Environmental Impact of Thermal Power Plant in India and Its Mitigation Measure

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Abstract: *This research paper discusses the impacts of the coal combustion in thermal power plant, emphasized the problems associated with fly ash, collection using Electro Static Precipitator, mitigation measures for fly ash has also been highlighted such as development of bricks, use of fly ash for manufacturing of cement, development of ceramics, fertilizer, development of distemper and use of fly ash in road construction and road embankment. This article gives the direction for the beneficial use of fly ash generated during coal combustion in power plants*

Keywords: *Coal, fly ash, thermal power plant, Electro Static Precipitator, combustion.*

I. Introduction

Coal is the only natural resource and fossil fuel available in abundance in India. Consequently, it is used widely as a thermal energy source and also as fuel for thermal power plants producing electricity [1]. Power generation in India has increased manifold in the recent decades to meet the demand of the increasing population [2]. Generating capacity has grown many times from 1362MW in 1947 to 147,403MW (as on December 2008). India has about 90,000 MW installed capacity for electricity generation, of which more than 70% is produced by coal- based thermal power plants. The only fossil fuel available in abundance is coal, and hence its usage will keep growing for another 2–3 decades at least till nuclear power makes a significant contribution. The coal available in India is of poor quality, with very high ash content and low calorific value, and most of the coal mines are located in the eastern part of the country. Whatever good quality coal available is used by the metallurgical industry, like steel plants. The coal supplied to power plants is of the worst quality. Some of the coal mines are owned by private companies, and they do not wish to invest on quality improvement [1]. Combustion process converts coal into useful heat energy, but it is also a part of the process that produce greatest environmental and health concerns. Combustion of coal at thermal power plants emits mainly carbon dioxide (CO_2), sulphur oxides (SOx), nitrogen oxides (NOx); CFCs other trace gases and air borne inorganic particulates, such as fly ash and suspended particulate matter (SPM). CO_2, NOx and CFCs are greenhouse gases (GHGs) High ash content in Indian coal and inefficient combustion technologies contribute to India's emission of air particulate matter and other trace gases, including gases that are responsible for the greenhouse effect. And mercury which is a dangerous metal released by this coal combustion.

II. Fly Ash

The present coal consumption in thermal power station in India results in adding ash estimated 12.21 million tons fly ash in to the environment a year of which nearly a third goes in to air and the rest is dumped on land or Water in spite of various research results a consistent utilization is not evident, and it expected that stocks piles Of fly ash will continue to grow with the increasing number of super thermal power station in India. As reliance upon coal as a fuel source increases, this large quantities of this material will be increasingly brought into contact with the water and soil environment [3].

2.1 Problems associated of increasing fly ash

India has about 211 billion tons of coal reserves, which is known to be the largest resource of energy and presently 240MT of coal is being used annually to meet the Nation's electricity demand. In terms of energy, India stands at world sixth position accounting 3.5% of the world commercial energy demand in 2001, but the electricity generation yet not completely fulfilled the present requirement. Environmental pollution by the coal based thermal power plants all over the world is cited to be one of the major sources of pollution affecting the general aesthetics of environment in terms of land use, health hazards and air, soil and water in particular and thus leads to environmental dangers[4]. Fly ash water also affects the scale structure because it is a directly in contact with water. Heavy metals can also adversely affect the growth rate in major carps[5]. Coal combustion residues (CCRs) are a collective term referring to the residues produced during the combustion of coal regardless of ultimate utilization or disposal. It includes fly ash, bottom ash, boiler slag, and fluidized bed combustion ash and other solid fine particles [6]. In India, presently coal based thermal power plants are releasing 105MT of CCRs which possess major environmental problems [7]. Presently from all these thermal power plants, dry fly ash has been collected through Electrostatic Precipitator (ESP) in dry condition as well as pond ash from ash ponds in semi-wet condition. In India most of the thermal power plants do not have the facility for automatic dry ash collection system. Commonly both fly ash and bottom ash together are discharged as slurry to the ash pond/lagoon these effect on environment, economy, and social factor.

