Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

Vol. 8	No. 3	pp. 565-569	2009

Review Paper

Feasibility of Coal Fly Ash in Soil Amelioration: An Overview

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Key Words:
Coal fly ash
Fly ash management
Utilization of fly ash
Soil amelioration

ABSTRACT

Fly ash is a noncombustible inorganic part of coal which is generated as a byproduct during coal combustion process in thermal power plants. Utilization of fly ash is important as it poses serious disposal and environmental problems. Fly ash, being rich in various essential and nonessential elements, it can be used in amending soils as a potential resource for agricultural activities. The present paper overviews the feasibility of fly ash in amelioration of soils for physico-chemical properties.

INTRODUCTION

Thermal power plants use pulverized coal as fuel and produce enormous quantities of coal fly ash each year as a byproduct of combustion. In view of high cost of coal fly ash disposal and its serious concern to environmental pollution, gainful utilization of fly ash to maximum extent is of vital importance in fly ash management. Percentage of ash utilization in different countries for various purposes amounts to more than 85% in West Germany, 73% in Denmark, 60% in France and UK, 50% in Poland, 32% in United States, 25% in China and 15% in India (Sinha & Basu 1998). Fly ash has been advocated as a promising material for soil amendment and reclamation of waste lands (Adriano & Weber 2001). Judicious application of fly ash can bring about favourable alteration in the nutrient status of soil, provided all aspects are constantly monitored for overall benefit. Several reviews have been published related to the use of fly ash in agriculture (Adriano et al. 1980, El-Mogazi et al. 1988, Carlson & Adriano 1993, Kumar et al. 2000, Singh & Yunus 2000, Gupta et al. 2002, Zhang et al. 2004). The present paper briefly overviews various aspects of fly ash for soil amelioration under the following headings.

Physical, chemical and mineralogical properties of fly ash: Physical, chemical and mineralogical characterization of fly ash depends on various factors like parent coal, combustion conditions, the efficiency and type of emission control devices and the disposal methods used (Adriano et al. 1980, Carlson & Adriano 1993). Physically, fly ash occurs as very fine particles having an average diameter of <10 µm and has low to medium bulk density, high surface area and light texture (Kumar et al. 2000). Fly ash consists of all the essential elements present in soil except organic carbon, nitrogen and available phosphorus due to volatilization during combustion (Singh & Yunus 2000, Gupta et al. 2007). Fly ash is generally referred as a ferroalluminosilicate mineral with Al, Si, Fe, Ca, K and Na as the predominant minerals and contains high levels of potentially toxic elements like V, Se, As, B, Al, Cd, Pb, Hg and Cr (Kalra et al. 1998, Gupta et al. 2002). Various elements that constitute fly ash are Si, Ca, Mg, Na, K, Cd, Pb, Co, Cu, Fe, Mn, Mo, Ni, Zn, B, F, Ca, and Al (Gupta et al. 2002). This means that fly ash contains most elements required for plant growth and metabolism with exception of nitrogen and available phosphorus (El-Mogazi et al. 1988, Singh & Yunus 2000). pH of fly ash varies from 4.5 to 12.0 depending largely on the sulphur content of the parent coal and the type of coal used for combustion affects the sulphur content of fly ash (Plank & Martens 1974, Page et al. 1979).

Impact of fly ash on soil properties: While considering the utilization of fly ash for plant growth and development, researchers have approached fly ash as particulate matter forming a substrate for plant growth and an additive or modifier when mixed with soils. If these approaches are economically and ecologically feasible, it would facilitate utilization of fly ash in soils. Fly ash has immense potential as a soil ameliorating agent in agriculture, forestry and waste land reclamation because of its heterogenous nature. Previous work to determine the feasibility of converting waste disposal problem into a soil benefication strategy has proven true (Reynolds et al. 1999). Fly ash has been studied extensively as useful soil amending agent with agronomic and environmental benefits (Plank &Martens 1974, Adriano et al. 1980, Elseewi & Page 1984, Zhang et al. 2004). The impact of fly ash on soil largely depends upon the properties of fly ash and soil examined. The physicochemical properties of soil and fly ash are similar in many respects. Therefore, fly ash has a great potential for utilization in agriculture as a soil conditioner and as a provider of macro and micronutrients for plants (Vijayan et al. 1999). As an alternative, fly ash could be used as soil amendment in agriculture as it contains many essential plant nutrients (Summers et al. 1998, Pathan et al. 2004). Amount of heavy metals present in the fly ash is also similar to that of normal soils (Bowen 1979, Vijayan & Behera 1999 b).

