A Review on Fly Ash Disposal, Utilization & Characterization

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Abstract - Current annual production of fly ash, a byproduct from coal based thermal power plant (TPPS) is 131 million tonnes (MT).some of the problems associated with fly ash are large area of land required for disposal and toxicity associated with heavy water leached to groundwater. This review presents different ways of using fly ash utilization and disposal. Environmental and occupational health hazards associated with fly ash are also discussed.

Keywords- Fly Ash, Thermal Power Plant, Environment, Occupational Health, Utilization.

I. INTRODUCTION

In India studies we have been carried out towards management of fly Ash (FA) disposal & utilization of total power generated India, about 70% is produced by thermal power plants (TPPS). With a 70 billion tones coal reserve, majority of TPPS (84%) are run on coal and rest on (13%) on gas, and oil (3%). Present generation of fly ash from coal based thermal power plants in India is 131 MT/year and it is expected to increase to 300-400 MT/year by 2016-17. FA depends on coal, coal particle fineness, percentage of ash in coal, combustion technique used, air/ fuel ratio, burner used, and type of boiler. The quality of coal depends upon its rank and grade. The coal rank arranged in an ascending order of carbon contents is: Peat << Lignite << sub-bituminous coal << bituminous coal << anthracite Indian coal is of mostly sub bituminous rank followed by bituminous and lignite (brown coal). The ash content in Indian coal ranges from 35 % to 50 %. The coal properties including calorific values differ depending upon the colliery. The calorific value of the Indian coal (~ 15 MJ/Kg) is less than the normal range of 21 MJ/kg to 33 MJ/kg (gross).

I. Types of Fly Ash

There are generally three categories of coal ashes available from thermal power stations:

1. Dry fly ash – collected from different rows of electrostatic precipitator in dry form. The fly ash produced from the burning of pulverized coal in a coal-fired boiler is a fine grained, powdery particulate material that is carried off in the flue gas and usually collected from the flue gas by means of electrostatic precipitators, bag-houses, or mechanical collection devices such as cyclones.
2. Bottom ash – collected at the bottom of the boiler furnace and is characterized by better geotechnical properties.
3. Pond ash – Fly ash and bottom ashes are mixed together with water to form slurry which is pumped to the ash pond area. In the ash pond the, ash gets settled and excess water is decanted. This deposited ash is pond ash.

II. Present scenario of fly ash in India

1. Over 73 % of the total installed power generation is thermal
2. 230 - 250 million MT coal is being used every year
3. High ash contents varying from 30 to 50%
4. More than 110 million MT of ash generated every year
5. Ash generation likely to reach 170 million MT by 2012.
6. Presently 65,000 acres of land occupied by ash ponds
7. Presently as per the Ministry of Environment & Forest Figures, 30% of Ash is being used in Fillings, embankments, construction, block & tiles, etc.

III. Utilization of fly ash in different country.

Table 1
Generation and utilization of fly-ash in different countries.

Country	Fly-ash production (million tons per year)	Fly-ash utilization (%)
India	112	38
China	100	45
USA	75	65
Germany	40	85
UK	15	50
Australia	10	85
Canada	6	75
France	3	85
Denmark	2	100
Italy	2	100
Netherlands	2	100

IV. Fly ash generation

The fly ash produced from the burning of pulverized coal in a coal-fired boiler is a fine grained, powdery particulate material that is carried off in the flue gas and usually collected from the flue gas by means of electrostatic precipitators, bag houses, or mechanical collection devices such as cyclones.
In general, there are three types of coal-fired boiler furnaces used in the electric utility industry. They are referred to as dry-bottom boilers, wet-bottom boilers, and cyclone furnaces. The most common type of coal burning furnace is the dry-bottom furnace. When pulverized coal is combusted in a dry-ash, dry-bottom boiler, about 80 percent of all the ash leaves the furnace as fly ash, entrained in the flue gas. When pulverized coal is combusted in a wet-bottom (or slag-tap) furnace, as much as 50 percent of the ash is retained in the furnace, with the other 50 percent being entrained in the flue gas. In a cyclone furnace, where crushed coal is used as a fuel, 70 to 80 percent of the ash is retained as boiler slag and only 20 to 30 percent leaves the furnace as dry ash in the flue gas. A general flow diagram of fly ash production in a dry-bottom coal-fired utility boiler operation is presented in figure [1-7].