Table-I
Composition of Indian coal and fly ash in ppm

Elements	Coal	Fly ash	Coal	Fly ash
Na	1500	6700	289	1299
K	10,000	15,000	2075	18,275
La	22.2	94	47.6	238
Ce	42	212	30.2	145
Hg	0.6	9	11	48
Te	NA	NA	1.83	8.87
Th	5.1	6.6	5.34	25
Cr	55	210	62.8	404
Hf	1.8	7	7.1	32.6
Sc	8.9	64	22.9	106
Zn	170	3100	539	2027
Fe	11,000	51,000	20,088	1,06,665
Ta	NA	NA	153	5.05
Co	13.9	520	33.4	128
Eu	0.8	8.6	0.95	5.6
Sm	NA	NA	0.65	1.99
Am	0.4	0.2	0.136	0.69

NA –Not Available

Table-II
Chemical Composition of Fly Ash

Name	Formula	Percentage
Silica	SiO_2	62
Iron oxide	Fe_2O_3	63
Aluminium	Al_2O_3	26
Titanium oxide	TiO_2	1.8
Potassium oxide	K_2O	1.28
Calcium oxide	CaO	1.13
Magnesium oxide	MgO	0.49
Phosphorus pent oxide	P2O5	0.40
Sulphate	SO_4	0.36
Disodium oxide	Na_2O	0.28

2.2 Problems associated with radionuclide increase in atmosphere coal combustion: Coal, like most materials found in nature, contains radionuclides. The levels of natural radionuclides in a geological formation depend on its composition and geological history. In the production of electric power, coal is burned in a furnace operating at temperatures of up to 1700°C [8]. In the combustion process, volatile radionuclide's such as Pb^{210} and Po^{210} are partly released in the flue gases and escape to the atmosphere. A significant fraction of the radioactivity is also retained in the bottom ash or slag .The greatest part of the radioactivity in coal remains with the ash but some of the fly ash from coal-fired power plants escapes into the atmosphere [9]. Air pollution in the vicinity of a coal fired thermal power station affects soil, water, vegetation, the whole ecosystem and human health [10]."Environmental impact of coal utilization in thermal power plant" notes that "Radon is a colourless, odourless but noble gas, which is radioactive and ubiquitously present. It poses grate health hazards not only to uranium miners but also people living in normal houses and buildings and at work place like coal mines, cement industry, thermal power plants etc. Coal, a naturally occurring fossil fuel is burnt in conventional power plants to meet out about 72% of the electricity needs in our country [11]. It was lesser known hitherto until recently that the fly ash which is a by-product of burnt coal is a potential radioactive air pollutant and it modifies radiation exposure.

III. Collection of Fly Ash

After the combustion of the coal in the boiler, 20% of the ash is collected at the bottom of the boiler called bottom ash and 80% is carried along with flue gases called fly ash. Bottom ash is mixed with water and made into sludge form and sent through pumps into the ash ponds. The Electro Static Precipitator is used to collect the ash particles in the flue gases. The era after the introduction of the Electro Static Precipitator has partly protected the environment from harmful gases and hazardous chemicals. Generally dust is collected from the waste in two processes that is mechanically and electrically.

Mechanically is by using filters and electrically is by using Electro Static Precipitators. The ESP is efficient in precipitation of particles from sub microns to large sizes of particles and hence they are preferred to mechanical precipitators. The efficiency of modern ESP's is of the order 99.9%.The Electro Static Precipitators have high collecting efficiency, low sensitivity to high temperatures, low pressure drop, limited process controls and an easy and reduced maintenance make the electro static precipitators one of the most reliable and appreciated units available at the moment in the market.

Electrostatic precipitators can be used for collecting virtually all kinds of dust coming from coal and oil fired power stations, blast furnaces and industrial furnaces, iron and steel processes, cement factories, municipal solid wastes incinerators , paper mills, wood factories, textile industries, food and pharmaceuticals industries.

