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RESEARCH ARTICLE

# FLY ASH: CHEMICAL OVERVIEW

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ABSTRACT

Today, electricity is a vital part of functioning as a society. Thermal power plant produces electricity and furthermore it produces secondary products in the form of different types of ash. The difference between a secondary product and waste is that the secondary product is generally both usable and not dangerous to people and the environment. Important however, is that technical and environmental properties of the secondary products are evaluated to the specific application. In many cases it saves a lot of energy, a lot of money and solution to environmental pollution problems, to use a recycled material instead of conventional ones.



## INTRODUCTION

The use of electricity has been an essential part of the nation's economy. Coal power, an established electricity source that provides vast quantities of inexpensive, reliable power has become more important as supplies of oil and natural gas diminish[1]. When burning of hard coal for power generation in a boiler takes place heat, flue gases and ash are produced.

### *Importance of coal in power generation*

Coal has played a major role in electrical production since the first power plant that was built in the United States in the1880's. The earliest power plants used hand fed wood or coal to heat a boiler and produce steam. This steam was used in reciprocating steam engines which turned generators to produce electricity. In 1884, the more efficient high speed steam turbine was developed by British engineer Charles A. Parsons which replaced the use of steam engines to generate electricity.
In the 1920s, the pulverized coal firing was developed. This process brought advantages that included a higher combustion temperature, improved thermal efficiency and a lower requirement for excess air for combustion. In the 1940s, the cyclone furnace was developed. This new technology allowed the combustion of poorer grade of coal with less ash production and greater overall efficiency. Presently, coal power is still based on the same methods started over 100 years ago, but improvements in all areas have brought coal power to be the inexpensive power source used so widely today[41].

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### *Coal formation process & Types of coal*

The majority of fossils recovered in Cape Breton can be traced to coal areas or coal fields. Fossils have been found ranging from whole or partial tree trunks and branches to shrubs and vine growth. Evolution dates back to pre-historic times – to approximately 325 million years ago when the region was covered in lush, dense vegetation. Coal beds consist of altered plant remains. When forested swamps died, they sank below the water and began the process of coal formation. However, more than a heavy growth of vegetation is needed for the formation of coal. The debris must be buried, compressed and protected from erosion. Even though all the biological, geographic and climatic factors may be favourable, coal could not be formed unless the plant debris was submerged and buried by sediments. There are four stages in coal formation: peat, lignite, bituminous and anthracite. The stage depends upon the conditions to which the plant remains are subjected after they were buried - the greater the pressure and heat, the higher the rank of coal. Higher-ranking coal is denser and contains less moisture and gases and has a higher heat value than lower-ranking coal.

### Stage One – Peat

Peat is the first stage in the formation of coal. Normally, vegetable matter is oxidized to water and carbon dioxide. However, if plant material accumulates underwater, oxygen is not present and so only partial decomposition occurs. This incomplete destruction leads to the accumulation of an organic substance called peat. Peat is a fibrous, soft, spongy substance in which plant remains are easily recognizable. It contains a large amount of water and must be dried before use. Therefore, it is seldom used as a source of heat. Peat burns with a long flame and considerable smoke.

**Stage Two – Lignite**

Lignite, the second stage, is formed when peat is subjected to increased vertical pressure from accumulating sediments. Lignite is dark brown in colour and, like peat, contains traces of plants. It is found in many places but is used only when more efficient fuel is not available. It crumbles easily and should not be shipped or handled before use.

**Stage Three– Bituminous Coal**

Bituminous Coal is the third stage. Added pressure has made it compact and virtually all traces of plant life have disappeared. Also known as "soft coal", bituminous coal is the type found in Cape Breton and is our most abundant fuel. It is greatly used in industry as a source of heat energy.

