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UTILIZATION OF FLY ASH IN INDUSTRIAL APPLICATIONS FOR CONTROLLING ENVIRONMENTAL POLLUTION

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ABSTRACT
Ash produced in small dark flecks by the burning of powdered coal or other materials and carried into the air is commonly known as fly ash, chemical composition of Fly ash particles contains silica, alumina, iron oxides, and alkaline earth elements along with trace amounts of toxic heavy metals. The annual production of fly ash in India is estimated to be around 300 million tonnes in 2022. Already 65,000 acres of land is used as ash ponds -- the land where fly ash is dumped by thermal power plants. Global energy demand is ever increasing and it is set to increase by almost 50% in the period 2016 to 2040. Much of this growth will continue to be concentrated in the developing world, primarily China and India, like industrialization, population growth, and the unprecedented expansion of the middle class will increasse the need for energy in general and coal. The Indian coal is of low grade having a high ash content of the order of 30 - 45% producing a large quantity of fly ash at coal/lignite-based thermal power stations in the country. Though it has effects on the environment the Fly ash can be also useful in various industries and utilization is equally important. This paper explains the utilization of Fly ash in the Building Industry, Agriculture, Floriculture, etc.

Keywords: Fly ash, Chemical composition, utilization of fly ash, effects on the environment

INTRODUCTION:
With increasing population and industrial growth, the power demand has increased many folds all over the world. The current share of energy production from coal-based thermal power plants in India is around 76%. When coal is burnt in boilers, minute particles of ash, commonly known as fly ash, are produced as a by-product. This is collected using electrostatic precipitators or particle filters and then the flue gases are released from the chimneys. Fly ash particles contain silica, alumina, iron oxides, and alkaline earth elements along with trace amounts of toxic heavy metals like arsenic, lead, mercury, cobalt, and copper **[1]**. In recent years, the maintenance of ecological balance and a pristine environment is considered to be of utmost importance. Minute particles of fly ash, being light and airborne, can cause serious environmental problems such as pollution of groundwater and air. Being very minute, fly ash tends to remain airborne for a very long duration of time which lead to serious health problems as the airborne ash can enter the body. It can irritate skin, nose, eye, throat, and respiratory tract. Inhaling fly ash dust containing crystalline silica can result in bronchitis and lung cancer. Disposal of slurry in lagoons/ponds can breed harmful insects such as mosquitoes. The annual production of fly ash in India is estimated to be around 225 million tons in 2017. Hence steps have to be taken for the disposal/storage/utilization of large quantities of fly ash produced every year. Enough care has to be taken to product human, wildlife and environment. In this review, the various means of the utilization of fly ash in construction, brick industry, and agriculture are described along with the latest development in this area.

Chemical composition: The color of fly ash particles is either tan or grey depending on their lime/ iron content. Fly ash particles are predominantly spherical with sizes ranging between 0.5-100 µ. They consist of metals like silica, alumina, iron oxides, calcium, and magnesium, and toxic heavy metals like lead, arsenic, cobalt, and copper. The composition of fly ash will depend on the type of coal burnt in a plant, combustion conditions, and the type of collecting devices. The major component of fly ash is oxides of Si, Al, Fe, Ca, and Mg (95-99%) **[2]**. Generally, the minor constituents are Ti, Na, K, and S along with trace amounts of As, Hg, Cr, Ni, V, Pb, Zn. There are two class of Fly ash, class C and Class F.

When old anthracite and bituminous coal are burnt, Class F fly ash is produced. This fly ash is pozzolanic and contains a minor quantity of lime. To produce cement type of compound, Class F fly ash requires agents like Portland cement, quicklime, or hydrated lime; this is mixed with water to produce the compound. Further, when a chemical activator such as sodium silicate is added to Class F ash, a geopolymer can be formed. When young lignite or bituminous coal is burnt, the fly ash produced is called Class C. This has pozzolanic as well as self-cementing properties. In the presence of water, this hardens and gets stronger with time. This ash generally contains a higher amount of lime (> 20%). It may be noted that, unlike Class F, Class C fly ash does not require an activator to form a cement compound. Sulfate, as well as alkali content, is usually more in this fly ash.

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Disposal of fly ash: In the last century, fly ash was generally released into the atmosphere; but air pollution control standards during the last few decades demand that it should be captured before release by pollution control equipment. Nowadays the fly ash is disposed of in the dry or wet form. The common practice is to dump fly ash over wastelands. However, to prevent fly ash particles from being carried out in the air, it is necessary to sprinkle water over the dumping area. These sites need to be lined; otherwise, this can lead to seepage, contamination of groundwater and soil. Dry ash can be transported in trucks/conveyor belts to storage sites. As an alternate method, fly ash is mixed with water and the slurry is transported through pipes and disposed of in ponds or dumping sites.

