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ENVIRONMENTAL ISSUES OF THERMAL POWER GENERATION AND ITS CONTROL MEASURES

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ABSTRACT

Coal dominates the country's economy accounting for meeting more than 50% of the commercial energy requirement in India. Since industrialization started and further expansion took place the demand for energy has increased three fold especially during last two decades. Environmental problems existent in our society can be traced back to the use of energy in one way or the other. Our environment is under tremendous pressure due to ever-increasing urbanization and population growth. Major portion of the electricity generated in our country is coal-based. There is a huge reserve of coal in our country. Coal is very easily and cheaply available and so used extensively for thermal power generation.

This paper is an attempt to address almost all the environmental issues i.e. impacts on air, water, soil, land use pattern and aesthetic of the area, attached with the thermal power station at one platform and also make the people, directly or indirectly associated with these thermal power stations, aware of the various issues. Some control measures for the impacts have also been presented from safety point of view

Keywords: *Environmental Issues, Thermal Power Stations, Mitigative Measures, Ash Generation.*

INTRODUCTION

In India, coal/lignite based thermal power stations account for more than 65% of the installed capacity of electricity generation and 70% of electricity generation (Kumar, 2003). There are more than 80 utility thermal power stations, besides several captive power plants that use bituminous and sub-bituminous coals and produce large quantities of coal combustion residues (CCRs), i.e., fly ash, bottom ash, etc. Indian coals are characterized by high ash contents to the tune of 30-55% (Kumar, 2003), which is the main reason for such a huge amount of CCR generation.

India has coal reserves of 308.801 billion tonnes, as per the exploration carried out by the Geological survey of India up to the depth of 1200 m as on April 1, 2016, which is enough to meet country's requirement for 100 years at current extraction and consumption rates. Out of the total reserves of coal 44.72% is in the proven category, 45.06% in the indicated category and 10.22% in the inferred category (Inventory of Coal, 2016). India is the fourth largest producer of coal and lignite next to US, China and Australia and its coal reserves comprise 6.8% of the world's total reserves (British Petroleum, 2016). Compared to the world production, India accounted for 7.2% of world total production in 2015 (British Petroleum, 2016). Table 1 gives the type-wise and category-wise coal reserves of India as on 01.04.16. Table 2 gives the power generation in the country from 1994-95 to 2015-16.

Table 1: Type-wise and Category-wise Coal Reserves of India as on 01.04.2016(in MT)

Coal Type	Proven	Indicated	Inferred	Total
Coking	18485.41	13815.95	2101.15	34402.51
Prime coking	4614.35	698.71	0.00	5313.06
Medium coking	13388.90	12113.56	1879.47	27381.93
Semi-coking	482.16	1003.68	221.68	1707.52
Non-coking	119007.98	125235.58	28663.13	272906.69
Tertiary Coal	593.81	99.34	799.49	1492.64
Total	138087.20	139150.87	31563.77	308801.84

(Source: Inventory of Coal: http://www.cmpdi.co.in/coalinventory.php)

Table 2: Year-wise Power Generation (1994-95 to 2015-16)

Year	Generation (BUs)	% of Growth
1995-96	380.00	8.26
1996-97	394.00	3.68
1997-98	420.00	6.60
1998-99	448.00	6.67
1999-00	480.00	7.14
2000-01	499.45	4.05
2001-02	515.27	3.17
2002-03	531.00	3.05
2003-04	558.34	5.15
2004-05	587.30	5.19
2005-06	617.50	5.14
2006-07	662.50	7.29
2007-08	704.50	6.34
2008-09	723.80	2.74
2009-10	771.55	6.60
2010-11	811.14	5.13
2011-12	876.89	8.11
2012-13	912.06	4.01
2013-14	967.15	6.04
2014-15	1048.67	8.43
2015-16	1107.82	5.64

Sources: TEDDY 2009-10; Kumar, 2009 & 2015; http://powermin.nic.in/en/content/power-sector-glance-all-india.