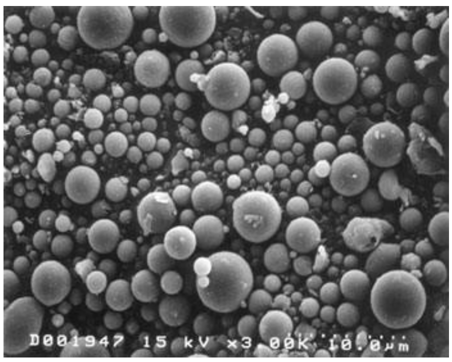
**Stage Four – Anthracite**

Anthracite, the fourth stage in coal formation, is also known as "hard coal" because it is hard and has a high luster. It appears to have been formed as a result of combined pressure and high temperature. Anthracite burns with a short flame and little smoke[42].

**Fly Ash**

Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. The heaviest and largest ash particles fall down in the furnace, and are called bottom ash, and are usually extracted below the furnace. The particles of the bottom ash are generally large and often have a certain amount of unburned organic material in it, often it is wetted in the process. The smaller ash particles are suspended in the flue gases, are removed through Electrostatic precipitators, Bag filters, flue gas desulphurization etc and remaining fly ash leave the plant with flue gases from stack. The lighter and smaller particles of ash caught in Electrostatic precipitators (filter), this ash is called fly ash.

As per Indian Government notification of November 2008, the term “fly ash” means and includes all categories or groups of coal or lignite ash generated at the thermal power plant such as Electrostatic Precipitator (ESP) ash, dry fly ash, bottom ash, pond ash and mound ash. ESP ash and dry fly ash are the components of fly ash collected by ESPs or bag filters or other similar suitable equipment and bottom ash is the ash collected separately at the bottom of the boiler. Pond ash and mound ash are the mixture of ESP ash or dry fly ash and bottom ash. Fly ash is vitreous to its structure, and contains pozzolanic materials. The burning temperature is important for the quality of the ash. A higher combustion temperature gives a more vitreous ash with finer particles, causing the ash to be more efficient as a binding agent. Hard coal is usually combusted at around 1300°C, and bio fuels at a slightly lower temperature, around 800°C. This is one of the reasons why bio ash usually has a lower stabilizing effect than hard coal ash. The pozzolanic materials in the ash react with water and CaO, both from the lime and from the cement. It forms similar products as in the cement reactions. Since the pozzolanic reactions are very slow, the strength caused by ash is also very slow. The size and the rate of the strength increase are mainly determined by the chemical composition of the fly ash. It can vary significantly from ash to ash since fuel, combustion and combustion technology are the main factors deciding the quality of ash.Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipments before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide ($SiO_2$) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata. Toxic constituents depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent: arsenic, beryllium, boron, cadmium, chromium, chromium VI, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds.[40][2] In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now require that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43 percent is recycled,[3] often used to supplement Portland cement in concrete production. Some have expressed health concerns about this.[4] Coal fly ash has been shown to have no toxic or ecotoxic properties. No significant impact on either human health or on the environment has been found after laboratory testing or during on-site monitoring. Therefore, the gathered knowledge about fly ash from coal-fired power plants and the fact that coal fly ash is listed as non hazardous in the European Union lead to the conclusion that the entry of coal fly ash in list A of the Basel Convention is unjustified and should be deleted. UNIPEDE/*EURELECTRIC* is convinced that coal fly ash should be properly listed as non-hazardous, List B, waste under the Basel Convention.[39]




**Structure of fly ash particles by Scanning Electron Microscope**

**Classification of fly ash**

Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).[7] Not all fly ashes meet ASTM C618 requirements, although depending on the application, this may not be necessary. Ash used as a cement replacement must meet strict construction standards, but no standard environmental regulations have been established in the United States as well in India. 75% of the ash must have a fineness of 45 µm or less, and have a carbon content, measured by the loss on ignition (LOI), of less than 4%. In the U.S., LOI needs to be under 6%. The particle size distribution of raw fly ash is very often fluctuating constantly, due to changing performance of the coal mills and the boiler performance. This makes it necessary that, if fly ash is used in an optimal way to replace cement in concrete production, it needs to be processed using beneficiation methods like mechanical air classification. But if fly ash is used also as a filler to replace sand in concrete production, unbeneficiated fly ash with higher LOI can be also used. Especially important is the ongoing quality verification. This is mainly expressed by quality control seals like the Bureau of Indian Standards mark or the DCL mark of the Dubai Municipality.