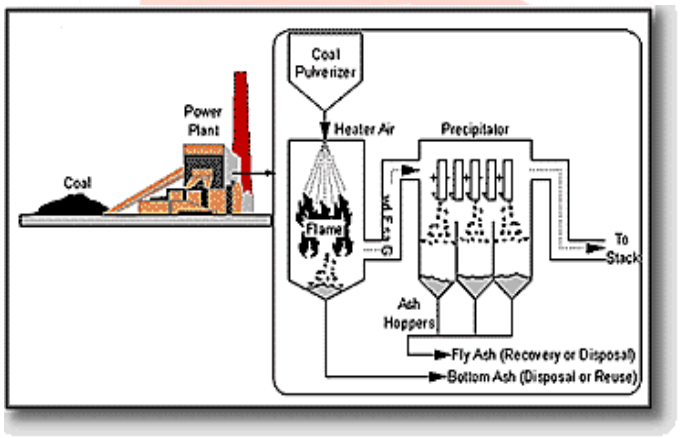

Fig.1 Generation of ash at the power plants

V. Characterization of Fly ash.

Coal-based thermal power plants all over the world face serious problems of handling and disposal of the ash produced. The high ash content (30–50%) of the coal in India makes this problem complex. At present, about 85 thermal power stations produce nearly 110 million tonnes of coal ash per annum. Safe disposal of the ash without adversely affecting the environment and the large storage area required are major concerns. Hence attempts are being made to utilize the ash rather than dump it. The coal ash can be utilized in bulk only in geotechnical engineering applications such as construction of embankments, as a backfill material, as a sub-base material, etc. For this, an in-depth understanding of the physical and chemical properties, and engineering and leaching behavior are required. This necessitates characterization of the fly ash with reference to geotechnical applications.

VI. Physical properties of Fly ash.

The physical properties of fly-ash vary widely depending on the coal type, boiler type, ash content in coal, combustion method and collector setup. Fly-ash generally has a silt loam texture with 65–90% of the particles having a diameter of less than 0.010 mm [8, 9]. Ash from bituminous coal is usually finer as compared with that of lignite one [10]. Fly ash particles are empty spheres (cenospheres) filled with smaller amorphous particles and crystals (plerospheres). The cenosphere fraction constitutes as much as 1% of the total mass and gets easily airborne [11]. In general, flyash has low bulk density (1.01–1.43 g cm_3), hydraulic conductivity and specific gravity (1.6–3.1 g cm_3) [9,10,12]. Mean particle densities for non-magnetic and magnetic particles are 2.7 and 3.4 g cm_3, respectively, while the moisture retention ranges from 6.1% at 15 bar to 13.4% at 1/3 bar

[13]. By virtue of its physical characteristics and sheer volumes generated, fly-ash is a serious problem. Some of the aspects of the problem are [14]:
(1) Due to heavy disposal, fly-ash particles both as dry ash and pond ash occupy many hectares of land in the vicinity of power station.
(2) Because of its fineness, it is very difficult to handle flyash
in dry state. Flying fine particles of ash corrode structural surfaces and affect horticulture.
(3) It disturbs the ecology through soil, air and water pollution.
(4) Long inhalation of fly-ash causes various serious diseases
like silicosis, fibrosis of lungs, bronchitis, and pneumonitis.
Moreover, the oxides of iron and aluminium present on the surface of the fly-ash particles attract toxic trace elements, such as Sb, As, Be, Cd, Pb, Hg, Se, and V, and they are found to be concentrated largely on the surface of fly-ash [15]. A study was conducted by Hicks and Yager [16].With six bituminus, sub-bituminus and lignite coal fired thermal power plants to measure the amount of airborne respirable crystalline silica in the breathing zone of workers engaged in fly-ash-related operations. It was found that in the bituminus, sub-bituminus and lignite coal-fired plants, the air samples (60%) collected during maintenance-related work exceeded the threshold limit. Similarly, in the case of normal production-related activities, the samples from bituminous (54%) and sub-bituminus (65%) coal-fired plants surpassed the limit. In the bituminus/ sub-bituminus and lignite coal, the minimum crystalline silica contents were observed to be 7.5% and 1.7%, respectively [16].

VII. Chemical properties of Fly ash.

The chemical properties of the coal ashes greatly influence the environmental impacts that may arise out of their use/disposal as well as their engineering properties. The adverse impacts include contamination of surface and subsurface water with toxic heavy metals present in the coal ashes, loss of soil fertility around the plant sites, etc. Hence this calls for a detailed study of their chemical composition, morphological studies, pH, total soluble solids, etc.

Table – 2. Normal range of chemical composition of fly ash produced from different coal types.

Component (wt.%)	Bituminous	Sub-bituminous	Lignite
SiO_2	20–60	40–60	15–45
Al_2O_3	5–35	20–30	10–25
Fe_2O_3	10–40	4–10	4–15
CaO	1–12	5–30	15–40
MgO	0–5	1–6	3–10
SO_3	0–4	0–2	0–10
Na_2O	0–4	0–2	0–6
K_2O	0–3	0–4	0–4
LOI	0–15	0–3	0–5

VIII. Environmental impacts of Fly Ash.

The World Bank has cautioned India that by 2015, disposal of coal ash would require 1000 sq. km. of land. Since coal currently accounts for 70% of power production in the country, there is a need of new and innovative methods for reducing impacts on the environment. The problem with fly ash lies in the fact that not only does its disposal require large quantities of land, water and energy, its fine particles, if not managed well, can become airborne. Currently more 100 million tones of fly ash are being generated annually in India, with 65000 acres of land being occupied by ash ponds. Such a huge quantity dose poses challenging problems, in the form of land use, health hazards and environmental damages [17,18,19]