Table 3 gives the data related to coal reserves, production and consumption and electricity generation in the world in the year 2015 and this is compared with the data of 2014 and presented as change 2015 over 2014.

Table 3: Status of World Energy in 2016

Energy	2015	Change 2015 over 2014 (%)
Electricity		
Generation (TWH)	24097	0.9%
Coal		
Reserves (MT)	891531	-
Production (MT)	7861.1	-4.0
Production (MT of oil equivalents)	3830.1	-4.0
Consumption (MT of oil equivalents)	3839.9	-1.8

Source: British Petroleum, Statistical Review of World Energy, 2016 (www.bp.com)

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ENVIRONMENTAL ISSUES

Energy production and utilization involves a disturbance to the state of the environment. Coal to be used for power generation is obtained from mining process that leads to land degradation, subsidence, loss of forest areas, etc. The utilization of this coal for the power generation results in the generation of huge quantity of coal combustion residues. India stands second only to China in the quantity of coal combustion residue generated every year. Of the total coal combustion residue generated 90% is disposed off to ash ponds in slurry form, which requires huge amount of water. Disposal of such a huge amount of coal combustion residue is a big problem as it not only demands for huge tract of land, which could otherwise be used for agricultural, or other economic purposes but it also results in the creation of wasteland and could also lead to leaching of heavy metals and soluble salts. Leakage from ash ponds to neighboring fields and water bodies can lead to surface and ground water pollution. Beside these problems, air pollution is yet another problem associated with the power generation using coal as a raw material.

The environmental issues associated with the thermal power generation include:

- Impacts due to air pollution
- Impacts due to water pollution
- Noise Pollution
- Thermal Pollution
- CCRs generation and
- Impacts on soil quality

These are discussed in brief below.

Impacts due to Air Pollution

Air Pollution from Indian coal-fired thermal power plants is yet major aspect, which requires utmost attention. This problem is basically related to the combustion of coal ingredients. The amount of trace elements emitted from a coal-fired power plant will depend mainly on the initial trace element concentration in coal. Besides this, combustion engineering and pollution control at the plant are other deciding factors.

Coal contains carbon, hydrogen, mineral matter, nitrogen, sulphur and moisture. During combustion and in the presence of sufficient oxygen, the products of combustion mainly include CO_2 and H_2O besides releasing CO, NO_x, SO_2 and fly ash and enough energy. In a situation of incomplete combustion, the reaction may not proceed to completion and may result in the formation of carbon, hydrocarbons, etc. The incombustible mineral matter ash may contain some carbon, if carbon conversion is not completed. Thus, different combustion processes yield different primary emissions.

The worst environmental impact of SO_X is the occurrence of acid rain and in case of NO_X is greenhouse effect and the possible formation of photochemical smog. Furthermore, NO_X has a global warming potential of 270 times more compared to CO_2.

These coal combustion residues (mainly fly ash) easily get air borne and have a high residence time. They cause poor visibility, respiratory problems and reduced silted fodder diet by the animals. For people living close to the plant sites, the presence of ash particulates in the atmosphere is a matter of great concern. This is especially so in summers due to the presence of high wind speeds. The finer fraction (<1 µm) of fly ash is potentially harmful as they get deposited in lungs/pulmonary tissues of respiratory tract when inhaled. These fly ash fractions are in fact found to be the most mutagenic and carcinogenic.

Impacts due to Water Pollution

This is yet another matter of great concerns because of disposal of coal combustion residues on land, which may several toxic trace elements to the soil. To understand the situation better, it is necessary to understand the factors, which determine the environmental mobility, and, in particular, the potential for ground water contamination and propensity for biological uptake. Recently, in this regard, much emphasis has been placed on measuring the chemical species of trace/heavy elements in environmental samples. It is believed to play a major role in determining the behaviour of the elements (Florence, 1986).

Much concern is there due to leaching behaviour when the ash is contact with water resulting in enrichment of aquatic environment with trace/heavy elements. Ground water is more prone to contamination compared to surface water mainly on account of accumulation of leached elements in the ground water. Due to low velocity and low permeability, not only more soluble sublimates on the surface of the ash particles but also the long-term dissolution of the glassy particles, which are unstable under natural condition, is expected to influence the ground water and soil environment (Mehmet et al., 2001, Lui and Yang, 2000b).

