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Fly ash for soil amelioration: A review on the influence of ash blending with inorganic and organic amendments

L.C. Ram *, R.E. Masto

Environmental Management Division, Central Institute of Mining and Fuel Research (Digwadih Campus),P.O. F.R.I.-828108, Dhanbad, Jharkhand, India

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ABSTRACT

Globally, fly ash (FA), generated in huge quantities from coal fired power plants is a problematic solid waste. Utilization of FA as an ameliorant for improving soil quality has received a great deal of attention over the past four decades, and many studies have been carried out worldwide. The silt-sized particles, low bulk density (BD), higher water holding capacity (WHC), favorable pH, and significant presence of plant nutrients in FA, make it a potential amendment for soils. The studies suggest enormous potential for the use of FA to improve cultivable, degraded/waste land, mine soil, landfills, and also to reclaim abandoned ash ponds, for agriculture and forestry. FA application improves the physical, chemical and biological qualities of soils to which it is applied. However, in some cases, depending on the characteristics of FA, the release of trace elements and soluble salts from FA to a soil–plant–human system could be a constraint. The effect is minimal in the case of weathered FA. The findings reflected the heterogeneity of ash characteristics, soil types, and agro-climatic conditions, thus a generalized conclusion on the impact of FA on plant species and soil quality is difficult. It is very important that the application of FA to soil must be very specific depending on the properties of the FA and soil. A considerable amount of research has been carried out to blend FA with varieties of organic and inorganic materials, like lime, gypsum, red mud, animal manure, poultry manure, sewage sludge, composts, press mud, vermicompost, biochar, bioinoculants, etc. Co-application of FA with these materials has much advantage: enhanced nutrient availability, decreased bioavailability of toxic metals, pH buffering, organic matter addition, microbial stimulation, overall improvement in the general health of the soil, etc. The performance of FA blending with organic and inorganic materials is better than FA alone treatments. Farm manure was found to be the most promising amendment used along with FA. While using FA in agriculture as a soil ameliorant, it is better to seek the locally available fitting blend materials for exploiting the benefits from their synergistic interaction. However, continuous research in parallel for long durations to dispel apprehension, if any, is desirable under well defined regulatory measures.

Contents

* Corresponding author. Tel.: +91 326 2388357; fax: +91 326 2381113.
E-mail addresses: lcramcimfr.dc@gmail.com (L.C. Ram), mastocfri@yahoo.com (R.E. Masto).

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1. Introduction

Global energy demand is largely (>30%) met by coal fired power plants. World coal production is about 3.5×10^9t/annum (AUA, Australian Uranium Association, 2007). World coal consumption is expected to increase by 49% from 2006 to 2030 as per the projection of International Energy Outlook (International Energy Outlook, IEO, 2009) In India, about 70% of the total energy requirement is met from the combustion of pulverized coal in thermal power plants (TPPs). This practice will continue for a long time into the future in view of the enormous coal reserves in India (Lior, 2010), estimated to be 287.0×10^9t (CIL, Coal India Limited, 2007). Total electricity generation in India is projected to increase to 1483 TWh by 2020 from 500 TWh in 2000 (OECD/IEA, Organisation for Economic Co-operation and Development/InternationalEnergy Agency, 2002). The combustion of coal to generate electricity in TPPs produces solid wastes like fly ash (FA) and bottom ash (BA). The total amount of ashes produced worldwide is enormous, which has been estimated to exceed 750 million t/annum, but only less than 50% of world FA production is utilized (Izquierdo and Querol, 2012). Country wise coal consumption for electricity generation and fly ash generation/utilization are presented in Tables 1a and 1b. The production of 160 Mt in 2007 in India is expected to increase to 300 Mt/year by 2016–17 (Singh et al., 2011a; Skousen et al., 2012). The use of high-ash coal with low calorific value for combustion in power plants, after the fast depletion of better quality coal, would result in a manifold increase in FA generation.

