprise of India located at Singrauli, 100 km away from Renukoot in Sonebhadra district of UP during May 2013. During study period, plant having power generating capacity was 2400 MW from 4 units of 600 MW each (Units-I, II, III and IV). Particulate matter (PM) from stack emission was collected isokinetically in pre-weighed micro glass fiber thimble (sampling period 30 min) using Stack Monitoring Kit (Model APM-615, Envirotech make, New Delhi) from stack sampling port located at a height of 110 m above ground and quantified gravimetrically [12]. Other pollutants present in stack gas (SO_2, NO_X, O_2, CO, CO_2 and HC) and ambient temperature were measured using Automatic Flu Gas Analyzer (Model KM-9106, Germany Make). Chemical characterization of coal fly ash (CFA) collected from sampling port in hopper of Electro Static Precipitator (ESP) was carried out with the Energy Dispersive X-ray (EDX) analysis. Particle size analyzer was used for measurement of the size range of particle. CFA was analyzed for major and minor trace element in namely Fe, Mg, Mn, Zn, Cu, Pb, Ni, Cr, Cd, As Se and Hg [2]. 2 g dried sample was taken into a Teflon vessel and tri acid digestion mixture (HNO3, HClO4 and HF 5:1:1 v/v) was added to the vessel and kept for digestion in a microwave digester (4782: Parr, USA) for 30 min at 443 K. Digested sample was filtered and transferred to a volumetric flask and volume was made up to 50 mL. These samples were analyzed for heavy metals by AAS (AAS, GBC Avanta-Sigma, Australia) [13]. Cold vapor atomic absorption Spectroscopy technique was employed for the analysis of Hg. The oxides of major elements, SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, Na_2O, K_2O and loss of ignition (LOI) of coal and CFA were determined for chemical composition [14].

2.1 Quality Assurance Planning and Quality Control

It is important to follow a set of operating principles during sample collection and analysis, which will produce reliable data of defensible quality. This is known as quality assurance and enables the analyst to have a high level of confidence in the accuracy of analytical results. Errors could be occurred during sampling, processing and analysis are linked to stack monitoring, instruments, chemical impurity, data processing, procedures followed and human mistakes. To limit the above errors, following measures were adopted. Isokinetic sampling was carried out during stack monitoring. High quality chemicals and reagent blanks were used in all analyses to check impurities. Before analysis of samples, instruments were calibrated and validated as per standard guidelines to avoid unreliable readings. Triplicate samples were read to verify the precision of the analytical method and instrument. Working standard solution of metals was prepared by CRM multi element standard solution IV (CertiPUR® 1.11355.0100 Lot. No. HC081563, Merck). From study design to manuscript processing, necessary measures were taken to minimize the uncertainty errors which should be < 5% of the observed value with respect to true value.

3.0 Results and Discussion

Quantity of fuel used, stack details, generation capacity and meteorological conditions of all the 4 units of power plant are given in Table 1. Table 2 shows the concentration of monitored parameters in stack emissions of all 4 units of plant.

Table 1: Quantity of Fuel Used, Stack Details, Generation Capacity and Meteorological Conditions of Plant

Particulars	Unit-I	Unit-II	Unit-III	Unit-IV
Quantity of fuel used (MT/hr)	452.0	439.0	413.0	386.0
Load during monitoring (MW)	495.0	512.0	502.0	479.0
Atmospheric pressure (mm of Hg)	742.0	742.0	742.0	742.0
Ambient temperature (K)	309.0	306.0	308.0	310.0
Stack gas temperature (K)	422.0	420.0	417.0	419.0
Flue gas exit velocity (m/sec)	29.5	28.7	23.6	22.8
Flue gas exit volume (Nm^3/hr)	2685421.0	2668451.0	2438456.0	2418526.0

Table 2: Concentration of Pollutants Emitted from Stacks

Pollutants	Unit-I	Unit-II	Unit-III	Unit-IV
PM (mg/Nm^3)	263.0	228.0	189.0	165.0
SO_2 (mg/Nm^3)	679.0	638.0	595.0	566.0
NO_X (mg/Nm^3)	453.0	422.0	287.0	376.0
O_2 (%)	22.8	20.5	14.6	11.4
CO_2 (%)	13.8	12.6	10.4	10.0
HC (ppm)	431.0	514.0	358.0	310.0
CO (ppm)	159.0	146.0	98.0	71.0