Mandal and Sengupta (2005) studied environmental implication of ash disposal and its effect on the water quality in and around Kolaghat Thermal Power Station. Water samples from different tube wells were collected and studied for radionuclide and trace element contamination. The study revealed high concentration of trace elements in the water samples of tube wells. Elements such as Al, Li, As, Zn, Ag, Sb, Si, Mo, Ba, Rb, Se and Pb were observed at higher concentration in the tube wells water near ash ponds, which imply that significant input from the ash pile has taken place. Some of the elements for example, Al, Fe, As and Mn were found above the WHO guidelines for drinking water denoting significant contamination of groundwater from the trace/heavy elements leached from the ash pile.

In thermal power plants water is required in huge quantity for various processes. The used up water is discharged into the neighbouring environment. Not only this, the present trend in most of the thermal power plants is to dispose of fly and bottom ash in wet slurry form to nearby ash ponds where ash settles and clear water is allowed to overflow. Ash disposal ponds are the primary source of groundwater pollution at power plants. Under past and present practice, coal-fired power plants frequently use one or more ponds, either in series or in parallel operation to treat or dispose of fly ash, bottom ash, flue gas, desulphurization sludge and other wastes generated within the plant. Both vertical and lateral seepage may occur at ponds. Due to leaching characteristics of ash, water and contaminants leaching into the ground are deposited in the soil over time and may move down through unsaturated sections of the soil until they reach ground water. Pollutants that reach ground water or are transported through the aquifers and may also subsequently be transferred into the surface water bodies. In fact, most coal-fired power plants are located near a significant source of surface water because of large volume of water necessary for plant cooling operations. For example, of the 21 coal fired power plants that were operating in Kentucky in 1989, all were located next to water bodies and most were situated along major rivers. Once the leachate enters the water bodies and accumulates up to significant levels, it may become a serious environmental threat. This leaching of trace/heavy elements from CCRs causes surface and ground water pollution and thus, affects human and aquatic life.

In India there is a great concern for trace/heavy elements contamination of surface and ground water due to leaching from the huge ash ponds situated in and around the water resources of the country. Accumulation of these residues in ponds for long makes the ground water vulnerable to metal contamination due to leachate percolation. There was no systematic study in the country with regard to leaching of trace/heavy elements from CCRs. The author in his PhD work carried out long-term leaching study for the first time in order to understand the leaching potential of trace/heavy elements from CCRs of different power plants.

Impacts due to Noise Pollution

This is yet another matter of great concerns because of the heavy noise that the workers are exposed to. In fact, noise pollution is a type of energy pollution in which distracting, irritating, or damaging sounds are freely audible. As with other forms of energy pollution (such as heat and light pollution), noise pollution contaminants are not physical particles, but rather waves that interfere with naturally-occurring waves of a similar type in the same environment. Thus, the definition of noise pollution is open to debate, and there is no clear border as to which sounds may constitute noise pollution. In the narrowest sense, sounds are considered noise pollution if they adversely affect wildlife, human activity, or are capable of damaging physical structures on a regular, repeating basis. In the broadest sense of the term, a sound may be considered noise pollution if it disturbs any natural process or causes human harm, even if the sound does not occur on a regular basis.

At thermal power stations lots of heavy machineries operate which makes communication between the workers very difficult. Long exposure to such heavy noise affects the workers health adversely.

Impacts due to Thermal Pollution

Nuclear, natural gas, and coal power plants inject heated water into rivers, raising temperatures above normal. This heat pollution can cause a devastating change in river ecology. Other pollutants are injected each time a plant cleans and flushes its cooling system. Coal-fired power plants pollute the air with mercury, which eventually falls on the land and runs off with rainwater, entering streams and poisoning the animals in them--as well as the fishermen who catch and eat their fish. Nuclear power plants must store their radioactive and other toxic wastes, which eventually leak into water tables and enter streams.

