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A Mini Review on Coal Fired Thermal Power Plant and Health Effects

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Abstract - Half of the world population lives in the developing countries, where high pace urbanisation and population explosion given rise to huge demand of electricity and other natural resources. This resulted in increased air pollution and health related issues through the world. Fossil fuels and bio fuels are the primary source of fuel used in India for energy purposes. India is among the 10 most industrialised nations in the world and approximately 70-74% of total power generation is contributed by the thermal power plants. India is the third largest country in term of coal production, annual production of coal is about 250mt. The quality of Indian coal is poor, having high ash content and low calorific value. Thus burning of coal results in high fly ash generation with subsequent increase in air pollution compared with other factors. At present 132 thermal power plants are operational in India. Which results in generation of 120-150 million tonnes of coal fly ash every year and achieving 4th position in production of fly ash after USSAR, USA and China. This review article is a small approach to quantify the problem associated with coal burning.

Key Words: Thermal Power Plant; Air Pollution; Coal; Health Effects; Environment.

I. INTRODUCTION

Air pollution is the major problem faced by world and the sources for pollution ranges from burning fossil fuel, transportations, power generations, industries and domestic sectors. Air pollution is also derived from natural sources like dust storms, forest fires and volcano eruptions (Bulter et al. 2008; Gurjar et al. 2015). India is one of the fastest growing economies. To support this rapid growth in economy electricity is a basic requirement and coal is the basic source for electricity generation in India (Mukhopadhay and Forssel 2005; Sahu et al. 2009).

The quality of Indian coal is very low having high ash content and low calorific value. These properties of coal increase total fly ash content in the emission; contribute to environmental pollution and adverse health effects to the human (Mukhopadhay and Forssel 2005; Sahu et al. 2009). India is the 4th largest consumer of coal in the world and 5th largest generator of electricity (Parayas 2011 and Parayas 2013). To meet the growing energy demand, currently 132 thermal power plants operating in India and disposal of increasing amounts of coal ash is becoming a serious concern. Coal fried thermal power plant also produces various air pollutants such as particulate matter (PM_{10} and $PM_{2.5}$), sulphur dioxide, oxides of nitrogen, carbon dioxide, mercury, arsenic, chromium, nickel, hydrocarbons (PAHs) and other heavy metals in varying levels in the form of fly ash (Cropper et al. 2012). In the vicinity of thermal power plants exposure of emissions depends upon the factor such as weather (temperature, precipitation, wind direction and speed) and topographical features of the local area. Emission can also be transported to long distance even globally and causing health effects to those who lives at great distance from the thermal power plants. The pollutants emitted from the coal fired thermal power plant are responsible for the increased environmental burden of diseases (EBD) from solid fuel use (SFU: like combustion of coal and biomass) (Mattigod et al. 1990).

The utilization of fossil fuels has created various adverse effects on human health as well as on environment in a whole. The use of coal for the production of electricity has been shown to increase illness and

mortality in general population through air pollution. The coal emission created adverse health effects also depends upon factor like age, underlying medical conditions and their living habits. Children, the elderly, pregnant women and people with lung conditions like asthma and chronic obstructive pulmonary diseases are more vulnerable to adverse health effects created by air pollution. The present review provides information about how operation of thermal power plant releases various pollutants in the environment and release of these pollutants are responsible for onset of different types of health problems.

II. CHARACTERISTICS OF INDIAN COAL

Indian coal is very poor in quality having high ash content and low calorific value. The Indian coal has general properties that of southern hemisphere gondwana coal, which seems inter banded with mineral sediments. When Indian coal was burned in the power plants for power generation, it releases substantial high amount of fly ash which contribute to increased air pollution by thermal power plant **(**Bhangare et al. 2011). Therefore the intensity of pollutant released from the Indian coal fired power plant is more compared with other countries (GAINS 2010).

The high amount of ash content in Indian coal has been reported by researcher. Majority of Indian coal contains 35-50% of ash by its weight, low sulphur content about 0.2 to 0.5 % by weight and has high moisture content about 4-20%. According to study conducted by Garg et al. (2002), Indian coal contains 45% of ash by its body weight and 0.51% low sulphur. Reddy and Venkataraman (2002) reported that Indian coal contains ash amount of 39% of its body weight and 0.59% of sulphur.

