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Smoke Pollution Control System

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Abstract

Coal is the primary fuel for electricity generation in India and its usage is continuously increasing to meet the energy demands of the country. This paper presents emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitric oxide (NO) from thermal power plants in India The emission estimate are based on a model in which the mass emission factors are theoretically calculated using the basic principles of combustion and operating conditions. Future emission scenarios for the period up to 2020-21 are generated based on the estimates combustion technologies and operating conditions. Computed estimates show the total CO_2 emissions from thermal power plants have increased from 323474.85 Gg for the year 2001-02 to 498655.78 Gg in 2009-10. SO_2 emissions increased from 2519.93 Gg in 2001-02 to 3840.44 Gg in 2009-10, while NO emissions increased from 1502.07 Gg to 2314.95 Gg during this period. The emissions per unit of electricity are estimates to be in the range of 0.91 to 0.95 kg/k Wh for CO_2, 6.94 to 7.20g/k Wh for SO_2, and 4.22 to 4.38 g/k Wh for NO during the period 2001-02 to 2009-10. The future emission scenario, based on the projected coal consumption in Indian thermal power plants by planning Commission of India under 'Business-as Usual (BAU)' and " Best case Scenario (BCS)' show the emission in the range of 714976 to 914680 Gg CO_2, 4734 to 6051 Gg SO_2 and 366 to 469 Gg NO in the year 2020-21. Increase in coal use efficiencies in electricity generation by thermal power plants can significantly reduce the emissions of greenhouse and polluting gases..

Air pollution – Fossil fuel power station and other plants which used coal boiler they release CO_2, $S0_2$, NO, and other air micro pollutants. These air pollutants thats particulates, biological molicules or other harmful micro particles spread into Earths atmosphere causing diseases and slow death of humans, damage to other essentials living organisms such as food crops or the naturallity or environment. Air pollution may come from anthropogenic or natural sources.

Stratospheric ozone depletion due to air pollution has been recognized as a threat to human health as well as a threat to the ecosystem of the earth. Photochemical smog results from large amount of coal burning in an area caused by a mixture of smoke and sulphur dioxide, carbonmonoxide, CO_2, nitrogen oxide, nitrogen dioxide etc. Acid rain has caused major problems in lakes throughout the India and the world. These pollutants are spread very harmful gases for ozone layer which controlled accurate atmospheric temperature and save the Earth from alnino effect. The alnino effect very serious problem to our planet. Alnino changes the atmospheric contaminations and weather cycle or climate of the Earth. About 60 % coal based thermal power plant station running in india at present.In this system controlling of air pollution with water pollution both, smoke pollution which developed by chimneys of coal based thermal power plants, process houses and other plants which used coal based boilers to steam generation as well as polluting water from these plants. So this air pollution creates lungs problems and water pollution creates skin and other many more diseases for humans. This system control hazardous gases, micro particles of smoke and pollution of water from one system. So in this system used a large amount of heat to vaporization of polluted water. This heat add a large amount of heat and increase atmosphere temperature. This system controlled easily pollution air and water both.
The heat captured by water and vaporization start after some time the heat of smoke diluted by many types of particles in twice set of well. In this well crash the smoke by polluted water rapidly. Well contains a pipeline to send to smoke in the bottom. So collected smoke from direct boiler and send by motorized system into the well. The motor has coupled with a heavy duty blower with regulator for synchronization of speed. The baffle plates fitted on the pipeline. The baffle plates has many opposite countersunk holes with different sizes. The baffle plates outer dia matched with inner dia of well. Baffle plates fitted on the pipeline for three to seven stages to crashed smoke properly. Then heat transferred from smoke to water. Then water changed into vapour and vapour collected This system strive to maintain responsible as the specialist solution and providing the most efficient.

Keywords: Emission Trends, Coal Combustions, Thermal Power Plant, Carbon dioxide, etc

Introduction

Emissions of greenhouse gases and other pollutants are increasing in India with the increasing demand for electricity. The aspiration for rapid economic growth leading to rapid industrialization coupled with accelerated urbanization and mechanization of agriculture has been responsible for this increasing demand of electricity ever since the independence. (www.eia.doe.gov, 2010) the growth of electricity generation and usage in India and China during the period 2000 to 2008 based on the EIA (www.eia.doe.gov, 2010) data. (www.powermin.nic.in

Coal is the favorite fuel for the electricity generation in countries like India and China. Abundant supply of coal locally sustained high prices for imported natural gas and oil make coal-fired generation of electricity more attractive economically. Coal is approximately 90% of the total fuel mix for electricity generation. Main emission from coal fired and lignite based thermal power plants are CO_2, NO_x, SO_x, and air-borne inorganic particles such as fly ash, carbonaceous material (soot), suspended particulate matter (SPM), and other trace gas species. Thermal power plants, using about 70% of total coal in India. (Garg et. al., 2002), are among the Large Point Sources (LPS) having significant contribution (47% each for CO_2 and SO_2) in the total LPS emission in India.

