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Disposal and Management of Flyash

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***Abstract*—In recent decades, the industrialization and urbanization are the two phenomena that are going unabated all over the world. Apart from the need for these phenomena, one has to look into their negative impacts on the global environment and social life. Most important ill effect of these global processes has been the generation of large quantities of industrial wastes. Therefore, the problems related with their safe management and disposal has become a major challenge to environmentalists and scientists. Second related problem is the pressure on land, materials and resources to support the developmental activities, including infrastructure.**

The thermal power plants generate significantly large quantities of solid byproduct namely flyash. At present, the disposal of generated flyash is by either wet disposal or dry disposal. It is *also* extensively used for a variety of construction materials. However, there is a need to address the problems encountered during the disposal or reuse flyash in construction materials.

An attempt has been made in this present paper to highlight on the pollution hazards due to the disposal of flyash into the environment and its utilization in civil engineering activities, their possible remedies and the research and development needed to address the above stated issues. The main topics covered in the present paper are flyash quantification and *characterization* in terms of physicochemical and mineralogical analysis and the classification of flyash; pollution problems due to flyash disposal systems, utilization of flyash in various construction activities and problems encountered during reuse and storage of flyash and its possible remedial measures. The scope of this paper is limited to flyash from thermal power plants. Bottom ash and slag as well as flyash generated from other industrial sources are beyond the scope of this paper.

Keywords-flyash; environmental hazards; thermal power plants

I. INTRODUCTION

Industrialization and urbanization are the two world wide phenomena. Though these are the necessity of the society and are mostly inevitable, one has to look into their negative impacts on the global environment and social life. The major ill effect of these global processes is the production of large quantities of industrial wastes and the problems related with their safe management and disposal. Second problem is the scarcity of land, materials and resources for ongoing developmental activities, including infrastructure.

The wastes generated from different industrial processes are of complex characteristics and composition and hence, their safe management and disposal is also intricate and complex. The disposal and storage of these wastes without treatment leads to contamination of surface and groundwater through long term leachate accumulation from the disposal sites and ultimately disturbs the ecological and environmental balance.

Flyash is produced as a result of coal combustion in thermal power plants. Flyash is defined as a heterogeneous mixture of amorphous and crystalline phases and is generally fine powdered ferroaluminosilicate material with Al, Ca, Fe, Na and Si as the predominant elements. Certain elements like B, Mo, S and Se are characteristically enriched in flyash particles [1]. The emission of flyash from the stack into the atmosphere is controlled by particulate devices such as scrubbers, mechanical and electrostatic precipitators (ESP) [2].

II. QUANTIFICATION AND CHARCTERIZATION OF FLYASH

The population explosion and industrial growth are the traits of present day society, which require more electricity generated from the coal based thermal power plants. Coal based thermal power plant installations in India contribute about 70% of the total installed capacity for power generation. In order to meet the growing energy demand of the country, coal based thermal power generation shall continue to play a dominant role in the future also [3].

At present in India, about 120 coal based thermal power plants are producing about 112 million tons of flyash every year. With the increase in demand of power energy and coal being the major source of energy, more and more thermal power plants are expected to be commissioned in near future. As per the estimates, flyash generation is expected to increase to about 170 million tons by 2012 and 225 million tons by 2017 [4].

III. CHARCTERISTICS AND COMPOSITION OF FLYASH

The flyash is characterised by conducting lots of tests in laboratory. The major parameters of physical and chemical characteristics are as follows:

A. Physical Characteristics of Flyash

The physical characteristics of the flyash are listed below

- Size distribution
- Morphology

- Surface area
- Permeability / hydraulic condition
- Specific gravity

B. Chemical Characteristics of Flyash

The major chemical characteristics of the flyash are as follows

- pH
- Solubility
- Leachability
- Toxicity
- Radioactivity

IV. Metal Composition of Flyash

Elemental chemical composition of flyash is highly variable. The variability is directly related to the source of the coal, its pretreatment, and the operation of the plant burning the coal. The chemical composition of the flyash core is nearly overshadowed by the importance of the enriched surface layer.

The major elements in the order of decreasing abundance are; Si, Al, Ca, C, Mg, K, Na, S, Ti, P and Mn. Most of these major elements exist in the core of the flyash which is relatively stable. This is probably because they are not volatilized in the combustion process [5].

Flyash contains large quantities of major impurities such as oxides, hydroxides and sulfates of iron and calcium, as well as significant quantities of hazardous leachable trace elements such as arsenic, boron, cadmium, chromium, manganese, selenium and vanadium [6]. During coal combustion, the organic matter in coal is utilised to produce heat and as a result, the concentrations of trace elements are increased relative to those in the source coal. Several trace elements such as As, Se, Cd, Cr, Ni, Sb, Pb, Sn, Zn and B are enriched by factors of 4–10 in coal combustion by-products [7]. These impurities have a negative impact on flyash utilization due to environmental restrictions.

The major constituents of the flyash are SiO_2, SO_3, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O and TiO_2.

A. Classification of Flyash

Flyash is normally classified into two main categories based on the percentage of CaO and on the type of coal used for burning as class F and class C flyash.

B. Disposal of Flyash

The flyash produced in the thermal power plant needs to be disposed outside the plant premises so that it causes least disturbance to the main plant operation. Two methods are in practice to dispose off the generated flyash. They are wet disposal and dry disposal methods with ash ponds being the most common methods of disposal in India.