Impact of coal fly ash on chemical properties of soil: The mobility of many plant nutrients is influenced by pH, therefore, the relative pH of the fly ash and the soil could determine the available concentrations of these constituents and the beneficial or harmful levels of predominating. Fly ash addition can improve nutrient status of soil and neutralize the soil reaction to a level suitable for agriculture (Moliner & Street 1982). Addition of fly ash improves soil pH and also adds essential nutrients (Jastrow et al. 1979). Fly ash amendment of soils increased the plant production in most cases when nutrient deficiencies are corrected by addition of fly ash (Adriano et al. 1980). Fly ash application is potentially valuable particularly in condition where trace metals are deficient (Gupta et al. 2006). Increase in values of electrical conductivity due to fly ash could suggest that the binding of metal ions occurred readily to soil particles, causing eventual availability or entry of metal nutrients to growing plants (Mishra et al. 2007).

There are several reports on the presence of radionuclides, especially of uranium and thorium series in fly ash. The activity of natural radionuclides from the U^{238} and Th^{232} series in the soil samples did not show significant difference in the concentration within and outside the disposal sites (Bem et al. 1998). The radioactivity analysis showed that the activity levels of gamma emitting radionuclides K^{40}, Ra^{226}, Ac^{228} were within the permissible limits when fly ash was mixed at a rate of 24% (v/v) (Goyal et al. 2002).

Impact of coal fly ash on physical properties of soil: Fly ash addition alters physical properties of soil such as texture, bulk density, water holding capacity and particle size distribution (Chang et al. 1977, Fail & Wochok 1977, Capp 1978, Page et al. 1980, Sharma 1989). Dominance of fine size particles in fly ash may promote better aeration, percolation and water retention in treated zone (Adriano & Weber 2001).

Bulk density of fly ash varies from 1 to 1.7 g cm^{-3}. (Arshad et al. 1996, Kumar et al. 2000). Amendment of fly ash to a variety of agricultural soils tends to decrease bulk density (Page et al. 1979, 1980). The optimum bulk density improves soil porosity, root penetration and moisture retention capacity of soil (Kumar et al. 2000).

Fly ash addition has been reported to alter the texture of sandy and clayey soil to loamy soil (Fail & Wochock 1977, Capp 1978, Mittra et al. 2003). Addition of 8% fly ash increased water holding capacity (WHC) of soil (Chang et al. 1977). Fly ash comprised primarily of fine sand and silt sized particles, so if applied at suitable rates it can be used to change the soil texture to increase soil WHC (Adriano et al. 1980, Aitken et al. 1984, Gangloff et al. 2000). Addition of fly ash to sandy soils has been shown to increase the WHC (Chang et al. 1977, Campbell et al. 1983, Aitken et al. 1984, Ghodrati et al. 1995). Addition of 10 % fly ash increased WHC by factors of 7.2 and 13.5 for fine and coarse sands, respectively (Campbell et al. 1983). Fly ash itself is not effective in retaining water but it significantly increases WHC of soil mixture (Chang et al. 1977).

Impact of coal fly ash on biological properties of soil: Very little is known about the effect of fly ash amendment on soil biological properties (Schutter & Fuhrmann 2001). Several short term laboratory incubation studies found that addition of unweathered fly ash to sandy soils severely inhibited microbial respiration, enzyme activity and soil nitrogen cycling processes such as nitrification and N mineralization (Pichtel 1990, Pichtel & Hayes 1990, Garau et al. 1991). Fly ash-sludge mixtures containing 10% ash had positive effect on soil microorganisms in terms of enzyme activity for urease, dehydrogenase and phosphatase, N and P cycling and reduction in the availability of heavy metals (Lai et al. 1999). A positive correlation between soil microbial activity in terms of rate of CO_2, soil microbial biomass and soil dehydrogenase activity was observed with 10 to 12% fly ash amendment (Jala 2005). Phosphate solubilizing bacteria showed good adaptability in fly ash amended soils (Jala 2005). Fly ash was observed to show a positive effect on soil dehydrogenase activity, bacterial enumeration and microbial biomass at a concentration of 10%.

Impact of coal fly ash on ground water quality: Fly ash contains small amounts of trace and heavy metals which may percolate down the soil profiles and pollute ground water. However, related studies have shown that solubility of these elements is < 10% (Rohriman 1971). Recent research has shown that the quality of groundwater did not change with the fly ash application and all the studied parameters including the trace and toxic metal contents were within permissible limits (Siddiqui et al. 2004). It has been found that heavy metal content of percolating water could be drastically diminished when soils were mixed with fly ash (Ciccu et al. 2001).

CONCLUSION

Most of the industrial wastes or byproducts may act as pollutants, yet some of them may be used profitably in agriculture provided that they are used scientifically and judiciously. Fly ash, a byproduct of coal combustion in thermal power plants has great potential for utilization in agriculture as a soil conditioner and as a provider of macro and micronutrients for plants. Since fly ash characterization depends upon various factors like parent coal and combustion conditions, the dose of fly ash incorporation to varied soils varies significantly. Hence, a number of field experiments have to be carried out for different plants in different soils under varied agroclimatic conditions to establish optimum doses of fly ash for soil amelioration to obtain maximum productivity.

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