Only limited efforts (Chakraborty et al., 2008) have been made so far for measuring the plant specific emission of different gases and particulate matter in India to generate plant specific emission factors. The IPCC default emission factors, used in Indian inventory estimation, represents the average of available emission values using the similar fuel and technical processes under similar national circumstances and do not account for Indian coal characteristics or the operating conditions at the various thermal power plants in India.

A time stories of emission trends of CO_2, NOx, and SO_x from the Indian coal fired and lignite based thermal power plants over a decade (2001-02 to 2009-10) is presented here. Eighty six power plants with total installed capacity of 77682 MW are considered in this analysis for which required input data was available from Central Electricity Authority of India (CEA). These plants represent about 76% of the total installed capacity of thermal power plants in India. As of March 2010, there are 105 thermal power plants in India of more than 100 MW capacity each, with total installed generation capacity of 93772 MW. As per the CEA (www.cea.nic.in, 2011).

There is a need modernize India’s thermal power plants and reduce the coal usage per unit of electricity generation (kg/k Wh). Modernization with reduction in coal usage (kg/k WH) will help in reducing the national emissions. Quality of Indian coal will remain same but with the improvement in combustion technologies, emissions can be reduced. (USAID/TVA/NTPC 2000).

The combustion process of the pulverized coal in the boiler is a complicated non-linear phenomenon. The pollutants emitted from thermal power plants depend largely upon the characteristics of the fuel burned, temperature of the furnace, actual air used, and any additional devices to control the emissions. At present, the control devices used in thermal power plants in India is electrostatic precipitator (ESP) to control the emission of fly ash (SPM). Some new plants use low NOx burners for high temperature (>1500 K) combustion technologies and dry/wet SO_2 scrubber, if chimney height is less than 275 meters. Mass emission factors for CO_2, SO_2, and nitric oxide (NO) are computed based on the input data, such as chemical composition of the coal used at the power plants and the actual air used during combustion. These calculations are based on theoretical ideals and do not take account for the control devices. Indian coal generally has low sulfur contents. The operative combustion temperature is assumed to be 1200 K.

Carbon Dioxide and Sulfur Dioxide

From the elemental analysis of the coal, the percentage of carbon, hydrogen, nitrogen, oxygen, ash, and moisture in the coal is known. Let C be the mass of the carbon, S of the sulfur, H of the hydrogen, O_2 of the Oxygen, and N_2 of the nitrogen, then Oxygen (Or) required to burn one kilogram (kg) of coal =

$O_r = C*(32/12) + H*(16/2) + S*(32/32)-O_2$ (1)

Air mass required for Or Kg of oxygen = (O_r/mass fraction of O_2 in the air)

= O_r /0.233 (2)

If E is the percentage of excess air used in the furnace to burn the coal,

the air mass used = Air (used) = (1+E)* O_r /0.233 (3)

Knowing the air mass used to burn one kg of coal, mass of O_2 and N_2 are calculated as

O_2 in the air used = (1+E)* O_r (4)

N_2 in the air used = 0.767* (1 +E)* O_r /0/233 (5)

Mass of CO_2, SO_2, NO, and H2O are calculated by mass balance as

$CO_2 = C*44/12$ (6)

$SO_2 = S*64/32$ (7)

$H_2O = H*18/2$ (8)

Oxidation of Nitrogen

Oxides of nitrogen ($NO_{x)}$ are nitrous oxide (N_2O), nitric oxide (NO), and nitrogen dioxide (NO_2). The formation of NO_x during coal combustion is a complex process involving both homogeneous and heterogeneous reactions. Most (about 90% or higher) of the NO_x emitted during combustion process is in the form of NO. No is formed by oxidation of (i) atmospheric nitrogen, known as ‘thermal NO’ and (ii) chemically bound nitrogen within the fuel matrix, known as ‘chemical NO’. Formation of ‘thermal No’is temperature sensitive whereas formation of ‘ chemical NO’ is insensitive to temperature and occurs on a time scale comparable to that of combustion reactions. A kinetic model is needed to describe the detailed mechanism of the formation of NO in flames and the prediction of No concentration in combustion products. Emission of NO varies widely with boiler conditions and is generally function of flame temperature, excess air or concentration of oxygen in the system, percentage of boiler load, nitrogen content in the coal, and rate of gas cooling. The actual mechanism, whereby atmospheric nitrogen is oxidized, goes through a complex chain of reactions initiated by oxygen atoms.