## Class F fly ash

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively, the addition of a chemical activator such as sodium silicate (water glass) to a Class F ash can lead to the formation of a geopolymer.

## Class C fly ash

Fly ash produced from the burning of younger lignite or subbituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate ($SO_4$) contents are generally higher in Class C fly ashes. At least one US manufacturer has announced a fly ash brick containing up to 50 percent Class C fly ash. Testing shows the bricks meet or exceed the performance standards listed in ASTM C 216 for conventional clay brick; it is also within the allowable shrinkage limits for concrete brick in ASTM C 55, Standard Specification for Concrete Building Brick. It is estimated that the production method used in fly ash bricks will reduce the embodied energy of masonry construction by up to 90%.[8] Bricks and pavers were expected to be available in commercial quantities before the end of 2009.[9]

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 100 µm. They consist mostly of silicon dioxide ($SiO_2$), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminium oxide ($Al_2O_3$) and iron oxide ($Fe_2O_3$). Fly ashes are generally highly heterogeneous, consisting of a mixture of glassy particles with various identifiable crystalline phases such as quartz, mullite, and various iron oxides.

## Chemical composition of fly ash

| Component | Bituminous | Sub bituminous | Lignite |
|---|---|---|---|
| $SiO_2$ (%) | 20-60 | 40-60 | 15-45 |
| $Al_2O_3$ (%) | 5-35 | 20-30 | 20-25 |
| $Fe_2O_3$ (%) | 10-40 | 4-10 | 4-15 |
| CaO (%) | 1-12 | 5-30 | 15-40 |
| LOI (%) | 0-15 | 0-3 | 0-5 |

Fly ash also contains environmental toxins in significant amounts, including arsenic (43.4 ppm); barium (806 ppm); beryllium (5 ppm); boron (311 ppm); cadmium (3.4 ppm); chromium (136 ppm); chromium VI (90 ppm); cobalt (35.9 ppm); copper (112 ppm); fluorine (29 ppm); lead (56 ppm); manganese (250 ppm); nickel (77.6 ppm); selenium (7.7 ppm); strontium (775 ppm); thallium (9 ppm); vanadium (252 ppm); and zinc (178 ppm).[5] The above concentrations of trace elements vary according to the kind of coal burnt to form it. In fact, in the case of bituminous coal, with the notable exception of boron, trace element concentrations are generally similar to trace element concentrations in unpolluted soils.[6]

## Disposal of Fly Ash

In the past, fly ash produced from coal combustion was simply entrained in flue gases and dispersed into the atmosphere. This created environmental and health concerns that prompted laws which have reduced fly ash emissions to less than 1 percent of ash produced. Worldwide, more than 65% of fly ash produced from coal power stations is disposed of in landfills and ash ponds.

## Environmental problem of Fly Ash

### Present production rate of fly ash

In India 110 million tons of fly ash are produced annually by 85 coal-fired power plants.

### Groundwater contamination

Since coal contains trace levels of arsenic, barium, beryllium, boron, cadmium, chromium, thallium, selenium, molybdenum and mercury, its ash will continue to contain these traces and therefore cannot be dumped or stored where rainwater can leach the metals and move them to aquifers.[31]

### Spills of bulk storage

Where fly ash is stored in bulk, it is usually stored wet rather than dry so that fugitive dust is minimized. The resulting impoundments (ponds) are typically large and stable for long periods, but any breach of their dams or bunding will be rapid and on a massive scale.