C. Metals Associated with Ash Pond

The metals present in flyash are in priority pollutants list as their leaching potentials have been expected to be high. It is recognized that health hazards and environmental impact from thermal power plants result from the mobilization of toxic and radioactive elements from the residues, which in turn mainly depends on meteorological parameters. Contaminated leachates from acidic flyashes can pose the highest toxicity problem for aquatic environments [8]. Non-toxic soluble elements will dissolve first in water or weak acids [9], but long term leaching of toxic trace elements are associated with slow mobility of elements from glass, magnetite and related minerals [10]. Interaction of groundwater and surface water in flyash emplacements will take a long time to remove mobile trace elements from the solid phase. Depending on the hydrogeochemical environment in which the flyash is emplaced or used, the elevated concentrations could be induced over long periods of time and create potential contamination of associated groundwater and surface water systems.

The flyash, which contains the chromium, has toxic and mutagenic properties related to its oxidizing activity [10]. The presence of excess chromium (VI) damages circulatory systems and causes carcinogenic changes. The concern is its bioactivity and biotoxicology, its ability to accumulate in plants, specially its mobility in the environment and its ability to migrate from flyash to water solutions in the common environmental conditions [11].

Flyash, which contains heavy metals like lead (Pb), is of large public concern due to toxicity to animals as well as human beings, especially young children. Lead contaminated soils are wide spread in the environment because of the extensive use of lead in industrial wastes [12].

D. Laws and Legislation of Disposal of Flyash

Historically, wastes have always created a disposal problem. The problem of flyash disposal has assumed such an enormous scale in the country that the Ministry of Environment and Forests (MoEF) issued a regulation on 14 September 1999 specifying normative levels for progressive utilization of flyash. According to the regulation, it is mandatory for the existing (old) and new coal based thermal power plants to utilize 100% of the flyash produced in a stipulated time horizon. The new coal thermal power plants are required to use 100% of the flyash produced within nine years of commencing operation. The old power plants, however, are required to achieve 100% flyash utilization goal within 15 years from the date of issue of the regulation.

V. Flyash Utilization and Problems Encoutered

Flyash from thermal power plants can be considered either as a waste or as a resource yet to be fully utilized. Indian coals have very high ash content. The flyash content of coal used by thermal power plants in India varies between 25 and 45%, with average flyash content being 40%. As a consequence, a large amount of flyash is generated from thermal power plants, causing several disposal related

problems. In spite of initiatives taken by the government, several non governmental and research and development organizations for flyash utilization, the level of flyash utilization in the country was estimated to be less than 10% prior to 1996–97 [13]. Globally, less than 25% of the total annual flyash produced is utilized [14]. However, in Germany, Belgium and Netherlands more than 95% of the total flyash produced during 1996 was reportedly used. In the United Kingdom, flyash utilization was around 50% during 1998. On the other hand, in the USA and China, huge quantities of flyash are produced and its reported utilization levels were about 32% and 40%, respectively during 1995 [15].

A. Flyash used as a Soil Stabilizer

In the application of flyash as highway construction material like soil stabilizer for road bases, the importance is given to the self hardening properties of flyash [16]. However, the majority of flyash stabilization projects implemented by various highway departments have devoted more to the measurement of strength and durability of the material rather than its environmental hazards through the leaching potential from flyash structures and possibility of heavy metals from flyash migrating to groundwater systems, thus, contaminating the drinking water sources [16].

B. Flyash as a Metal Releaser

The amounts of trace metals released from flyash into solution and the rates of release depend on three factors namely [17]:

- The total concentration of elements in the solid phases,
- The distribution of elements in the flyash particles. and
- Incorporation of the elements into secondary solids.

Dudas [18] conducted long term leaching experiments on flyash from a thermal power plant to determine its ion releasing characteristics. The results indicated that initial ion release was largely controlled by the dissolution of various simple discrete inorganic salts admixed with the glassy siliceous flyash particles. The mobilization of metals in flyashes has been reported to be a very slow process.

C. Effect of Flyash as Construction Materials

Flyash, when mixed with cement and water to form concrete, mortar, render or grout, will produce a mixture that releases alkalis into solution. Contact with the wet mixture may cause serious burns and ulceration to eyes or skin. The eyes are particularly vulnerable and damage will increase with contact time. Strong alkaline solutions in contact with the skin tend to damage the nerve endings first, before damaging the skin and therefore, chemical burns can develop without the pain being felt at the time [19].

Mixtures of flyash with cement and water until set, cause irritant dermatitis. Irritant contact dermatitis is due to a combination of the wetness, alkalinity and abrasiveness of the constituent materials. If used outside the declared shelf life of the cement, there may be a risk of allergic dermatitis. Allergic dermatitis is caused mainly by the sensitivity of an individual's skin to soluble chromium released from the cement [19].

VI. SUMAARY AND CONCLUSIONS

The overall summary of this paper are as follows.

- The current world wide production of the flyash is more than 700 million tons.
- In India, about 120 coal based thermal power plants are producing nearly about 112 million tons of coal flyash per annum.
- Indian thermal power plants generate both class F and class C flyash and are disposed in ash ponds or lagoons.
- Flyash is a potential source of pollution not only for the atmosphere but also for the other components of the environment. Deposition in storage places can have negative influences on water and soil because of their granulometric and mineral composition as well morphology and filtration properties.
- Flyash is now recognized as valuable substances which confers certain desirable characteristics in its many applications.
- Utilization of flyash is already well established in various construction and waste solidification and stabilization process.
- The flyash utilization rate in the construction field is 38%. Remaining portions of the flyash stored in pond and pollute the environment of the region.

There is urgent need to undertake research and development for studying the metal speciation and the changes associated with flyash reuse in the construction purposes and during the wet storage of flyash in ash ponds.

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