IX. Hazards

By virtue of its physical characteristics and sheer volumes generated, fly ash poses problems like:
1. It is a very difficult material to handle in dry state because it is very fine and readily airborne even in mild wind.
2. It disturbs the ecology of the region, being a source of soil, air and water pollution.
3. Long inhalation of fly ash causes silicosis, fibrosis of lungs, bronchitis, pneumonitis etc.
4. Flying fine particles of ash poses problems for people living near power stations, corrode structural surfaces and affect horticulture.
5. Eventual settlement of fly ash particles over many hectares of land in the vicinity of power station brings about perceptible degeneration in soil characteristics.[20,21,22]

X. Application & Utilization of Fly Ash.

Fly Ash is a major issue because electricity generation in the country would remain predominantly coal-based for a couple of coming decades. The coal being made available to thermal power stations has ash content in relatively large proportions. Below are the facts of data received from 88 (Eighty eight) coal/ lignite based thermal power stations of various power utilities in the country during the year 2010-12.

- Total installed capacity: 80458 MW
- Coal consumed: 407.61 million-tonne
- Average ash content: 32.16%

- Total ash generated: 131.09 million-tonne
- Total ash utilised: 73.13 million-tonne
- Percentage utilisation: 55.79%

There are many reasons to increase the amount of fly ash being re-utilized. A few of these reasons are given below. Firstly, disposal costs are minimized; secondly, less area is reserved for disposal, thus enabling other uses of the land and
decreasing disposal permitting requirements; thirdly, there may be financial returns from the sale of the by-product or at least an offset of the processing and disposal costs; and fourthly, the by-products can replace some scarce or expensive natural resources. Utilization of coal combustion by-products, namely fly ash, can be in the form of an alternative to another industrial resource, process, or application. These processes and applications include, but are not limited to, addition to cement and concrete products, structural fill and cover material, roadway and pavement utilization, addition to construction materials as a light weight aggregate, infiltration barrier and underground void filling, and soil, water and environmental improvement. The following is a brief description of each of the previously mentioned alternative uses of fly ash and associated research that has been conducted and how it relates to each alternative use. In this section, the application of fly ash has been discussed. Many experiments and studies on the effect and potentiality of fly-ash as an amendment in agricultural applications have been conducted by various agencies, research institutes at dispersed locations all over the world. with the aim of helping opening up the usage of fly-ash and reducing the environmental and economic impacts of disposal. . Fly-ash for improving soil properties Soil properties as influenced by fly-ash application have been studied by several workers [24–30] for utilizing this industrial waste as an agronomic amendment. Physical and chemical properties of soil due to fly-ash amendment vary according to the original properties of soil and fly ash but certain generalization could be made in most cases like, Soil texture, Bulk density, Water-holding capacity, Soil pH, Biological properties.

To meet the growing energy demand and thereby increase power generating capacity, the dependency on coal for power generation and disposal of fly-ash will continue to increase along with various unavoidable problems[31]. Moreover, keeping in view of developmental problems like burgeoning population, growing food demand, shrinking natural resources, it is necessary to sustain the production of crop yield as well as soil health in an eco-friendly way. Hence, it is required to involve fly-ash more effectively in agriculture sector to exploit its various physical and chemical properties fully, which are beneficial for soil and crop health. In view of the above discussions, the salient points from this extensive review could be summarized in the following sections:

(1) Advantages of fly-ash use in agriculture:

(i) It could be stated that the potentiality of fly-ash for its use in agriculture is popularizing day by day due to the fact that it contains almost all the essential plant nutrients i.e., macronutrients including P, K, Ca, Mg and S and micronutrients like Fe, Mn, Zn, Cu, Co, B and Mo, except organic carbon and nitrogen.

(ii) It is now well proved that though it can substitute lime, a costly amendment for acid soils, it cannot be a substitute for chemical fertilizers or organic manures. However, integrated application of all these can foreshorten the plant uptake of different heavy metals from fly-ash-amended soils as well
as can reduce the use of chemical fertilizers and thereby reduces environment pollution.

(iii) Fly-ash is also useful for stabilizing erosion-prone soils. Phyto remediation can prevent cycling of toxicants from fly-ash and growing of multipurpose tree species on problem soils.

(iv) According to IPCC, agricultural lime application contributes to global warming through emission of CO2 to the atmosphere. Use of fly-ash instead of lime as soil ameliorant can reduce net CO2 emission and thereby lessen global warming.

CONCLUSION

Fly ash has become an important raw material for various industrial and construction application. Fly ash is widely used in construction of bricks, cements, asbestos-cement production, and roads.fly ash is being studied for improvement of agricultural crops because of some physical and chemical properties of FA. It is also used in Wastelands and zeolites. It has found application at domestic and wastewater treatment and purification, paint and enamel manufacturing. In future, large scale application of FA may be possible for recovery of heavy metals, reclamation of wastelands and floriculture.

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