In 1998 researchers from Ohio state university have conducted an analysis on Indian coal from five different thermal power plants. They have found that Indian coal on average has 39% of ash content and 0.48 % of sulphur in it. In the same year another study was carried out in eastern USA, which shows that the ash content of USA coal ranges from 7.5 to 20% and sulphur content 1.0 to 2.5 % when compared to Indian coal. The calorific value of Indian coal is in between 2500-5000 kcal/kg which is pretty low, when compared with calorific value of the USA coal (6378 kcal/kg). For these reason the USA thermal power plant consumes 0.45 kg of coal per KWh, in the same process Indian thermal power plant consumes 0.72 kg of coal per KWh (Chhikatpur 2008). According to ministry of coal report (2006), the coal obtained from open cast mines usually have large ash content and most of the coal obtain in India is from open cast mine. Therefore, Indian coal having high ash content and low calorific value greatly affects the efficiency of the thermal power plants and contributes to high amount of pollutants released in air, which pose a much greater threat to the human health including plants and animal (Prayas 2011; Bhattacharjee et al. 2013 a, b)

III. CURRENT SCENARIO OF INDIAN THERMAL POWER PLANT

To meet the ever growing energy demand of India, coal fired thermal power plant activity has rising substantially as per International Energy Agency (OECD 2007; Energy Statistics 2012). According to World Resource Institute report, 1200 new thermal power plants has been proposed globally, among them 76% are power plants are proposed to establish in China and India (Yang and Cui 2012). Ministry of Central Electricity Authority (CEA) Government of India (2011 and 2016) reported that most of the power generation in India comes from thermal power sector. To meet the growing demand power plant operation will increasing day by day in India and subsequently the consumption of coal for power generation will also increase.

The coal fired thermal power plant is a main focus area for generation of energy in India. Till 2016 there are 132 coal fired thermal power plant (TTP) present in different regions of India i. e. Eastern region, Western region, Northern and Southern region. Out of 132 thermal power plants (TPP), maximum numbers of power plants are present in western region i. e. 41 and minimum numbers of power plants are present in Northern region i. e. 27, whereas Eastern and southern region contribute 36 and 28 TPP respectively (**Table 1**). Total power generated from thermal power plants were 67029.01, 28892.87, 40493.50, and 30842.01 MW from western, Eastern, Northern and Southern regions in India, respectively (CEA 2016; IESS 2016). According to 2016 reports of central electricity authority (CEA 2016), the target amount of electricity generation in 12^{th} year plan (2012-2017) will be 72153.01, 30662.87, 45864.8 and 37042.00 MW from Western, Eastern, Northern and Southern region, respectively. The amount of coal consumption is about 278 MT in year 2004, which has increases up to 545 MT by the year 2015-16 (CEA 2016; IESS, 2016) (**Table 2**). As discuss earlier, Indian coal is very poor in quality having high ash content and low calorific value, therefore increase in consumption of Indian coal subsequently increases the generation of fly ash (waste) from thermal power plants. Whereas proper waste disposal method has not been adopted by the

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thermal power plants, which will lead to over burden of pollutant emitted from TTP. This over burden of fly ash is becoming a great issue in relevance to environmental pollution and related adverse health effect.

Table 1: The Central Electricity authority (CEA) reports 2016 the target amount of electricity will be generated till 12th year plan.

S.No		**Eastern**	**Western**	**Northern**	**Southern**	**Northeastern Region**	**Total**
1		Bihar Jharkhand West Bengal Odisha Sikkim	Goa Gujrat Mandhya Pradesh Maharastra Chhatisgarh Naveli Dadra And Nagar	Delhi Haryana Himachal Pradesh Jammu And Kashmir Uttar Pradesh Uttarakhand Chandigarh	Andhra Pradesh Telengana Karnatak Kerala Tamilnadu Puduchery	Arunachal Pradesh Manipur Meghalaya Tripura	
2	Number Of Power Plant	36	41	27	28		`132
3	Power Generation Capacity In (MW)	28,892.87	67,029.01	40,493.50	30,842.00		Total No. 167,707.88
4	Target Upto 12th Year Plan (2012-2017)in M	Total-30,662.87	Total-72153.01	Total-45864.8	Total - 37042.00	310.00mw	

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Table 2: Shows that Year wise coal consumption in (MT) and Fly generation from TPP.