Generally accepted principle reactions (Zeldovich, 1946) for ‘thermal No’ formation are

$O + N_2 = NO + N$ (09)

$N+O_2 = NO + O$ (10)

$N+OH = NO + H$ (11)

A kinetic model is beyond the scope of present analysis. Present estimates give the equilibrium concentrations of NO assuming long residence as found in large boilers. The oxidation of nitrogen is represented by the overall balance (Hanby, 1994).

$N_2 + O_2 = 2\ NO$ (12)

A simple stoichiometric calculation gives the equilibrium NO concentration as

$X_{NO} = K_{10.1}(X_{N2})^{0.5} (X_{O2})^{0.5}$, (13)

Where X is the species concentration and K10.1 is is an equilibrium constant that depends upon the temperature of the gas. At 1200 K, K10.1 = 0.00526, [13] (Hanby, 1994).

Characteristics of the Indian Coal

Indian coal has the general properties of the southern Hemisphere Gondwana coal, whose seams are inter-banded with mineral sediments. Run-of-mine coals typically have high ash content (ranging from 35-50%), high moisture content (4-20%), low sulfur content (0.2-0.7%), and low calorific values (between 2500-5000) kcal/kg, which is much less than the normal range of 5000 to 8000 kcal/kg. The calorific value of the Ohio (USA) coal is 6378 kcal/kg and that of the Logn Kou (China) is 6087 kcal/kg[14] (Visuvasam et al., 2005). The design rating of a coal-fired burner in USA is at 6214 kcal/kg. The low calorific value implies more coal usage to deliver the same amount of electricity. The high ash content also leads to technical difficulties for utilizing the coal, as well as lower efficiency and higher costs for power plants. some specific problems with the high ash content include high ash disposal requirements, corrosion of boiler walls and fouling of economizers, and high fly ash emissions.

Indian coal is classified by grades[15] (Coal Atlas of India, 1993) defined on the basis of useful Heat Value (HUV), which is derived from the empirical relation of moisture and ash contents of coal.Indian coal is mostly of sub-bituminous rank, followed by bituminous rank and lignite (i.e.brown coal).The average net calorific Value (NCV) for the Indian the Indian coal is estimated to be 19.63 tera-joules/kilo-tons(INCCA, 2007). Elemental analysis of D, E, and F grade coal (personal communication from central Institute of Mining and Fuel Research (CIMFR), Jharkhand, India).

Emissions Estimates

The present (as on March, 2010) capacity for electricity generation from coal and lignite-based thermal power plants in India (including private and captive power plants) is 93772 MW. Based on the information from Central Electricity Authority10 (CEA, 2010) for the 86 coal and lignite-based power generation capacity of 19164.5 (MW), Western region has 27 plants with a total of 30225.0 (MW) capacity, Southern region has 13 plants with a total of 9962.5 (MW) capacity, and the Eastern region has 24 plants with a total of 18330.0 (MW) capacity. The total capacity (77682 MW) of the the 86 plants represent about 85% of the total installed capacity in India.

Carbon dioxide Emissions

CO_2 emissions are estimated based on the carbon content as obtained from the elemental analysis of the coal and the excess air used at the power plants. A small percentage of the carbon in the coal remains un-burnt due to factors, such as reactivity of the coal particles, milling, air to fuel ratio, flame turbulence, fuel residence time etc.A small portion of the un-burnt carbon goes with the fly ash (FA) and the remaining un-burnt carbon goes in the bottom ash (BA). Exact portion of un-burnt carbon can only be determined by experimental measurements. There are a few studies (Bartonova et al., 2011; Mandal, 2008; Sathynathan and Mohammad, 2004)[16, 17, 18] to estimate un-burnt carbon in coal ash.