The concentration of PM, SO_2, NO_X in stack emissions was in the range of 165–263, 566–679, 287–453 mg/Nm^3 respectively. The percentage of O_2 and CO_2 was 11.4–19.2% and 10.0–13.8% whiles the concentration of CO and HC was 71–159 and 310–514 ppm. The stack gas temperature ranged from 417–422 K with an average of 419.5K The hourly released volume of flue gases from stacks of Units-I, II, III and IV of plant was 2685421, 2668451, 2438456 and 2418526 Nm3/h respectively with an average of 2552714 Nm^3/h. The release of high CO in the flue gas is the indicator of incomplete burning of coal. The particulate matters for all units were higher than the prescribed concentration of 150 mg/m^3 for power plant emission. Although, high efficiency ESPs installed in the thermal power plants can trap about 99.5–99.9% of CFA, about 0.1–0.5% of total CFA still remain in the flue gases, may carry 2.5–12.78 MT/hr CFA particles per day which is sufficient enough to cause environmental hazards. The metals concentration and chemical compositions in coal and CFA are given in Tables 3 and 4.

Table 3: The Range of Metal Concentrations (Mg/Kg) In Coal and Coal Fly Ash

Metals	Coal (mg/kg)	Coal fly ash (mg/kg)	Detection limit of AAS (mg/kg)
Fe	483.0-487.0	454.0-470.0	0.02
Mg	81.5-83.4	71.3-75.1	0.003
Mn	148.3-153.9	142.1-148.5	0.02
Zn	128.4-133.2	193.3-199.5	0.025
Cu	69.6-74.6	104.5-112.1	0.025
Pb	27.2-30.6	54.4-62.0	0.01
Ni	148.0-159.6	75.8-83.4	0.04
Cr	75.6-89.8	112.4-124.2	0.025
Cd	3.3-4.3	4.9-5.5	0.009
As	2.9-3.3	13.6-16.8	0.005
Se	10.2-12.8	14.2-19.4	0.001
Hg	0.14-1.96	0.04-0.09	0.001

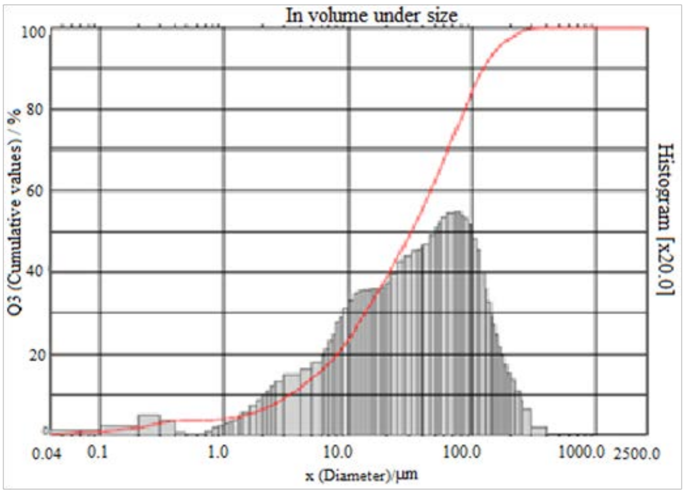
Table 4: Chemical Composition (%) In Coal and Coal Fly Ash

Chemical composition	Coal (%)	Coal fly ash (%)
Silicon oxide (SiO_2)	57.80	62.24
Aluminum oxide (Al_2O_3)	19.90	21.50
Iron oxides (Fe_2O_3)	8.80	9.20
Calcium oxide (CaO)	1.39	1.42
Magnesium oxide (MgO)	1.28	1.46
Potassium oxides (K_2O)	0.47	1.05
Sodium oxide (Na_2O)	0.23	0.47
Titanium oxide (TiO_2)	0.98	2.38
Loss of Ignition (LOI)	8.82	2.28

From the above Table 3 it is cleared that the concentration of metals such as Fe, Mn, Mg, Ni and Hg were higher in case of coal whereas Zn, Cu, Pb, Cr, Cd, As and Se were more in CFA. It was due to burning of coal at higher temperature (1400–1600 K). The elements such as Fe, Mg, Mn, Ni and Hg were found in coal more concentrated form as compared to CFA whereas remaining elemental concentrations present in CFA were more. This variation may be ascribed to the fineness of CFA particles with large surface ratio to mass preferentially concentrate more these elements. Sarkar et al., [15] also observed similar observation. Improper disposal of CFA in agricultural land is of high environmental health risk and possibly the source of ground water contamination through leaching of metals. The contamination of surface water can't be avoided due to surface run off from ash dump site, lateral migration of leachates or discharge of ash pond effluent [16].