Waste Heat

A pollutant as dangerous to waters as more tangible of forms of waste Human activity can change normal temperature: By altering environment of watercourse: road building, logging, impoundments, diverting flows for irrigation adding or removing heat. On national scale, industrial cooling waters are a first-order source of heat. Electro power generation uses 80% of cooling waters. Best single index of thermal pollution lies in projecting future electric power generation. Past experience has indicated that thermal pollution has not multiplied as fast as power generation because of improvements in thermal plant efficiency and development of hydropower. Nuclear plants - waste even higher proportion of heat than fossil-fuel plants. Heat rejection is expected to increase nine fold by the year 2000. Problem is one of managing tremendous amounts of waste heat in a manner that will maintain or enhance physical, chemical and biological nature of our water resources.

Coal Combustion Residues Generation

When one looks into the various sources, coal is the most economical source of energy for industrial development. India has diverse quality of coal reserves, which contain 30-55% ash. These coal when used for power generation results in the generation of huge quantity of coal combustion residues (CCRs). There are more than 100 thermal power stations in India generating coal combustion residues (CCRs) of which 80% are fly ash. Annual production of CCRs has already crossed 130 MT and with the present rate of growth (8-10%) of power generation it is expected that this figure would be 175 MT by 2020 (TEDDY 2014/15).

The quantum of CCRs generated in India is a matter of great concern. Of the total coal combustion residues generated, only approximately 57% is being utilized (TEDDY 2014/15). Utilization, which was around 1% in 1994, has shown a sharp increase in two decades. However, the 56% utilization is still low as compared to more than 50% utilization in some other countries. One of the main reasons for its improper utilization in India is its poor availability in usable forms and lack of characterization of coal combustion residues generated from various thermal power stations.

Impact on Soil Quality

During combustion, trace elements get more associated with the surface of ash particles due to evaporation and condensation and as a result of carbon loss as carbon dioxide. Hence, disposal of CCRs in the terrestrial ecosystem has been regarded as a potential source of trace elements in the ash particles (Hassett, 1994).

Several field investigations have been carried out in recent years to assess the magnitude of atmospheric trace elements deposition from power plants. In their study Klien and Russel (1973) claimed that soils around a power plant were enriched with Cd, Co, Cr, Cu, Hg and Ni with concentration trend reflected in the prevailing wind pattern. In another study Jena and Singh (1993) revealed the presence of many toxic elements in the soil horizons around the thermal power plant.
Joworoski and Grzybowska (1997) found that the surface soils from industrial areas in Poland reportedly contained increased U and Th concentrations compared to the rural regions. The reason given was the presence of power plants. Similarly, Marten (1971) reported elevated concentrations of Ra, Th and U in air 6 km downwind of a coal power plant.

Around Nevada Power Plant, which burns coal containing high As (>50 μg/g), plants and soils downwind of the power plant were found to be markedly enriched in As (Berry and Wallace, 1974). With the hazard of As transfer to the people from the milk of cows feeding in the area.

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Greater solubility of elements in fly ash compared to soil not only increases biological availability and potential for bio-accumulation, but also lead to greater mobility, resulting in rapid passage through the soil. Van Hook (1978) considered that microbial soil processes are particularly susceptible to small increments in trace elements deposition, as microorganisms are in intimate contact with trace elements, being found in the immediate vicinity of soil particles. In a study conducted by Singh and Jena (1993) concentration of Cu, Ni, Pb, Co, Bi, Sb and Zn up to a depth of 90 cm was found in soil horizon around a thermal power plant. This was higher than that found in the top 30 cm thickness in the un-contaminated areas. This may prove hazardous for the crop generation capacity of soil as well as for the animals in the grassland near the power plant and human health, especially infants.

CONTROL MEASURES

Air Pollution
The control measures for air pollution includes the use of electrostatic precipitators, low NOx burners and flue gas stack.