Sr. No	Name Of The State	Number Of Thermal Power Plant	Year	Coal Consumption In MT	Fly Ash Generation In MT
1	Andhra Pradesh	3	2004-2005	278	3.6988
2	Bihar	3	2005-2006	281	3.1712
3	Chhatisgarh	11	2006-2007	302	9.637
4	Delhi	2	2007-2008	330	0.3528
5	Haryana	10	2008-2009	355	3.4587
6	Gujrat	5	2009-2010	267	2.222
7	Jharkhand	7	2010-2011	387	3.6583
8	Karnatak	4	2011-2012	417	2.3741
9	Madhya Pradsh	5	2012-2013	454	6.1773
10	Maharastra	17	2013-2014	484	9.0924
11	Odisha	5	2014-2015	530	4.0462
12	Punjab	3	2015-2016	545	1.3439
13	Tamil Nadu	6			2.3435
14	Telengana	12			3.9862
15	Uttar Pradesh	6			5.3663
16	West Bengal	16			1.2732
		Total-132			9.324
					83.6379

IV. THE POLLUTANT EMITTED FROM THE THERMAL POWER PLANT

In thermal power plant operation the chemical energy of coal was first converted to thermal energy (through combustion process) and then it converted to mechanical energy (through turbine) and finally converted into electrical energy with the help of generator. Fly ash is the leftover product of coal combustion process in TPP. Fly ash is powdery particulate matter, which is carried out by smoke stack and captured by the pollution control devices as the coarse particles. Fly ash generated from Indian TPP mainly classified into two category, F class and C class. Fly ash contains 1) SiO_2, 2.) Al_2O_3, 3) Different types of heavy metals such as cadmium (cd), chromium (cr), Cobalt (co), Lead (pb), Manganese (Mn), Mercury (Hg), Selenium(Se), Vanadium (V), PAH, Fe_2O_3 (Chaddha and Shehra 1983; Flanders1999; Lu et al. 2009). Combustion of coal also releases sulphur dioxide (SO_2), oxides of nitrogen (NO_2), carbon dioxide, particulate matter and volatile organic compounds which is disperse in across a large area (Hulter et al. 1980; Moon and Dermatas 2007). Comparatively to C class, F class is more harmful to human being as it contains very high amount of SiO_2+Al_2O_3+Fe_2O_3 (~70%), lime content less than 15% and has very low cement binding capacity (therefore it is not reusable) (Chaddha and Shehra 1983; Flanders 1999; and Lu et al. 2009). Chudury et al. 2012 estimated the approximate percentage of pollutant. They observed that approximately 15% of PM 2.5, 30% of NOx and 50% of SOx is present in fly ash, which is emitted into the atmosphere by TPP. Satellite studies were carried out for measurement of the environmental pollutant released by thermal power plants. These studies provided information that how emission from power plant and other sources influence the concentration of NOx and other gaseous pollutants in the environment (Gains et al. 2012; Lu and Streets 2012: Prasad et al. 2012).

Operations of thermal power plant generates substantial amount of particulate matter (PM) (George et. al. 2013). Particulate was characterised according to their size, larger particles up to 10 micrometer are designated as PM 10 and smaller particles 2.5 micrometer are designated as PM 2.5 (Yi et al. 2006). Due to this size difference PM 2.5 travels deeper into the airways and causes much greater damage to human lungs compared to PM 10 (Lu et al. 2010). Studies have estimated that TPP producing 660MW of electricity can probably emits 50-60% of PM2.5 and 90-95% of PM10 particles in to air. The particulate matter contains high concentration of heavy metals. Different studies were carried out in India and China to characterize the chemical composition of fly ash emitted from TPP, according to studies particulate matter contains 1-7% of zinc, 2-7% of copper , 5-8% of manganese , 7-10 % of cobalt , 12-8% of cadmium , 60-70% of selenium and 70-80% of mercury (Finkalman 2007; Reddy et al. 2005; Chen et al. 2013). Thus fly ash generated from TPP has adverse health effects on human health, agricultural activities and also contaminates soil (Manoj et al. 2012)