3.1 Principle of Electro Static Precipitator

The electro static precipitator utilizes electrostatic forces to separate dust particles from the gas to be cleaned. The flue gas is ionized in the electro static field and large quantities of positive and negative ions are formed. The positive ions are immediately attracted towards the negative wires by the strength of the field. The negative ions however attracts towards the positive diode.

IV. Fly Ash Mitigation Measure

Fly ash is fine glass powder, the particles of which are generally spherical in shape and range from 0.5 to 100 micron in size. The fine particles of fly ash reach the pulmonary region of the lungs and remain there for long periods of time; they behave like cumulative poisons. The submicron particles enter deeper into the lungs and are deposited on the alveolar walls where the metals could be transferred to the blood plasma across the cell membrane fly ash can be disposed-off in a dry or wet state. Studies show that wet disposal of this waste does not protect the environment from migration of metal into the soil. Heavy metals cannot be degraded biologically into harmless products like other organic waste. Studies also show that coal ash satisfies the criteria for landfill disposal, according to the Environmental Agency of Japan. According to the hazardous waste management and handling rule of 1989, fly ash is considered as non-hazardous. With the present practice of fly-ash disposal in ash ponds (generally in the form of slurry), the total land required for ash disposal would be about 82,200 ha by the year 2020 at an estimated 0.6 ha per MW. Fly ash can be treated as a by-product rather than waste [12].

4.1 Fly ash bricks: The Central Fuel Research Institute, Dhanbad has developed a technology for the utilization of fly ash for the manufacture of building bricks. Fly ash bricks have a number of advantages over the conventional burnt clay bricks. Unglazed tiles for use on footpaths can also be made from it (Figure 1). Awareness among the public is required and the Government has to provide special incentives for this purpose [12]. Six mechanized fly ash brick manufacturing units at Korba are producing about 60000 bricks per day. In addition to this, two mechanized fly ash brick manufacturing units have been set up by private entrepreneurs also at Korba [13], the total production being about 30000 bricks/day. Apart from this about 23 entrepreneurs have registered in DTIC proposals for establishing ash brick units. To give impetus to ash brick manufacturing [13]

Orissa Government in India has banned the use of soil for the manufacture of bricks up to 20 km. of a thermal power station. In the case of fly ash-clay fired bricks, a mixture of clay and fly ash is fired. The unburnt carbon of the fly ash serves as fuel for burning. Approximately 20-30% energy can be reduced by adding25-40% fly ash [14].

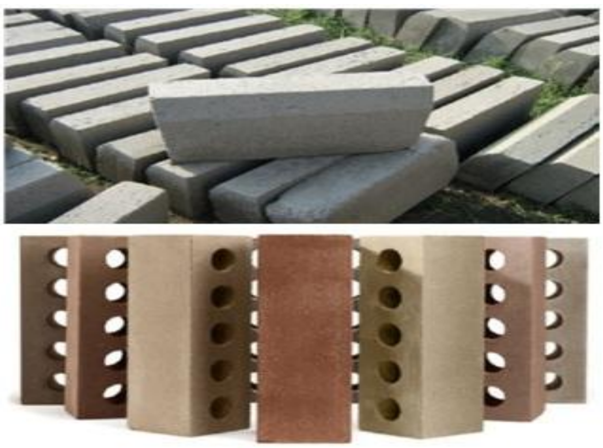

Figure-1

Fly ash using for making bricks

4.2 Fly ash in manufacture of cement: In the presence of moisture, fly ash reacts chemically with calcium hydroxide and CO_2 present in the environment attack the free lime causing deterioration of the concrete. A cement technologist observed that the reactive elements present in fly ash convert the problematic free lime into durable concrete [15]. Fly ash can substitute up to 66% of cement in the construction of dams. Fly ash in R.C.C. is used not only for saving cement cost but also for enhancing strength and durability. Fly ash can also be used in Portland cement concrete to enhance the performance of the concrete. Portland cement is manufactured with Calcium oxide, some of which is released in a free state during hydration. Studies show that one ton of Portland cement production discharges 0.87 tonnes of carbon dioxide in the environment. Another Japanese study indicates that every year barren land approximately 1.5 times of the Indian Territory need to be afforested to compensate for the total global accumulation of carbon dioxide discharged into the atmosphere because of total global cement production. Utilization of fly ash in cement concrete minimizes the carbon dioxide emission problem to the extent of its proportion in cement.

