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Utilization in agricultural and related fields; a better alternative for ecofriendly maintenance of Coal Fly Ash

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ABSTRACT

With the rising energy demand and dependence on coal for power generation management of large volumes of coal fly ash (CFA) produced in thermal power plants is one of the challenging issues to the country along with other environmental aspects. An ecofriendly solution of the problem is the logical necessity of today. After the large scale efforts at various levels in India the percent utilization of total generated CFA of thermal power plants is increasing. Researches till date show that it has immense potentiality in agriculture and related fields as an additive or soil ameliorating material which is a promising indication for sustainable growth and development for a country like India and ecofriendly maintenance of CFA generated in large volumes in such an economic way. The present paper deals with various aspects of utilization of CFA in agriculture and related fields.

Keywords: Coal Fly Ash, ecofriendly, Thermal Power Plants, agriculture and related fields, ameliorating material.

INTRODUCTION

Disposal of enormous quantity of coal fly ash (CFA) generated regularly from the Thermal Power Stations (TPSs) has been a matter of national concern and point of attention to the technologists in the country. Major drawbacks of converting coal into useful form of energy, is generation of huge quantity of CFA. Nearly 73% of India's total installed power generation capacity is thermal of which coal based generation is nearly 90%. The 85 utility TPSs, in addition to several Captive Power Plants, use bituminous coal and produce large volumes of CFA. Coal constitutes one of the prime sources of energy in India and number of other countries where huge coal reserves are available.

Coal available for use in TPSs in the country carries 30 to 50 percent of ash. Disposal of ash from such TPSs is a challenging issue particularly in situations when available land area for disposal are limited and lies in the vicinity of urban and potential agricultural belts. Further the inherent nature of ash brings adverse effects to the environment and ecological features of the region.

Researches till date prove that Indian CFA is safer than those produced in other countries especially on account of lower content of sulphur, heavy/toxic elements and radio nuclides, however management of large volumes produced poses a big challenge to the country.

At present more than 90 million tones of CFA is being generated annually in India and nearly 65000 acres of land is presently occupied by ash ponds. The ash produced in TPSs can cause all three environmental risks-air, water and ground (land) and spoils the aesthetics of the locality. Therefore environment friendly maintenance is the prime necessity of today.

Most of these polluting conditions can be minimized up to permissible level by incorporating engineering measures in the design of ash ponds and continuous monitoring of surface and ground water system, adopting safe handling and disposal methods, using effective filters and collection system by TPSs. Several pilot projects are undertaken in recent years to demonstrate the bulk utilization of CFA. CFA can be utilized in major construction projects such as dams, ash dykes, land fills, roads and pavements, soil stabilization and for other purposes such as brick manufacture, cement industry, rubber industry, dye industry, adsorption, tiles and paint industry, in the preparation of refractories etc. Agriculture and waste land management have also emerged as prime bulk utilization areas for CFA in the country. CFA is low cost adsorbent and also used as a solid heterogeneous catalyst in many chemical reactions [1-21].

CFA is a heterogeneous mixture of amorphous and crystalline phases and is generally considered to be a ferro aluminosilicate mixture with Al, Ca, Fe, K, Na and Si as predominant elements. Particle size greatly influences chemical composition of CFA & how it may affect physical and chemical properties of soil. The pH of CFA can vary from 4.5 to 12.0 depending largely on the S content of the parent coal [22-23].

The chemical and physical properties of CFA are determined by several variables such as coal source, degree of pulverization, design of boiler unit, loading and firing conditions, type of emission control devices, handling and storage methods. Thus higher degree of variation can occur in ash, not only between TPSs but within a single Thermal Power Station also. A change in any of the above factors can result in detectable changes in the properties of the CFA produced. The degree to which any change affects the utilization potential of CFA is a function of the nature and degree of the change and the particular application for the CFA might be used. The physical, geotechnical and chemical parameters to characterize CFA are the same as those for natural soils.

CFA as a material is siliceous and aluminous with pozzolanic properties. It is refractory and generally alkaline in nature, having fineness in the range of 3000-6000 cm^2 gm^{-1}. The fine particles of CFA by virtue of their lightness can become air-borne, if not managed well. In general density of Indian CFA is 1.22-1.40 gm cm^{-3}, colour is whitish grey, pH is 7.5 to 8.20 containing 55-65% silica, 22-28% Al_2O_3, 5-10% Fe_2O_3, 1-1.9% CaO with specific gravity 2.15 [24].

Anthracite, bituminous and lignite coals produce ashes of different compositions. Combustion temperature influences the degree to which many mineral elements may volatilize. Storage methods may affect weathering rates, especially under humid conditions where soluble constituents may be leached.

Use of CFA in Agriculture:
It consists of practically all the elements present in soil except organic carbon and nitrogen and can be utilized as a resource material. Because of the dominance of silt-size particles in CFA, this material may often be substituted for topsoil in surface mine lands, thereby enhancing physical conditions of soil, especially water holding capacity (WHC). It has also been reported by Sharma et al. [25] that the use of excessive quantities of CFA to alter pH can cause increase soil salinity especially with unweathered CFA.

Sharma et al. [25] studied that in the U.S. the average silt content in CFA is about 63.2% while according to Indian Research and Development Agencies in India this content ranges from about 16% (IIT Kharagpur [26]) to 45% (CAS Raichur [27]). Because of their ability to provide essential macro and micronutrients for plant nutrition, CFA are being considered for amending agricultural soils to improve both chemical and physical properties [28-31].

Addition of CFA with soil alters its physical and chemical characteristics mostly in such a way that it becomes more fertile i.e. having positive impact on growth and yield. The researches till date show that it has great potential in agriculture and related fields. Fail and Wochock [32] reported that addition of appropriate quantities of CFA alters the texture of sandy and clayey soil to loamy. The treatment may be applied to both agricultural soils as well as strip mined soils.

