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PR Ramteke
Ph.D Scholar, Department of Soil Science, Dr. PDKV Akola, Maharashtra, India

Puja Mate
Department of Agricultural Botany, College of Agriculture Nagpur, Dr. PDKV Akola, Maharashtra, India

Kantilal Chande
Department of Agricultural Botany, College of Agriculture Nagpur, Dr. PDKV Akola, Maharashtra, India

Krunal Bele
Department of Agricultural Botany, College of Agriculture Nagpur, Dr. PDKV Akola, Maharashtra, India

PP Wani
Ph.D Scholar, Department of Agricultural Economics, Dr. PDKV Akola, Maharashtra, India

Harish Bajad
Department of Soil Science, Dr. PDKV Akola, Maharashtra, India

Corresponding Author:
PR Ramteke
Ph.D Scholar, Department of Soil Science, Dr. PDKV Akola, Maharashtra, India

Soil properties in relation to fly ash utilization in agriculture

PR Ramteke, Puja Mate, Kantilal Chande, Krunal Bele, PP Wani and Harish Bajad

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Abstract
There are the positive and some negative aspect of agricultural utilization of fly ash. Positive aspects namely: Improvement of the nutrient levels, increasing the water holding capacity, texture, reducing the acidity of the soil, use as an insecticide to effectively control various pests infesting several vegetables etc. However, negative aspects namely; toxic heavy metals and radioactive content in fly ash. Negative aspect can be nullified and be helpful in tackling the waste management problem of fly ash. The article will elaborate how soil properties have changed with fly ash utilization.

Keywords: Fly ash, soil physical properties, nutrient status

Introduction
Fly-ash, an end residue from combustion of pulverized bituminous or sub-bituminous coal (lignite), is one of the major causes of particulate air pollutant (Gupta *et al*., 2012) [17]. In India, annual fly ash production is 112 MT, whereas fly ash utilisation is about 38%. Over the past few decades there has been interest in developing strategies to use fly ash in agriculture. It is indeed economical to use fly ash as a soil amendment (Gupta *et al*., 2012) [17]. Various types of residues such as fly ash, bottom ash, and flue gas desulphurization waste, fluidized bed boiler waste and coal gasification ash are produced due to coal combustion. The residues from coal combustion entering the flue gas stream are known as fly ash. Fly ash is also generated by factory boilers, cement industries. The causal of low fly-ash utilization in India is the unavailability of appropriate cost-effective technologies as well awareness among peoples. In India, the majority of fly ash produced is disposed off in ash ponds and landfills and rest of fly ash (<15%) is being used for preparing bricks, ceramics and cements (Pandey *et al*., 2009) [22]. Earlier fly ash was seen as a waste but now time has changed and it is now considered as a valuable resource. Fly ash can be utilized as a soil amendment in agriculture, improving soil texture (Chang *et al*. 1977; Garg *et al*., 2003) [11, 15], improving nutrient status of the soil, wasteland reclamation (Jala and Goyal, 2006) [18] etc. But most of the fly ash still remains in the ash pond, causing many deleterious effects on the environment, resulting in the degradation of land due to accelerated erosion rates and ground water pollution problem.
The physicochemical properties of fly ash depends primarily on the parent coal composition of which it is produced and secondly on its combustion condition (Gupta *et al*., 2012) [17]. Due to varying nature of coal the fly ash characteristics are also changing. Generally Indian coals have a high mineral matter percentage, low sulphur content, high moisture, high ash content and low calorific value of 3,500–4,000 kcal kg^{-1} (Gupta *et al*., 2012) [17]. Ash content of Indian coals varies between 15% and 30% and the S content is generally less than 1% (Srivastava, 2003; Bhatt, 2006) [28, 5]. It is very hard to generalize the composition of ashes. Physically fly ash is very fine glass like particles with an average diameter of less than 10 mm, having low to medium bulk density, large surface area and very light texture where as its chemical composition depends on the parent coal quality and its operating conditions. Fly ash consists of approximately 95–99% oxides of Si, Al, Fe and Ca and about 0.5–3.5% of Na, P, K and S and the remaining ash is trace elements. Typical coal fly ash constituents are SiO_2 (49–67%), Al_2O_3 (16–29%), Fe_2O_3 (4–10%), CaO (1–4%), MgO (0.2–2%), SO_3 (0.1–2%). Some of the important elements constituting fly ash are Si, Ca, Mg, Na, K, Cd, Pb, Cu, Co, Fe, Mn, Mo,

Ni, Zn, B, F and Al (Gupta *et al*., 2012) [17]. So fly ash contains all the important metals needed for plant growth and its metabolism except organic carbon and nitrogen. Fly ash contains very less or no nitrogen as the N present in the coal is volatilized during its combustion (Bradshaw and Chadwick, 1980) [7], however it has high concentration of phosphorous (P) (400– 8,000 mg P kg^{-1}), but the form of P is not readily available to plants, probably due to interactions with Al, Fe and Ca present in alkaline fly ash.