4.3 Fly ash-based ceramics: Ceramic products with up to 50 wt% of mullite and 16 wt% of feldspars were obtained from binary mixtures of fly ash from the Teruel power station (NE Spain) and plastic clays from the Teruel coal mining district [16]. The firing behaviour of fly ash and the ceramic mixtures was investigated by determining their changes in mineralogy and basic ceramic properties such as colour, bulk density, water absorption and firing shrinkage. To determine the changes on heating suffered by both the fly ash and the ceramic bodies, firing tests were carried out at temperatures between 900 and 1200°C in short firing cycles [17]. The resulting ceramic bodies exhibit features that suggest possibilities for use in paving stoneware manufacture, for tiling and for conventional brick making (fig-2). The National Metallurgical Laboratory; Jamshedpur has developed a process to produce ceramics from fly ash having superior resistance to abrasion [12].

(a)

(b)

Figure-2

a) Mosaic tile b) Interlocking paver

4.4 Fly ash as fertilizer: Fly ash provides the uptake of vital nutrients/minerals (Ca, Mg, Fe, Zn, Mo, S and Se) by crops and vegetation, and can be considered as a potential growth improver [18]. Because it can be a soil modifier and enhance its moisture retaining capacity and fertility the improvement in yield has been recorded with fly ash doses varying from 20 tone / hectare to 100 tone / hectare (Figure 3). On an average 20-30% yield increase has been observed. Out of 150 million hectare of land under cultivation, 10 million hectares of land can safely be taken up for application of fly ash per year. The fly ash treated fields would give additional yield of 5 million tone food grains per year valued at Rs.3000 per year.

(a)

(b)

Figure-3

a) Cabbage at Dobhar, fly ash amended soils
b) Reclamation of saline soils using fly ash
(75% saving in gypsum)

4.4 Fly ash based polymer products: Fly ashes are also being used as wood substitutes. They have been developed by using fly ash as the matrix and jute cloth as the reinforcement. The Jute cloth is laminated by passing through a polymer fly ash matrix and then cured. The number of Laminates is increased to get the desired thickness. The product can be used in many applications like door shutters, partition panels, flooring tiles, wall panelling and ceiling. The developed material is stronger more durable, resistant to corrosion and cost effective as compared to wood. This technology has been developed by the Regional Research Laboratory, Bhopal in collaboration with Building Materials and Technology Promotion Council (B.M.T.P.C) and TIFAC [19]. One commercial plant has been set up based on this technology near Chennai, India. The Government of India has withdrawn an 8% excise duty imposed earlier on fly ash products.

4.5 Fly ash in road construction: The use of fly ash in large quantities making the road base and surfacing can result in low value–high volume utilization technology demonstration projects at New Delhi, Dadri (U.P.) and Raichur (Karnataka) have been successfully completed for use of fly ash in road / flyover embankments (figure-4). Guidelines have been prepared and approved by Indian Roads Congress (IRC) as national standard. More than 10 multiplier effects have taken place across the country.

In the recent past CRRI offered advise/ consultancy services in the following road/embankment projects in which fly ash was utilized:

1. Construction of plant roads at Budge-Budge thermal power plant using fly ash based pavement specifications (Collaboration with CESC Ltd, Kolkata),
2. Construction of one km long rural road near Raichur in Karnataka with fly ash based flexible/semi-rigid pavement composition (Collaboration with Karnataka PWD and Raichur thermal power station -executed as Fly Ash Mission demonstration project)
3. Construction of plant road and two rural roads using fly ash (collaboration with National Capital Power Station, NTPC, Dadri, U.P) [20].