The chemical analysis of coal and CFA are given in Table 4. The compositions of coal and CFA were silicon oxide (SiO_2 = 57.80 and 62.24%), aluminum oxide (Al2O3 = 19.90 and 21.50%), iron oxide (Fe_2O_3 = 8.80 and 9.20%) while, calcium oxide (CaO), magnesium oxide (MgO), potassium oxide (K_2O), sodium oxide (Na_2O), titanium oxide (TiO_5) were found in traces. The loss of ignition (LOI) of coal was 8.82% and 2.28% in coal and CFA respectively. Absence of significant irregularity in the observed result with compared to reported values indicates that chemical composition of Indian coal is similar to others country except the high ash content. The SiO_2 percentage in Chinese CFA is as high as 70.10% [17].

Figure 1: Particle Size Distribution of Coal Fly Ash



The particle size of CFA is in very wide range, from 0.1 to more than 120 µm. The ESP removes the larger particles with greater efficiency than what they do for the finer ones [6]. Particle Size Analyzer was used for measuring the particle size of CFA. Effective diameters D_{10}, D_{50}, D_{90} and the arithmetic mean diameter of CFA was found to be 20.92, 64.01, 119.27 and 67.66 µm respectively (Figure 1). On the basis of particle length, CFA has following distribution: 0.04 to 0.1 µm (0.89%), 0.1 to 1.0 µm (3.18%), 1.1 to 10 µm (19.47%), 10.1 to 20 µm (14.74%) 20.1 to 50 µm (24.18%) and 50.1 to 100 µm (22.26%). 84.72% particles are fall in the range in between 0.04 to 100 µm. 15.28% particles having the size of >100 µm. Larger particles easily settled down near to power plant. Out of total particles, about 23.54% particles fall in the category of inhalable particles (cut off size >10 µm) which are mainly responsible for health hazards.

From the above Tables, it is clear that tons of aerosols are escaped from the power plant in the upper atmosphere through stacks. These aerosols range from 0.1 nm to >100 µm in size and in varying shapes. These aerosols have a major impact in Earth's climate. Different aerosols interact with sunlight and other electromagnetic radiation in various ways. All aerosols, including sulfate and nitrate aerosols, scatter light to some extent. Therefore, aerosols of different types can influence climate in one or more ways. However, aerosols that also absorb sunlight especially black carbon effectively increase albedo (both directly and indirectly via clouds) warming the atmosphere in their vicinity when they reradiate the absorbed energy. Such absorption and heating may occur near Earth's surface or high above it in the stratosphere and that the location of heating can make a big difference in terms of the overall effect on climate [18]. Aerosols alter Earth's energy budget (some scatter or reflect light, while others are strong absorbers of solar energy) and cause changes to the water cycle. The overall effects of aerosols are complex phenomena. The chemical composition and properties of aerosols can play a key role in their abilities to influence climate. Some are relatively inert, others are highly reactive and some react strongly only with certain substances. Chemical reactions involving aerosols can generate new substances that influence climate or they can diminish the amounts of certain other chemicals in the atmosphere, again altering the existing balance. Reactions can cause aerosols to grow in size, altering their ability to absorb or scatter light or other electromagnetic radiation.

Aerosols play a critical role in cloud and rain drop formation. Clouds formed as parcels of cool moist air and the water vapor in them condenses, forming small liquid droplets of water. The particles around which cloud droplets coalesce are called cloud condensation nuclei (CCN) or sometimes "cloud seeds". Amazingly, in the absence of CCN, air containing water vapor needs to be "supersaturated" to a humidity of about 400% before droplets spontaneously form. So, in almost all circumstances, aerosols play a vital role in the formation of clouds. As humidity accumulates on the particles droplets are formed, which later develop into clouds.

Any disturbance to the normal mix of aerosols, whether from natural events or from anthropogenic ones like emissions from fossil fuel burning, tends to alter the types and numbers of clouds which appear in that region or downwind of it. Changes to clouds alter solar energy input via an altered albedo, alter precipitation patterns and alter the strength of the greenhouse effect. These changes affect large areas but are not uniform on a global scale. One area might be more clouds, another fewer and another changed abundance of high altitude clouds. Such changes impact climate in important but complex ways. Global dimming may also be interfering with the water cycle. Less sunlight upon water (especially the oceans) leads to a diminished evaporation rate. This may be responsible for droughts in some regions. The increase in incident radiation, in combination with a growing greenhouse effect from the continuing emissions of greenhouse gases, may lead to an accelerated rate of global warming. It can also be stated that "more aerosols mean more clouds and greater albedo and hence less light at the surface and thus cooling".