Depending upon the combustion condition and the fuel, un-burnt carbon varies from 0.5% to 10% in FA and 2% to 30% in BA. It is difficult to get the measurement data for un-burnt carbon at each plant, and hence, this analysis is based on the available information (obtained as personal communication from the site visits of the plants). It is assumed that 10% un-burnt carbon mixes with the BA and 2% un-burnt carbon remains in the FA.

Sulfur dioxide Emissions

SO_2 emissions from coal combustion mainly depends on the sulfur content in the coal unlike the emission of CO_2 and NO which depends on the operating conditions and the design of the plant. Sulfur content in Indian coal is much lower compared to the coal in the United States. coal used in power plants in India the sulfur content as less than 0.5% compared to 1.8% sulfur content in USA (Ohio) coal[14] (Visuvasan et. al., 2005), though lignite has higher sulfur content. Acid rain by SO_2 emissions is presently not observed but may become a problem in future with increasing use or blending of Indian coal with imported coal of higher sulfur content. Power plant combustors operate at temperatures usually around 1200 K. These temperatures are above the thermal decomposition temperature of calcium sulfate, it does not serve as a sulfur retaining agent. The small amount of sulfur found in power plant coal ash is of no practical significance in reducing SO_2 emissions to the atmosphere[23] (Rees et al., 1966). Hence in these estimates all the sulfur in the coal is considered to have been converted to SO_2. Table 4A shows the region wise estimates of SO_2 emissions from thermal power plants in India assuming that no control technology is in use.

Annual SO_2 emissions have increased from 2.5 million tons in 2001 to 3.8 million tons in 2009 at an average annual rate of 169.39 thousand tons per year. Lignite fuel has higher sulfur content and hence Western region and the Southern region which have lignite based power plants show higher SO_2 emissions. The national average based on the 86 power plants is 8.04 g/kWh. Chowdhury et al. (2004)24 have given an average emission factors for SO_2 emission as 8.7 g/kWh (range 5.21-15.99 g/kWh). Chakraborty et al.(2008)5 measured SO_2 emissions in the range of 7.445-8.763 g/kWh for plants of the 250 MW capacities.

Emission of oxides of Nitrogen

The formation of No is influenced by the concentration of oxygen (which depends on the excess air) in the system and the flame temperature. NO emissions are estimated based on equilibrium reaction calculated at an average gas temperature of 1200 K. This is a theoretical ideal.In reality the gas temperature in the boiler varies from 1000 K to 2500 K and the reaction also occurs in several phase..

Results and Discussions

Emissions from thermal power plants are influenced by many factors. CO_2 and SO_2 emissions are influenced by the chemical composition (Particularly carbon and sulfur content) of coal and the coal usage per unit of electricity. NO emissions are influenced by the excess air used during combustion and the coal usage.

Coal combustion in power plants is a complex phenomenon. Formation of the heat and other by-products like pollutant gases go through many complex non-linear processes. Present analysis gives theoretical estimates of emissions of CO_2, SO_2 and NO based on ideal conditions. Assumptions involved in these estimates introduce many uncertainties including the non-availability of the exact input data. Due to differences in assumptions, some discrepancies are expected between present estimates and measurements of emissions based on IPP's emissions factors.

Emission Trends

Two scenarios are generated for future emission trends. (1) PC-BAU scenario is based on coal consumption projected by planning commission of India in 2020 for thermal power generation under business-as-usual (BAU) scenario (scheme 1) ; and (2) PC-BCS scenario is based on future coal consumption projection for thermal power generation in India in 2020 by Planning Commission of India under best case scenario (BCS) (Scheme 2). Under BCS, the electricity generation from coal and lignite based power plants will taper off to approximately 650000 GWH while under PC-BAU scenario, electric power generation from coal and lignite based power plants will continue to grow and is expected to rise as 950000 GWH by the year 2020-21.

Conclusions

This study provides a viable "bottom-up" methodology for the development of emission control of different trace atmospheric species from coal combustion in thermal power plants in India for which measured emission factors are still sparse.Thermal power plants vary widely in design and operating conditions and hence it is relatively cumbersome to develop plant specific emission factors by measurements. There is a wide diversity between plants for coal usage (kg/kWh), coal quality, and the operating conditions. Hence there are large differences in emission factors (g/k/Wh) of CO_2, SO_2, and NO as shown earlier. This is the first study which gives the emission from 86 operational thermal power plants with future trends nationally.

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