The utilization of fly ash: Continuous research efforts are being done to convert this waste into wealth **[3]**. Fly ash is rich in oxides of silicon and aluminum and hence can be used as the raw material in different industries. In developed countries, more than 80% of fly ash is used in road construction, manufacture of bricks, concrete blocks, land filling, ceramics, agriculture, and dam construction. In India, in states like Delhi, Gujarat, Haryana, Jharkhand, and Punjab, about 50% of fly ash is used in the production of cement, asbestos cement, concrete, bricks, tiles, blocks, and also in land development, reclamation of the coal mine. In 2016-17, about 170 million tonne fly ash was produced and 63% of this was used in the above applications **[4]**. The details of these applications are briefly described below.

(i) Building industry: Fly ash F with good Si content is pozzolanic and is ready mixed with concrete and used as a green building material. Precast fly ash concrete can be used for slabs, doors, window frames, and also in flooring and roofing units. When fly ash is mixed with clay, light bricks are made. These bricks find use as building materials. Lime fly ash bricks have high strength with lime as a binder and gypsum as a catalyst. They are mixed in the high-speed mixer; to the slurry with a foaming agent is added. The aerated slurry is set in steel molds and the bricks are removed and autoclaved in steam. This is very good for wall block and floor slabs. Wherever stones are costly, sintered fly ash-light weight concrete can be used for buildings. Portland pozzolanic cement is prepared by partly replacing cement with fly ash (15-30%) reducing the overall cost of the material. This is the major application of fly ash in the U.S.A. In India, fly ash is used for part replacement of cement in mortar and concrete. The Indian Institute of Technology, Delhi has taken taking in this use. The use of fly ash in the construction of roads and embankments has been demonstrated elsewhere and is now gaining acceptance in our country. NTPC **[5]** (National Thermal Power Corporation) has set up fly ash brick manufacturing plants.

(ii) Mines backfills: By filling mines with fly ash, a large quantity of sand can be saved. Coal recovery also can be enhanced.

(iii) Road construction: a layer of compact pond fly ash can be used at the intersection of sub-grade soil. The addition of lime fly ash to soil decreases dry density and the strength of soil shows improvement.

(ii)Agriculture: Indian fly ash being alkaline, improves soil fertility. Fly ash composition is close to soil composition except for the elements carbon and nitrogen. Being porous, fly ash can give micronutrients (K, Ba, Zn, Fe, Cu, Ca) to the soil, improving its fertility **[6]**. When porous globules of fly ash are buried around a crop, they retain water for a long time leading to an increase in crop yield (10-40%). Fly ash and chemical fertilizers mixed in equal proportions were found to improve the yield of grain and fodder **[7]**. If the soil is acidic, fly ash can increase its pH. Along with bio-waste, fly ash supplemented as fertilizer, resulting in increased crop yield. Though fly ash amendment of soil can lead to accumulation of heavy elements like As, Se, etc., research shows that only marginal variation in their levels are observed and hence the technology is safe for humans**[8]**.

Floriculture: Research work in TERI **[9,10]** showed that by adding suitable organic matter and symbiotic fungi, fly ash dumps can be reclaimed, suggesting the commercial viability of such activities. They have successfully reclaimed a part of an ash pond at the Badarpur Thermal Power Station by introducing a mycorrhizal fungi-based organic bio-fertilizer. As the fungus germinates, it sustains on the partner plant and quickly spreads to the roots and beyond. It improves the plant's water and nutrient uptake, helps in the development of roots and soil-binding, stores carbohydrates and oils for use when needed, protects the plants from soil-borne diseases, and detoxifies contaminated soils**[11]**. This helps in keeping both air and water pollution under control. It can also help to revive wastelands and save a large quantity of precious water from going down the fly ash slurries. Many flower plants and commercially valuable trees like poplar, Sheesham, and eucalyptus are now grown at the demonstration site of the power station.

The use of fly ash in agricultural applications has been demonstrated and is being adopted by many farmers.

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Wood substitute: Fly ash as filler in Jute fiber reinforced hybrid composite results in a product, which substitutes for wood used for doors, windows, partitions, ceiling, and furniture. They are durable and cost-effective.

Distemper: The base material white cement is substituted partially with fly ash, resulting in cost reduction. In the Neyveli power plant, interior surfaces of buildings have been coated with this composite.

Asphalt concrete: Fly ash can be used as a cost-effective mineral filler in hot mix asphalt (HMA) paving applications **[12]**, reducing the amount of asphalt drain down in the mix during construction. Fly ash is hydrophobic, reducing the potential for asphalt stripping; the presence of lime in some fly ashes also reduces stripping.