Chang et al. [33] and Page et al. [34-35] reported modification in bulk density of soil on CFA application. Experiments carried out by Page et al. [34-35] with calcareous and acidic soils revealed that CFA addition increased the pH of the former from 8.0 to 10.8 and that of the latter from 5.4 to 9.9. Chang et al. [36] observed that an addition of 8% CFA by weight increased the WHC of soil. They also observed that soil hydraulic conductivity improved at lower rates of CFA application but deteriorated when the rate of CFA amendment exceeded 20% in calcareous soils and 10% in acidic soils. Improvement in WHC is beneficial to the plants especially under rain fed agriculture.

In India most of the CFA produced are alkaline in nature. Hence application of these to agriculture soils increases the soil pH. This property of CFA can be exploited to neutralize acidic soils. Jastrow et al. [37], Phung et al. [38] and Elseewi et al. [39] reported that addition of CFA not only improves soil pH but also adds essential plant nutrients to the soil. Effects of CFA on microbial CO_2 evolution from agricultural soil have been reported by Arthur et al. [40]. Ciravolo and Adriano [41] discussed utilization of CFA by crops under green house condition, in ecology and resource development.

From extensive studies carried out by various research and development agencies on varied agro climatic conditions and soil crop combinations with broad objectives of building confidence towards safe disposal and scientific utilization of CFA, it has been shown that CFA has a vast potential for use in agriculture [42-47] .

For agricultural related studies a large number of demonstrative trials executed by different technological institutes and laboratories at various sites in dispersed locations across the country under varied agro–climatic conditions on a spread of crops forestry and horticulture species had brought into focus CFA as an important resource material [48-60].

During late nineties researchers shown a considerable interest regarding CFA utilization, its influence on soil properties and its scope in agriculture and related fields. Vast amounts of CFA accumulating on land surfaces and therefore interacting with the environment. Researchers attempting to convert this waste into wealth by exploring viable avenues for CFA management. Because of the limiting potential of certain CFA and their ability to provide essential micronutrients and macronutrients for plant nutrition, CFA is being considered for amending agricultural soils to improve both chemical & physical properties [61-69].

In conjunction with organic manure and microbial inoculants, CFA can enhance plant biomass production from degraded soils. Revegetation of coal spoil by CFA and pulp and paper mill waste has been reported by Pandya S. R. and et al. [70]. They also reported that when pots containing mine spoil treated with industrial wastes like CFA from Thermal Power Plant and lime sludge from paper mill when planted to soyabean, mung, jowar to evaluate the effects of amendments on the above ground plant biomass and element content of the soil, both the wastes did not cause elemental toxicities to the plants. The results indicated the CFA and lime sludge both are feasible alternatives to lime for treating acidic coaspoil of the region.

It has soil ameliorating properties because of its physical conditions and presence of macro and micronutrients but in long time repeated applications of CFA to the soil may result in hyper accumulation of the heavy metals. According to Saxena M., Chauhan A., Asokan P. [71] the long use of CFA may impart toxicity due to the hyper accumulation of heavy metals in the soil. Their paper deals with biologically modified form of CFA by practicing vermi technology. According to Dwivedi J. [72], CFA is basic in nature and it has good mineral content. Addition of CFA in soil is useful because it increases pH of soil, converts the nutrients in available form, supplies nutrients to soil and it solves disposal problem of CFA. They studied on the effect of CFA amelioration on amino acids and protein content of the seeds of H. annuus.

Rani Krishna and S. Kalpana have investigated that the application of different percentage of CFA and biomodification with organic waste (water hyacinth/grass cuttings+cow dung) resulted in an increase in available nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) in the soil, which altered the physicochemical properties of soil and after deciding the quality and by variation in applied proportion the desirable results for amendment of soil can be obtained [73-78].

A number of studies in the U.S. such as that by Stevens and Dunn [79] reported increase by a unit in pH for every 3.7 tones/hectare of CFA applied to a fine sandy loam. A similar outcome was observed by Mc Callister et al. [80] in a laboratory study in which pH was equally raised by both CFA and agricultural limes. Growth of plants on soils amended with CFA provides an overall benefit due to amelioration of both physical and nutritional constraints of soil. In the study of Stevens and Dunn [79] lint produced by cotton increased by 28% with application of 3.5 tones/hectare of CFA primarily due to the neutralization of acidity. In Australia, dry matter increase of almost 3–fold for clovers *(Trifolium subterraneum)* on media treated with CFA has been reported by Summers R. Clarke M. Pope T. and O' Dea T. [81]. According to Pathan et al. [82-83] a 3–fold increase in water availability in coastal sands mentioned earlier produced up to 4–fold increase in biomass yield of turf grass (*Cynodon dactylon*). Aitken and Bell [84] however, found no improvement in the yield of bean (*Phaseolus vulgaris*) and Rhodes grass (*Chloris gayana*) despite increase in available water of CFA–treated sandy soil, which they attributed to the effects of boron toxicity on grass.

CONCLUSION

A survey of literature clearly reveals that there has been considerable interest and efforts regarding use of CFA as resource material in agriculture and related fields. On addition of CFA the texture of soil changes from clayey to loamy and from sandy clay to loamy clay, pH and conductivity increases. It works as soil modifier and nutrients supplier in cultivation of plants and crops by improving physical and morphological properties of soil, water retention capacity of soil and increasing release of nutrient elements such as Ca, Mg, S, K, Cu, P, Zn etc. Biomodification further increases the efficiency.

As only cost of transportation and labour of mixing is required the technique is cost effective and ecofriendly because no production of harmful byproducts is in reports.

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