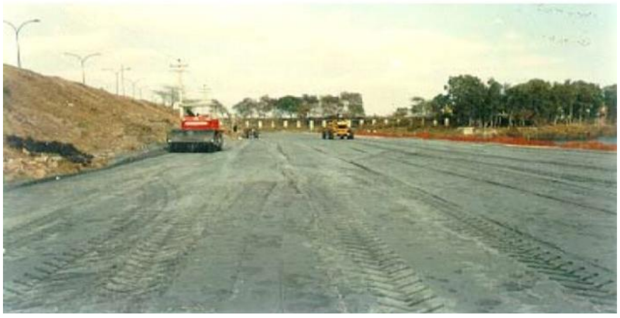

Figure 4

Nizamuddin Bridge approach road embankment at New Delhi (in flood zone of river Yamuna)

4.6 Roads and Embankments: Another area that holds potential for utilization of large volumes of fly ash is road and flyover embankments. Fly ash embankments at Okhla, Hanuman Setu, Second Nizamuddin bridge in Delhi and roads at Raichur, Calcutta, Dadri etc. have established that on an average Rs. 50 to 75 per MT of earth work cost can be saved by using fly ash (in lieu of soil) in such works, primarily due to reduction in excavation & transportation costs[18].

In the recent past CRRI offered advise/ consultancy services in the following road/embankment projects in which fly ash was utilized:

1. Fly ash embankment construction for Okhla flyover at Delhi adopting 'Reinforced Embankment Technique' (Collaboration with Delhi PWD – executed as Fly Ash Mission demonstration project),
2. Fly ash embankment construction for Hanuman Setu flyover at Delhi adopting 'Reinforced Embankment Technique' (Collaboration with Delhi PWD and Badarpur Thermal Power Station, Delhi).
3. Construction of reinforced approach embankment using fly ash at SaritaVihar flyover in Delhi (Collaboration with Delhi Development Authority and Badarpur Thermal Power Station, Delhi).
4. Construction of embankment for Noida-Greater Noida Expressway project (Collaboration with IRCON International and Badarpur Thermal Power Station, Delhi)[19]

V. Environmental Impact of Fly Ash Usage

Utilization of fly ash will not only minimize the disposal problem but will also help in utilizing precious land in a better way. Construction of road embankments using fly ash, involves encapsulation of fly ash in earthen-core or with RCC facing panels. Since there is no seepage of rain water into the fly ash core, leaching of heavy metals is also prevented. When fly ash is used in concrete, it chemically reacts with cement and reduces any leaching effect. Even when it is used in stabilization work, a similar chemical reaction takes place which binds fly ash particles. Hence chances of pollution due to use of fly ash in road works are negligible [21].

VI. Energy Saving and Environmental Benifits

Most of the developing countries face energy scarcity and huge housing and other infrastructure shortage. Ideally in these countries materials for habitat and other construction activities should be energy efficient (having low energy demand). The following table shows some examples of energy savings achieved through the use of Fly Ash in the manufacture of conventional building materials [22].

VII. Conclusion

Coal is used widely as a thermal energy source in thermal power plant for production of electricity but available coal in India is of poor quality, with very high ash content and low calorific value. Utilization of huge amount of coal in thermal power plant has created several adverse effects on environment leading to global climate change and fly ash management problem. Coal based thermal power plants all over the world is cited to be one of the major sources of pollution affecting the general aesthetics of environment in terms of land use, health hazards and air, soil and water in particular and thus leads to environmental dangers. So, the disposable management of fly ash from thermal power plant is necessary to protect our environment. It is advisable to explore all possible application for fly ash utilization. Several efforts are needed to utilize fly ash for making bricks, in manufacture of cement, ceramics etc. Various governmental and nongovernmental bodies working in the field of utilization of fly ash for construction of road/road embankment The utilization of fly ash gives good result in almost every aspects including good strength, economically feasible and environmental friendly.

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