V. ADVERSE HEALTH EFFECTS DUE TO AIR POLLUTION

Developing countries has poor breathable air quality and this deprived air quality, presents a great threat to human health. Inhalation of polluted air leads to pathogenesis of many chronic and acute diseases (Abbey et al. 1995). The poor air quality creates physiological effects like headache, eye irritation, respiratory diseases, cardiovascular diseases and even some time death of an individual (Chikkatpur and Sagar 2009; Chikkatpur et al. 2011; Parayas 2011; Parayas 2013). The main constituent of polluted air is particulate matter, which is emitted via different sources such as vehicular, transportation and coal combustion process (Funasak et al. 2000). The effects of particulate matter depends upon their size, many studies reported that small particulate matter PM 2.5 is more harmful than PM 10 (Chikkatpur and Sagar 2009; Chikkatpur et al.2011; Parayas 2011; Parayas 2013; Chen 2016; Miller 2016; Rohr et al. 2016)

The U.S Environmental Protection Agency concludes that PM 2.5 causes respiratory diseases, especially damage development of asthma and also involved in decrement of lung function in children (USEPA 2009). IHME 2013 report has established a relationship between the pollutant emitted from coal combustion process and diseases. WHO (2013, 2015) and Global Burden of Diseases study (2010, 2013, 2015) showed that the outdoor air pollution which is contributed by the particulate matter and ozone pollutant may be causative factor for onset of 10 major health risks in India (For example – annual premature death, respiratory illness and cardiovascular diseases).

A. RESPIRATORY EFFECTS

Respiratory track is the first site which gets affect after inhalation of polluted air. Particulate matter below PM2.5 present in air enters directly into lungs, get absorb into our blood through respiratory tract and is responsible for respiratory disorder. Epidemiological study conducted in Delhi and Chennai under Public Health and Air

Pollution in Asia (PAPA) programme also highlighted the problem of outdoor air pollution and its related diseases (Wong et al. 2008; Balakrishnan et al, 2011). Researchers have extensively documented a direct link between outdoor air pollution (emission from TTP) and related health impacts. Studies have concluded that inhalation of pollututed air is responsible for onset of many different type of diseases like chronic obstructive pulmonary diseases (COPD), cardiovascular diseases, bronchitis, Ischemic disease, lung damage and even premature deaths (Brunekreef 1997; Pope et al. 2009; HEI 2004; Laden et al. 2006; USEPA 2009; HEI 2010; Atkinson et al. 2011; Global Burden of Disease Study 2010, 2013, 2015).

The operations of TPP contribute toward the global burden of cardiovascular diseases. PM 2.5 was linked with the progression of cardiovascular diseases and even death (USEPA 2009, 2016). According to World Health Organisation (WHO) an estimates of 5% of cardiopulmonary deaths occur worldwide due to inhalation of particulate matter present in polluted air (WHO 2013, 2015). As per the report published in scientific report, occurrence of cardiovascular diseases in world increased in range between 8-18% due to increase in coal combustion process (Lewtas 2007). Children and adults directly or indirectly link to the TPP exposure and the association between the air pollution and lung function are inconsistent. Association studies has been conducted in highly polluted area and the scientific evidence indicated that exposure of high level of pollution has the adverse effects on human health (WHO 2013, 2015). Children's are more susceptible to air pollution compared with adults, because children's have relatively higher rates of breathing, narrow airways and their lungs are in developing stage (American Thoracic society 1996). Further studies have established a strong relationship between ambient air pollution and respiratory diseases like asthma, lung function and respiratory disorder (Miller and Marty 2010; Gauderman et al. 2004; Darrow et al. 2014; Urman et al. 2014; Gauderman et al. 2015). Effects of the particulate matter differ depending upon season i. e. summer, winter and monsoon, because the concentration of particulate matter present in the atmosphere varies depending upon the moisture, wind speed, rains and climate. When compared maximum concentration of particulate matter was observed during winter and minimum concentration was observed in summer season, this seasonal variation in particulate matter may be due to increased vehicular traffic problem in winter (Brunekreef 1997; Pope et al. 2009; HEI 2004; Laden et al. 2006; USEPA 2009; HEI 2010; Atkinson et al. 2011; Global Burden of Disease Study 2012, 2013, 2015).

In humans, respiratory illness caused by air pollution is term as acute respiratory illness (ARI) and classified into two types i. e. upper respiratory tract infection (UTRI) and lower respiratory tract infection (LTRI). Acute respiratory tract illness usually includes influenza, bronchitis and pneumonia and we talk about epidemiological point of view, the symptoms include shortness of breath, weakens, chest tightness, fever, coughing and fatigue. After inhalation of particulate matter the occurrence of acute respiratory infection (ARI) much higher in children compare to adults (Romieu et al. 2002). Evidence suggests that the inhalation of PM 2.5 severely affect to those who have existing health problems (especially heart attacks, strokes, and other issues infarct) and it has also been observed that exposure of particulate matter increase the increases the risk of heart attack by 50%. Thus long term exposure of particulate matter affect respiratory track severely.