4.0 Conclusions

The present study concludes that aerosols emitted from coal based thermal power plant can hamper the light scattering and there by affect the energy budget of the earth surface and can influence the climatic change. It might be played a great role in cloud formation or diminishing the condition of cloud formation because of its chemical composition and reaction in the upper atmosphere. The percentage of O_2 and CO_2 were ranged from 11.4–19.2% and 10.0–13.8% while, the concentration of CO and hydrocarbon (HC) range from 71–159 ppm and 310–514 ppm. It was observed that the higher percentage of chemical compound (SiO_2: 57.80% and 62.24%; Al_2O_3: 19.90% and 21.50%; Fe_2O_3: 8.80% and 9.20% respectively in coal and coal fly ash). SO_2 reacts with other substances to produce sulfate aerosol. Detail climatic research is envisaged to understand the mechanism of positive or negative role of aerosols in coal power plant which are different from the natural aerosols. Though it's a multifarious phenomenon but definitely the particulate matter, oxides of sulphur and nitrogen are three major players in climate change, global warming and cloud formation.

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References

1. Annual Report on Fly ash utilization, Central Electricity Authority India, (2014) cea.nic.in/reports/annual/annual reports/annual_report-2014.

2. Kisku GC, Yadav S, Sharma RK, et al. (2012) Potential environmental pollution hazards by coal based power plant at Jhansi (UP) India. Environ Earth Sci 67: 2109-2120.

3. Forster PMD, Taylor KE (2006) Climate forcing and climate sensitivities diagnosed from coupled climate model integrations. J Climate 19: 6181-6194.

4. Zhuang G, Yi Z, Duce RA, et al. (1992) Chemistry of iron in marine aerosols. Global Biogeochem Cyc 6: 161-173.

5. Aerosols, Cloud Nucleation and Global Dimming available at [http://www.windows2universe.org/ earth/ Atmosphere/ aerosol_cloud_nucleation_dimming.html].

6. Markandeya, Shukla SP, Kisku GC (2016) A clean technology for future prospective: emission modeling of gas based power plant. Open J Air Poll. 144-159.

7. Chung C, Ramanathan V, Kim D, et al. (2005) Global anthropogenic aerosol direct forcing derived from satellite and ground-based observations. J Geophys Res 110: D24207.

8. Kamra AK, Singh D, Pant V (2009) Scavenging of atmospheric ions and aerosols by drifting snow in Antarctica. J Atm Res 91: 215-218.

9. Maricq MM (2007) Chemical characterization of particulate emissions from diesel engines: A review. J Aeros Sci 38: 1079-1118.

10. Gramotnev DK, Gramotnev G (2005) A new mechanism of aerosol evolution near a busy road: fragmentation of nano-particles. J Aeros Sci 36: 323-340.

11. Talukdar SS, Swihart MT (2004) Aerosol dynamics modeling of silicon nanoparticle formation during Silane pyrolysis: a comparison of three solution methods. J Aeros Sci 35: 889-908.

12. IS: 11255 (Part-I Particulate Matter) (1985) Methods for measurement of emissions from stationary sources.

13. Tiwari M, Shukla SP, Mohan D, et al. (2015) Modified Cenospheres as an Adsorbent for the Removal of Disperse Dyes. Advan Environ Chem.

14. Kisku GC, Markandeya, Shukla SP, et al. (2015) Characterization and adsorptive capacity of coal fly ash from aqueous solutions of disperse blue and disperse orange dyes. Environ Earth Sci 74: 1125-1135.

15. Sarkar A, Rano R, Udaybhanu G, et al. (2006) A comprehensive characterization of fly ash from a thermal power plant in Eastern India. Fuel Proc Tech 87: 259-277.

16. Prasad B, Banerjee NN, Dhar BB (1996) Environmental assessment of coal ash disposal: a review. J Sci Indus Res 55: 772-780.

17. Koukouzas NK, Zeng R, Perdikatsis V, et al. (2006) Mineralogy and geochemistry of Greek and Chinese coal fly ash. Fuel 85: 2301-2309.

18. Andreae MO, Gelencser A (2006) Black carbon or brown carbon? The nature of light-absorbing carbonaceous aerosols Atm. Chem Phys 6: 3131-3148.

Citation: Markandeya Tiwari (2017) Role of Aerosols in Climate Change and Cloud Formation Emitted from Coal Based Power Plant. SF Drug Deliv Res J 1:1.