## Contaminants

Fly ash contains trace concentrations of heavy metals and other substances that are known to be detrimental to health in sufficient quantities. Potentially toxic trace elements in coal include arsenic, beryllium, cadmium, barium, chromium, copper, lead, mercury, molybdenum, nickel, radium, selenium, thorium, uranium, vanadium, and zinc. Approximately 10 percent of the mass of coals burned in the United States consists of unburnable mineral material that becomes ash, so the concentration of most trace elements in coal ash is approximately 10 times the concentration in the original coal.[33] A 1997 analysis by the U.S. Geological Survey (USGS) found that fly ash typically contained 10 to 30 ppm of uranium, comparable to the levels found in some granitic rocks, phosphate rock, and black shale.[33] In 2000, the United States Environmental Protection Agency (EPA) said that coal fly ash did not need to be regulated as a hazardous waste.[34] Studies by the U.S. Geological Survey and others of radioactive elements in coal ash have concluded that fly ash compares with common soils or rocks and should not be the source of alarm.[33] However, community and environmental organizations have documented numerous environmental contamination and damage concerns.[35][36][37] A revised risk assessment approach may change the way coal combustion wastes (CCW) are regulated, according to an August 2007 EPA notice in the Federal Register.[38] In June 2008, the U.S. House of Representatives held an oversight hearing on the Federal government's role in addressing health and environmental risks of fly ash.[39]

## Exposure concerns

Crystalline silica and lime along with toxic chemicals are among the exposure concerns. Although industry has claimed that fly ash is "neither toxic nor poisonous," this is disputed. Exposure to fly ash through skin contact, inhalation of fine particle dust and drinking water may well present health risks. The National Academy of Sciences noted in 2007 that "the presence of high contaminant levels in many CCR (coal combustion residue) leachates may create human health and ecological concerns." [40] Fine crystalline silica present in fly ash has been linked with lung damage, in particular silicosis. OSHA allows 0.10 $mg/m^3$, (one ten-thousandth of a gram per cubic meter of air).Another fly ash component of some concern is lime (CaO). This chemical reacts with water ($H_2O$) to form calcium hydroxide [$Ca(OH)_2$], giving fly ash a pH somewhere between 10 and 12, a medium to strong base. This can also cause lung damage if present in sufficient quantities.In a study by NIOSH at a cement company, crystalline silica exposures from fly ash were determined to be of no concern. For maintaining a safe workplace emphasis must be placed on maintaining low nuisance dust levels and to use the appropriate personal protective equipment (PPE).

## Reuse of Fly Ash

The recycling of fly ash has become an increasing concern in recent years due to increasing landfill costs and current interest in sustainable development. As of 2005, U.S. coal-fired power plants reported producing 71.1 million tons of fly ash, of which 29.1 million tons were reused in various applications.[10] If the nearly 42 million tons of unused fly ash had been recycled, it would have reduced the need for approximately 27,500 acre·ft (33,900 dam³) of landfill space.[10][11] Other environmental benefits to recycling fly ash includes reducing the demand for virgin materials that would need quarrying and substituting for materials that may be energy-intensive to create such as Portland cement. As of 2006, about 125 million tons of coal-combustion byproducts, including fly ash, were produced in the U.S. each year, with about 43 percent of that amount used in commercial applications, according to the American Coal Ash Association Web site. As of early 2008, the United States Environmental Protection Agency hoped that figure would increase to 50 percent as of 2011.[12] There is no U.S. governmental registration or labelling of fly ash utilization in the different sectors of the economy - industry, infrastructures and agriculture. Fly ash utilization survey data, acknowledged as incomplete, are published annually by the American Coal Ash Association.[13]