Adsorbents for pollutant gases/dyes in waste streams: In place of commercial activated carbon or zeolites, fly ash can be used for adsorption of gases such as nitrogen and sulfur oxides, organic compounds, and mercury in the air **[13]**; similarly it can also be used for removal of cations, anions, dyes and other organic matters in water. Chemically treated fly ash proves to be more efficient adsorbent for gas and water cleaning. The unburnt carbon in fly ash plays an important role in adsorption capacity. Fly ash was reported to be effective for the removal of methylene blue (MB) from an aqueous solution **[14]**. The suspended solid concentration of a dye effluent sample was reduced 92% by fly ash, due to its high porosity. Removal of malachite green14 and chrome dye from aqueous solutions have also been studied.

Oil pollution in seawater: In their natural state, fly ash particles do not absorb much oil due to their small surface areas and pore sizes. They contain hydrophilic, or water-loving, compounds. This means a bulky, soggy mess is formed when fly ash is placed in the oil-water mixture resulting from wind and wave action on spilled oil. Oil optimized particle surfaces were created using chemical treatment of activated fly ash with sodium hydroxide, resulting in the formation of zeolitic fly ash. Bonded strings from this fly ash attract long-chain hydrocarbons from water-oil mixture and store on their surfaces **[15]**. Similarly fly ash, organically modified using the cationic surfactant, hexadecyltrimethylammonium (HDTMA), could be used to clean crude oil and weathered oil-contaminated seawater (WOCS).

Metallurgy: Fly ash contains about 20-25% aluminum oxide and about 40% SiO2. Value-added products like zeolites and alumina oxide can be separated from fly ash with suitable cost-effective technology.

Zeolite: Al-Si fly ash dissolved in NaOH/KOH. Subsequently, zeolite precipitated. Best quality Na-X zeolite can be obtained. This can be used for the removal of ammonia from wastewater **[16]**. *Alumina*: Using magnetic separation, part of iron oxide was separated from fly ash. Later the fly ash was leached with HCl. To the leached liquor, ammonia was added to precipitate hydroxides of alumina and iron; this precipitate was heated at dehydrated at high temperature (1100 °C) to obtain a mixed powder of iron and aluminum oxides. Under optimum conditions (HCl 6 N, (ii) fly ash/ HCl acid (ml) ratio 1:4, leaching at 107 °C, for 5 h., iron oxide and aluminium oxide were recovered (63% /73%) **[17]**. In another report **[18]**, Aluminum was leached out from coal fly ash by the pressure acid-leaching method. Fly ash with the size of 74 µm and concentric sulfuric acid are mixed in a pressure reaction kettle to react for 4 h at 180°C. Under the optimal conditions, the fly ash can extract nearly 82.4%.of aluminum.

Carbon: Separation of unburnt carbon from fly ash (and produce activated carbon). Separation of unburned carbon from fly ash is an efficient way to achieve higher efficiency in the utilization of waste fly ash and greater economic and environmental benefits. Sieving, gravity separation, electrostatic separation, froth flotation, and oil agglomeration are latest methods for separating unburned carbon from fly ash. The recycling process was developed to remove and recover unburned carbon from fly ash using kerosene extraction **[19]**. The content of unburned carbon decreased successfully to less than 3% under the following conditions; 15 min in shaking time, 10% in pulp density, 30 °C in temperature, 200 rpm in shaking speed, and 0.5 in O/S ratio.

Mosquito control: Fly ash is a carrier for Bti (derived from microbial cultures), a biopesticide for killing larvae of mosquitoes, containing 1% carboxymethyl cellulose **[20]**. (IJMR).

Coatings for concrete structures: Fly ash coated with stearic acid rolled off a surface or stuck to the surface depending on coating **[21]**. When Fly ash was coated with stearic acid before coating on the surface, the surface was like Lotus leaf -water repellent. When Fly ash was deposited on the surface and then coated with stearic acid, the surface was water attractive- like a rose petal. This finding will be useful for developing water repellent coating/paints.

CONCLUSION:

Due to the high rate of utilization of fossil fuels like coal for power generation all over the world, a huge quantity of fly ash is produced. The utilization of this ash to the maximum extent possible will reduce adverse effects on the environment, such as pollution of water, air, and soil. The use of Fly ash in cement leads to saving of energy and reduction of greenhouse emission. As fly ash bricks are produced at low temperature compared to clay bricks produced at high temperature. in kilns, leading to less power consumption. Currently, new targets such as heavy metal recovery, and floriculture have been identified. Due to the decelerating real estate industry, it is necessary to identify new areas of utilization of fly ash in the Indian context, such as the production of high added value products such as aluminum oxide and silicon oxide, and ceramic fibers.

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