B. CHRONIC OBSTRUCTIVE PULMONARY DISORDER (COPD)

Chronic obstructive pulmonary disorder occurs due to insufficient or limitation of air flow in the lungs. It is a life threatening disease that causes breathlessness and later it promotes serious illness in human being. COPD has become public health issue at global level with increase in air pollution (Ko and Hui 2012; Germet et al. 2016). According to the global burden of disease report 2010, 2013, 2015 COPD occupied sixth position as a leading cause of death till 1990 and it is estimated that COPD may be become third largest cause of death worldwide by 2020 due to production of high fly ash). Globally it is estimated that 3 million deaths are caused by COPD. Low and middle income countries have 90% of COPD deaths which is be linked to outdoor air pollution (Global burden of disease report). United States Environmental Protection Agency (USEPA) reported that with increase in per 10 ug/m^3 of PM2.5 concentration in air there is nearly 2.4% increase in hospital admission due to COPD (USEPA 2009). Studies conducted in Latin America and China also reported that with increase in outdoor air pollution, increase incidence of COPD observed (Romieu 2012; Fang et al. 2013). From the literature it can be inferred that there is direct relations between COPD and outdoor air.

C. ASTHMA

The short term changes in the ambient air caused by different types of process such as burning of coal, operation of TPP and vehicular pollution increase asthma related emergency in hospitals. It has been known that vehicular traffic and power generation are main sources of urban air pollution and deposition of the PM2.5 particles

in to the respiratory tract, particularly in small airways and alveoli is responsible for asthmatic attack in human (Zahran et al. 2015; Byers et al. 2016). The direct relation between deprived air quality and asthma is known. To proved that the increase of particulate matter (PM2.5) concentration in air may be responsible for the increase of asthma symptoms, Mirabelli et al. 2016 conducted the study to know the severity and persistent of asthma due to changes in ambient air quality. They concluded that the nearly 2/3 rd of children's and adults participated in study developed asthma with change in air quality. Thus identifying the relative risk factors could help to improve targeted interventions and strategies to reduce the effects.

D. EYE IRRITATION

Air pollution is one of the major causes of eye allergies and conjunctive in all age groups of people according to doctors. Eye irritation is a serious problem and if not treated in time, it can lead to development of problems in cornea there after affecting vision (Rizwan et al. 2013). Particulate matters which are emitted by TTP in to the atmosphere results in eye irritation termed as watery eyes (Environmental Health Series: EHS/1/2008 CPCB), which is observed in all age group (young children, middle and senior citizen). A study suggests there is increase in the corneal infection due to increase in the concentration of particulate air pollutant in the major cities of India (Saxena 2003). Literature has provided information that particulate matter present in the air leads to pathogenesis of eyes diseases, but still there is need to address air pollution induced eye diseases problem.

VI. CONCLUSION

Coal has becomes the choice of fossil fuel for power generation (thermal power plant) due to its easy availability. Power sector of India currently dealing with two major priorities which is needed to be properly addressed,

1. For improving the Indian economy, the demand for power generation will also increase and subsequently increase in use of fossil fuel.
2. The huge amount of coal which will be used for power generation will emit different types of pollutants. The adverse effects of released pollutants on human health and environment need to be properly studied.

Thermal power plant operation generated fly ash which pollutes air, water and also soil. Management of fly ash is a big problem for thermal power plant operators and new method for fly ash disposal should be developed by plant operators. Pollutants emitted from transport and domestic sectors are difficult to control, but the pollutants emitted from thermal power plant can be controlled. The stack emission of the TPP with a point source can be easily monitored compared to non point sources such as vehicles, domestic burning process, garbage burning process, fugitive dust process, etc. Every TPP should use the air pollution control devices for improving the air quality. Power generation will likely to be increasing by 2030, new policies and regulations should be implemented for all running TPP in countries for minimize the air pollution. For management of the air quality, tree plantation programme should be enhanced, so that it can tolerates the pollution load.

Conflict of interests

The authors declare that there is no conflict of interests.

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