## Fly Ash utilised by

### 1) Portland cement

Owing to its pozzolanic properties, fly ash is used as a replacement for some of the Portland cement content of concrete.[18] The use of fly ash as a pozzolanic ingredient was recognized as early as 1914, although the earliest noteworthy study of its use was in 1937.[19] Before its use was lost to the Dark Ages, Roman structures such as aqueducts or the Pantheon in Rome used volcanic ash (which possesses similar properties to fly ash) as pozzolan in their concrete.[20] As pozzolan greatly improves the strength and durability of concrete, the use of ash is a key factor in their preservation. Use of fly ash as a partial replacement for Portland cement is generally limited to Class F fly ashes. It can replace up to 30% by mass of Portland cement, and can add to the concrete's final strength and increase its chemical resistance and durability. Recently concrete mix design for partial cement replacement with High Volume Fly Ash (50 % cement replacement) has been developed.

For Roller Compacted Concrete (RCC)[used in dam construction] replacement values of 70% have been achieved with processed fly ash at the Ghatghar Dam project in Maharashtra, India. Due to the spherical shape of fly ash particles, it can also increase workability of cement while reducing water demand.[21] The replacement of Portland cement with fly ash is considered by its promoters to reduce the greenhouse gas "footprint" of concrete, as the production of one ton of Portland cement produces approximately one ton of $CO_2$ as compared to zero $CO_2$ being produced using existing fly ash. New fly ash production, i.e., the burning of coal, produces approximately twenty to thirty tons of $CO_2$ per ton of fly ash. Since the worldwide production of Portland cement is expected to reach nearly 2 billion tons by 2010, replacement of any large portion of this cement by fly ash could significantly reduce carbon emissions associated with construction, as long as the comparison takes the production of fly ash as a given.

### 2) Embankment

Fly ash properties are somewhat unique as an engineering material. Unlike typical soils used for embankment construction, fly ash has a large uniformity coefficient consisting of clay-sized particles. Engineering properties that will affect fly ash's use in embankments include grain size distribution, compaction characteristics, shear strength, compressibility, permeability, and frost susceptibility.[21] Nearly all fly ash used in embankments are Class F fly ashes.

### 3) Soil stabilization

Soil stabilization is the permanent physical and chemical alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load-bearing capacity of a sub-grade to support pavements and foundations. Stabilization can be used to treat a wide range of sub-grade materials from expansive clays to granular materials. Stabilization can be achieved with a variety of chemical additives including lime, fly ash, and Portland cement, as well as by-products such as lime-kiln dust (LKD) and cement-kiln dust (CKD). Proper design and testing is an important component of any stabilization project. This allows for the establishment of design criteria as well as the determination of the proper chemical additive and admixture rate to be used to achieve the desired engineering properties. Benefits of the stabilization process can include: Higher resistance (R) values, Reduction in plasticity, Lower permeability, Reduction of pavement thickness, Elimination of excavation - material hauling/handling - and base importation, Aids compaction, Provides “all-weather” access onto and within projects sites. Another form of soil treatment closely related to soil stabilization is soil modification, sometimes referred to as “mud drying” or soil conditioning. Although some stabilization inherently occurs in soil modification, the distinction is that soil modification is merely a means to reduce the moisture content of a soil to expedite construction, whereas stabilization can substantially increase the shear strength of a material such that it can be incorporated into the project’s structural design. The determining factors associated with soil modification vs soil stabilization may be the existing moisture content, the end use of the soil structure and ultimately the cost benefit provided. Equipment for the stabilization and modification processes include: chemical additive spreaders, soil mixers (reclaimers), portable pneumatic storage containers, water trucks, deep lift compactors, motor graders.