Electrostatic precipitator: The ash left behind after combustion of coal is arrested in high efficiency Electrostatic precipitators (ESP) and particulate emission is controlled well within the stipulated norms. The ash collected in the ESP is disposed to ash ponds in slurry form. Emission standard as per World Bank for particulate matter is 50 micrograms per cubic meter (maximum).

Low NOx burner: NO_2 emissions are controlled by provision of low NO_2 burners and by adopting best combustion practices. Emission standard as per World Bank (in micrograms peer cubic meter) is 100 for NO_2 and 80 for SO_2.

Flue gas stack: Tall flue gas stack is provided for wide dispersion of gaseous emission (SO_2, NO_2 etc) into atmosphere. Stack height is given in meters and is different for different capacity thermal power stations. Stack height for 500 MW and above and 200 MW and less than 500 MW are 275m and 220m respectively.

Water Pollution
The source of liquid effluent include Cooling tower blow down, Boiler blow down, Power area service water waste, Water treatment plant waste, DM plant regeneration plant, CHP/AHP waste and Effluent from silo area. Besides this, leachates from the ash pond area are also likely to contaminate surface water and/or groundwater. The control measures for water pollution includes use of coal /oil settling pits, neutralization pits, ash dykes & disposal system, ash water recycling system and effluent treatment plant.

Coal & oil settling pits: In these pits, coal dust and oil are removed from the effluents from coal handling plant, coal yard and fuel oil handling areas before discharge into Effluent Treatment Plant (ETP).

Neutralization pits: Neutralization pits are provided in water treatment plant (WTP) for pH correction of effluents before discharge into effluent treatment plant (ETP) for further treatment and use.

Ash dyke disposal system: huge amount of ash generated during the process of power generation using coal as a fuel is mixed with water and in slurry form sent to the ash pond especially made for this purpose. Here ash particles settles and effluent water finds it's either to the surface water bodies and/or again used by the power plants after treatment and thus the requirement of fresh water is avoided.

Ash water recycling system: The effluent water from ash pond is circulated back to the power plant for further sluicing to the ash pond. This helps in savings of fresh water requirement for transportation of ash from the plant.

Effluent treatment plants (ETP): The objective of industrial liquid effluent treatment plant (ETP) is discharge clean effluent from the power plants to meet environmental standards and to reduce intake water requirement.

The scheme involves collection of various effluents and their appropriate treatment centrally and recirculation of the treated effluent for vvarious plant uses.

Leachate management from ash pond: Water entering the surface water from the disposal point of ash pond should be treated and then released. Similarly, some mitigative measures need to be taken to avoid any chance of contamination of groundwater from water entering from below the pond area.

Soil Pollution

Use of electrostatic precipitators has reduced the chances of particulate matter getting deposited on the soil surface and thereby contaminating it. Further, these particulate matters has got every chances of getting air borne in dry condition in ash pond and this way it can cause soil pollution. To prevent this ash in the pond is always kept wet.

Thermal pollution

Cooling towers are provided for cooling the hot condenser cooling water in closed cycle condenser cooling water system. This helps in reduction in thermal pollution and conservation of fresh water. Condenser outlet cooling water (once through) should not be more than 3 degree than intake temperature (World Bank standard)

Noise Pollution

The entire plant is so procured / installed that the resultant noise level within premises remains with standard limits. Standard (World Bank) for industrial area - 70 dB max outside the project property boundary.

Coal Combustion Residues

Ash ponds are provided for ash disposal. Ash ponds are divided into lagoonsν ν and provided with garlanding arrangements for change over of the ash slurry feed points for even filling of the pond and for effective of ash particles. Ash in slurry form is discharged into the lagoons where ash particle settled from the slurry and clear effluent water is discharge from ash ponds.

CONCLUSION

In this paper the environmental issues attached with the coal-based thermal power generation have been focused. The environmental issues have been elaborately discussed and control measures on such issues have been highlighted. It is believed that through eco-friendly management and integrated development practices, coal-fired thermal power stations can be changed to a centre of intense industrial activities. With such practice coal combustion residues can be made a useful raw material for variety of industries.

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