FA generated in huge quantities is being disposed in ash ponds. FA can be utilized as an alternative to other industrial resources, processes, or applications. These include mainly addition to cement and concrete products, structural fill and cover material, roadway and pavement utilization, as a light weight aggregate, infiltration barrier and underground void filling, and soil, water and environmental improvement. The global average utilization of FA is about 25% (Wang, 2008). Thus it is evident that a major proportion of the global FA is unutilized and needs urgent measures to identify potential avenues. In India, FA is utilized as (i) a raw material in cement, cellular concrete, lime bricks, lime gypsum blocks, and building tiles; (ii) admixtures in cement concrete and in products made of timber substitutes; (iii) an aggregate in concrete, roads, and building blocks; (iv) pozzolana in lime mortars and plasters and Portland cement; (v) a stabilizer for soil and for road construction; (vi) a filler in consolidation of ground, land, and mine-filling; and (vii) a soil conditioner and source of plant nutrients in agriculture and forestry. The other potential applications of FA include metal extraction, creation of cenospheres, and wastewater treatment (Asokan et al., 2005). As per CEA (Central Electricity Authority) (2011), in India, the maximum utilization of FA to the extent of 48.50% has been in the cement sector, followed by the reclamation of low lying areas (12.73%), roads and embankments (11.65%), mine filling (8.26%), bricks and tiles (6.3%), agriculture (1.74%), and others (10.82%). Even after application in these sectors, only 55.79% of the total ash generated is utilized (CEA, Central Electricity Authority, 2011). Thus there exists a wide scope and an imperative need to increase the quantum of FA use in each sector. Especially there is a wide scope for soil amendment as the present utilization in this sector is very little. In fact, there exists a great deal of opportunities in view of the vast degraded soil/land available in the world which needs to be reclaimed with suitable amendments. Further, thousands of hectares of land have been occupied for the storage of FA all over the world that could be reclaimed through different plant species (Pandey et al., 2012).

According to UNCCD, 1.9×10^9 ha of lands are degraded. The total land area that is degraded has increased from 15% in 1991 to 25% in 2011 (Gnacadja, 2013). About 1.5 billion ha of land are suitable for restoration by means of agroforestry and agriculture (UNCCD, United Nations Convention to Combat Dessertification, 2012), particularly to meet the requirements of the ever increasing population. The current world population of 7.2 billion is projected to increase by 8.1 billion in 2025 and 9.6 billion in 2050 (UNWPP, United Nations World Population Prospects, 2013). About 99.9% of the human food supply (calories) comes from land; during the last 50 years, global cultivated land per person has gradually declined from 0.44 ha to less than 0.25 ha (FAO, Food and Agriculture Organization of the United Nations, 2013). Thus the reclamation of waste/degraded and non-fertile lands to make them fertile and agriculture-forest worthy is the other current point of focus (Ram and Masto, 2010). Application of FA as a soil ameliorant is a potential area from the considerations of utilizing its huge amount, solving of its environmental concerns, and tapping economic potentials. Numerous studies point to the wider potential of FAs to increase soil productivity and ameliorate degraded land and soils for agriculture or re-vegetation (Mishra and Shukla, 1986a, 1986b; Bhumbla et al., 1991; Saxena et al., 1997; Ram et al., 2006a; Ram et al., 2007a; Ram et al.,

Table 1a
Country wise coal consumption (million tons) by electric plants (in 2009; data source: IEA, International Energy Agency, 2013).

S No	Country	Anthracite	Coking coal	Other bituminous coal	Sub-bituminous coal	Lignite	Peat
1	Australia	–	–	27.40	28.38	644.6	–
2	Canada	–	–	3.58	28.75	10.08	–
3	China	–	0.169	1439.5	–	–	–
4	EU-27	4.21	5.58	115.27	2.02	289.07	4.17
5	India	–	24.19	393.79	–	28.14	–
6	Indonesia	–	–	–	33.52	–	–
7	Japan		–	86.36	–	–	–
8	South Africa	–	–	121.39	–	–	–
9	Turkey	–	0.55	5.781	0.19	62.64	–
10	USA	0.610	–	332.09	438.74	58.04	
	World (total)	19.67	304.87	2722.9	558.2	575.2	4.17