### 4) Flowable fill

Fly ash is used as a component in the production of flowable fill (also called controlled low strength material, or CLSM), which is used as self-leveling, self-compacting backfill material in lieu of compacted earth or granular fill. The strength of flowable fill mixes can range from 50 to 1,200 lbf/in² (0.3 to 8.3 MPa), depending on the design requirements of the project in question. Flowable fill includes mixtures of Portland cement and filler material, and can contain mineral admixtures. Fly ash can replace either the Portland cement or fine aggregate (in most cases, river sand) as a filler material. High fly ash content mixes contain nearly all fly ash, with a small percentage of Portland cement and enough water to make the mix flowable. Low fly ash content mixes contain a high percentage of filler material, and a low percentage of fly ash, Portland cement, and water. Class F fly ash is best suited for high fly ash content mixes, whereas Class C fly ash is almost always used in low fly ash content mixes.[21][22]

### 5) Asphalt concrete

Asphalt concrete is a composite material consisting of an asphalt binder and mineral aggregate. Both Class F and Class C fly ash can typically be used as a mineral filler to fill the voids and provide contact points between larger aggregate particles in asphalt concrete mixes. This application is used in conjunction, or as a replacement for, other binders (such as Portland cement or hydrated lime). For use in asphalt pavement, the fly ash must meet mineral filler specifications outlined in ASTM D242. The hydrophobic nature of fly ash gives pavements better resistance to stripping. Fly ash has also been shown to increase the stiffness of the asphalt matrix, improving rutting resistance and increasing mix durability.[21][23]

### 6) Geopolymers

Fly ash has been used as a component in geopolymers, where the reactivity of the fly ash glasses is used to generate a binder comparable to a hydrated Portland cement in appearance and properties, but with possibly reduced $CO_2$ emissions.[24] It should be noted that when the total carbon footprint of the alkali required to form geopolymer cement is considered, including the calcining of limestone as an intermediate to the formation of alkali, the net reduction in total $CO_2$ emissions may be negligible. Moreover, handling of alkali can be problematic and setting of geopolymer cements is very rapid (minutes versus hours) as compared to Portland cements, making widespread use of geopolymer cements impracticle at the ready mix level.

### 7) Bricks

Fly ash bricks gain strength as they age. In India fly ash is being used to make fly ash bricks. Leading manufacturers like Puzzolana Green Bricks have introduced high strength bricks in Delhi- NCR region which can be used like normal bricks. In the United Kingdom fly ash has been used for over fifty years to make concrete building blocks. They are widely used for the inner skin of cavity walls. They are naturally more thermally insulating than blocks made with other aggregates. Ash bricks have been used in house construction in Windhoek, Namibia since the 1970s. There is, however, a problem with the bricks in that they tend to fail or produce unsightly pop-outs. This happens when the bricks come into contact with moisture and a chemical reaction occurs causing the bricks to expand. In May 2007, Henry Liu, a retired 70-year-old American civil engineer, announced that he had invented a new, environmentally sound building brick composed of fly ash and water. Compressed at 4,000 psi and cured for 24 hours in a 150 °F (66 °C) steam bath , then toughened with an air entrainment agent, the bricks last for more than 100 freeze-thaw cycles. Owing to the high concentration of calcium oxide in class C fly ash, the brick can be described as "self-cementing". The manufacturing method is said to save energy, reduce mercury pollution, and costs 20% less than traditional clay brick manufacturing. Liu intended to license his technology to manufacturers in 2008.[25][26] Bricks of fly ash can be made of two types. One type of brick is made by mixing fly ash with about equal amounts of soil and proceeding through the ordinary process of making a brick. This type of formation reduces the use of sand in making bricks. Another type of brick can be made by mixing soil, plaster of paris and fly ash in a definite proportion with water and allowing the mixture to dry. Because it does not need to be heated in a furnace this technique reduces air pollution.

### 8) Waste management

Fly ash, and its alkalinity, may be used to process human waste sludge into fertilizer.[27] Other applications include cosmetics, toothpaste, kitchen counter tops, floor and ceiling tiles, bowling balls, flotation devices, stucco, utensils, tool handles, picture frames, auto bodies and boat hulls, cellular concrete, geopolymers, roofing tiles, roofing granules, decking, fireplace mantles, cinder block, PVC pipe, Structural Insulated Panels, house siding and trim, running tracks, blasting grit, recycled plastic lumber, utility poles and crossarms, railway sleepers, highway sound barriers, marine pilings, doors, window frames, scaffolding, sign posts, crypts, columns, railroad ties, vinyl flooring, paving stones, shower stalls, garage doors, park benches, landscape timbers, planters, pallet blocks, molding, mail boxes, artificial reef, binding agent, paints and undercoatings, metal castings, and filler in wood and plastic products.[11][16][17] Similarly, the Rhenipal process uses fly ash as an admixture to stabilize sewage and other toxic sludges. This process has been used since 1996 to stabilize large amounts of chromium(VI) contaminated leather sludges in Alcanena, Portugal.[28][29]

**Conclusion**

The disposal, management and proper utilization of waste products has become a concern for the scientists and environmentalists. Proper management of solid-waste fly ash from thermal power plants is necessary to safeguard our environment. Because of high cost involved in land and road transportation for the dumping of fly ash, it is advisable to explore all its possible applications. Indian government has taken various steps for the use of fly ash as mandatory vide notification in 1999 and 2003. Wherein directions are given for unit / industry within a radius of 100 Kms from Thermal Power Plants to utilize at least 25% of ash in manufacturing of bricks and blocks, construction of road, construction material, embankments, cement etc and also for the purpose of landfill to reclaim low lying areas including back filling in abandoned mines or pitheads. It is also made mandatory to Thermal power plant authority to make available ash for the purpose of manufacturing ash-based products such as cement, concrete blocks, bricks, panels or any other material or for construction of roads, embankments, dams, dykes etc. Concentrated efforts are needed to utilize fly ash to mitigate the unemployment and environmental pollution problem.

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## REFERENCES

1. http://www.geology.utoledo.edu
2. Human and Ecological Risk Assessment of Coal Combustion Wastes, RTI, Research Triangle Park, August 6, 2007, prepared for the U.S. Environmental Protection Agency
3. American Coal Ash Association www.acaa-usa.org
4. Is fly ash an inferior building and structural material" Science in Dispute. 2003.
5. Figures refer to media values of samples of fly ash from pulverized coal combustion. See Managing Coal Combustion Residues in Mines, Committee on Mine Placement of Coal Combustion Wastes, National Research Council of the National Academies, 2006.
6. EPRI (Project Manager K. Ladwig) 2010, Comparison of coal combustion products to other common materials - Chemical Characteristics, Electric Power Research Institute, Palo Alto, CA
7. "ASTM C618 - 08 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete". ASTM International. 2008.
8. Chusid, Michael; Miller, Steve; & Rapoport, Julie, May 2009, "The Building Brick of Sustainability". The Construction Specifier.
9. Burke, Michael, April 1, 2009, "Coal by-product to be used to make bricks in Caledonia". The Journal Times.
10. American Coal Ash Association. "CCP Production and Use Survey" (PDF). http://www.acaausa. org/PDF/ 2005.
11. U.S. Environmental Protection Agency. "Using Coal Ash in Highway Construction - A Guide to Benefits and Impacts". http://www.epa.gov
12. Robert McCabe (March 30, 2008). "Above ground, a golf course. Just beneath it, potential health risks". The Virginian-Pilot. http://hamptonroads.com/2008.
13. American Coal Ash Association. "Coal Combustion Products Production & Use Statistics". http://acaa.affiniscape.com.
14. Gaarder, Nancy, February 17, 2010, , "Coal ash will fight flooding", Omaha World-Herald.
15. Josephson, Joan, February 13, 2010, , "Coal ash under fire from Portland resident", "ObserverToday".
16. U.S. Federal Highway Administration. "Fly Ash". http://www.fhwa.dot.gov
17. Public Employees for Environmental Responsibility. "Coal Combustion Wastes in Our Lives". http://www.peer.org
18. Scott, Allan N; Thomas, Michael D. A. (January/ February 2007). "Evaluation of Fly Ash From Co-Combustion of Coal and Petroleum Coke for Use in Concrete". ACI Materials Journal (American Concrete Institute) 104 (1): 62–70.
19. Halstead, W. (October 1986). "Use of Fly Ash in Concrete". National Cooperative Highway Research Project 127.
20. Moore, David. The Roman Pantheon: The Triumph of Concrete.
21. U.S. Federal Highway Administration. "Fly Ash Facts for Highway Engineers" (PDF). http://www. fhwa. dot.gov
22. Hennis, K. W.; Frishette, C. W. (1993). "A New Era in Control Density Fill". Proceedings of the Tenth International Ash Utilization Symposium
23. Zimmer, F. V. (1970). "Fly Ash as aBituminous Filler". Proceedings of the Second Ash Utilization Symposium
24. Duxson, P.; Provis, J.L.; Lukey, G.C.; van Deventer, J.S.J. (2007). "The role of inorganic polymer technology in the development of 'Green concrete'". Cement and Concrete Research 37 (12): 1590–1597.
25. Popular Science Magazine, INVENTION AWARDS : A Green Brick, May 2007
26. National Science Foundation, Press Release 07-058, "Follow the 'Green' Brick Road?", May 22, 2007

27. "Toxic Sludge stabilisation for INAG, Portugal". DIRK group. http://www.dirkgroup.com
28. DIRK group (1996). "Pulverised fuel ash products solve the sewage sludge problems of the wastewater industry". Waste management 16 (1-3): 51–57.
29. Chemical & Engineering News, 23 February 2009, "The Foul Side of 'Clean Coal'", p. 44
30. A December 2008 Maryland court decision levied a $54 million penalty against Constellation Energy, which had performed a "restoration project" of filling an abandoned gravel quarry with fly ash; the ash contaminated area waterwells with heavy metals. C&EN/12 Feb. 2009, p. 45
31. "TVA Widows Creek coal waste spill". http://www.sourcewatch.org
32. U.S. Geological Survey (October 1997). "Radioactive Elements in Coal and Fly Ash: Abundance, Forms, and Environmental Significance" (PDF). U.S. Geological Survey Fact Sheet FS-163-97. http://pubs.usgs.gov
33. Environmental Protection Agency (May 22, 2000). "Notice of Regulatory Determination on Wastes From the Combustion of Fossil Fuels". Federal Register Vol. 65, No. 99. p. 32214. http://frwebgate.access.gpo.gov McCabe, Robert; Mike Saewitz (2008-07-19). "Chesapeake takes steps toward Superfund designation of site.". The Virginian-Pilot. http://www.norfolk.com
34. McCabe, Robert, 2008-03-30."Above ground golf course, Just beneath if potential health risks", The Virginian-Pilot,
35. Citizens Coal Council, Hoosier Environmental Council, Clean Air Task Force (March 2000), "Laid to Waste: The Dirty Secret of Combustion Waste from America's Power Plants"
36. Environmental Protection Agency (August 29, 2007). "Notice of Data Availability on the Disposal of Coal Combustion Wastes in Landfills and Surface Impoundments" (PDF). 72 Federal Register 49714. http://edocket.access.gpo.gov
37. House Committee on Natural Resources, Subcommittee on Energy and Mineral Resources (June 10, 2008). "Oversight Hearing: How Should the Federal Government Address the Health and Environmental Risks of Coal Combustion Wastes?". http://resourcescommittee.house.gov.
38. Union of the Electricity Industry EURELECTRIC association of Europe, October 1999,Fly ash from coal fired power plants, A non Hazardous material, Residue Task Force. http://www.eurelectric.org.
39. Managing Coal Combustion Residues in Mines, Committee on Mine Placement of Coal Combustion Wastes, National Research Council of the National Academies, 2006
40. http://starfire.ne.uiuc.edu
41. http://www.minersmuseum.com/educational_resources/Coal%20Formation%20Text.pdf


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