Influence of fly ash utilization on soil properties

Fly ash amendment in soil affects all its physical characteristics such as bulk density, pH, water holding capacity, electrical conductivity etc. The fly ash addition alters soil physical properties such as its texture, bulk density, water holding capacity (Chang *et al*., 1977) [11] and particle size distribution (Sharma, 1989) [25]. Campbell *et al*., (1983) [8] found that fly ash addition at the rate of 10% increased the water holding capacity 7.2 and 413.2 times for fine and coarse sands respectively. The fly ash amendment also stabilizes soil aggregates as it works as soil binders or stabilizers of self cementing material which result in reduced leachable contaminants in the fly ash. The impact of fly ash amendment depends largely on the properties of parent coal and the soil. The electrical conductivity of the soil was increased as a result of fly ash amendment as the levels of soluble major and minor inorganic constituents' increases in soil (Adriano *et al*., 1980; Eary *et al*., 1990; Adriano and Weber, 2001) [2, 12]. The Indian fly ashes are mostly alkaline in nature, hence their application increases the soil pH (Gupta and Sinha, 2006; Pandey *et al*., 2009) [16]. The pH of soil increases as a result of fly ash amendment with its alkaline nature due to rapid release of Ca, Na Al and OH^- from the fly ash (Wong and Wong, 1986) [30]. As fly ash contains hydroxide and carbonate salts it has an ability to neutralize acidity in soils (Pathan *et al*., 2003) [23]. This property of fly ash can be used in neutralizing the acidic soil but using excessive quantities of fly ash for altering soil pH can cause increase in soil alkalinity especially with unweathered fly ash (Sharma *et al*., 1989) [25]. Some fly ashes are acidic in nature which can be used in reclaiming alkaline soils. Soil texture of sandy and clayey soil was altered to loamy soil as a result of fly ash addition at the rate of 70 t/ha (Fail and Wochok, 1977) [14].

A gradual increase in fly-ash amendment in the normal field soil (0%, 10%, 25%, up to 100% v/v) was reported to increase the water holding capacity, electrical conductivity, EC, and pH and (Sinha and Gupta, 2005) [27]. This improvement in water holding capacity is beneficial for the growth of plants especially under rainfed agriculture. Amendment with fly ash up to 40% also increased soil porosity from 43% to 53% and water holding capacity from 39% to 55% (Singh and Siddaqui, 2003) [26]. Generally, the bulk density of soil decreased due to fly ash addition, which in turn decreases porosity and enhanced water holding capacity (Page *et al*., 1979) [21]. The fly ash amendment increases the water holding capacity of sandy and loamy soils by 8% yet fly ash alone, is not very effective in retaining water (Chang *et al*., 1977) [11]. The higher B availability from fly ash limits its use in crop production, by proper weathering of fly ash this problem can be overcome, as it reduces the B availability below the toxic levels (Townsend and Gillham, 1975) [29].

The fly ashes are also rich in heavy metals; the soil chemical property is affected too. As the fly ash contains trace elements as well as heavy metals, it may contaminate the soil. The metals can readily percolate down and contaminate ground water or it may contaminate the nearby water body. Nearly 5–30% of toxic elements present in fly ash, especially Cd, Cu and Pb is leachable (Natusch and Wallace, 1974) [20]. At higher level of fly ash amendment some heavy metals might become more active and hinder the microbial activity (Adriano *et al*., 1978) [3]. Alteration in soil texture has been reported by some workers due to amendment of fly ash in soil (Chang *et al*., 1977; Carlson and Adriano, 1993) [11, 9]

Influence of fly ash utilization on nutrient status of soil

Fly ash usually contains virtually no N and has little plant-available P (Bradshaw and Chadwick, 1980; Singh and Yunus, 2000; Jala and Goyal, 2006; Basu *et al*., 2009) [2, 7, 18]. Application of fly ash to soil may cause P deficiency, even when the ash contains adequate amounts of p because soil P forms insoluble complexes with the Fe and Al in more acidic ashes (Adriano *et al*., 1980) [2] and similarly insoluble Ca-P complexes. Amendment of K-deficient soil with fly ash increases plant K uptake, but the K in fly ash is apparently not as available as fertilizer K, possibly because the Ca and Mg in the fly ash inhibit K absorption by plants (Martens, *et al*., 1970). The pH of fly ash can vary from 4.5 to 12 depending mainly on the S content of the parent coal (Plank and Martens, 1974; Page *et al*., 1979) [21]. The pH of some alkaline ashes can exceed 12 and this may be a factor limiting plant growth, particularly on unweathered deposits (Carlson and Adriano, 1993) [9]. A high pH can induce deficiencies of essential nutrients such as P and essential trace elements such as Fe, Mn, Zn and Cu in plants grown in ash deposits and soils amended with substantial amounts of ash (Cary *et al*., 1983; Carlson and Adriano, 1993) [9]. Application of fly ash to agricultural soil generally results in increased soil concentrations of extractable Ca, Ba, Mo, Se, S, B, Pb, and Cd other elements may also be enriched depending on the rate of its application, type and composition of the soil and properties of the fly ash (Page *et al*., 1979; Adriano *et al*., 1980; Carlson and Adriano, 1993; Bilski *et al*., 1995; Jala and Goyal, 2006; Basu *et al*., 2009) [21, 18, 9, 2]. Fly ash also has been shown to supply essential nutrients to crops on nutrient-deficient soils and has been reported to correct deficiencies of B, Mg, Mo, S and Zn (Carlson and Adriano, 1993; Jala and Goyal, 2006) [9, 18]. The availability of Mg, Mo, S and Zn in some ashes is comparable to the availability of these nutrients in commonly used fertilizers (El-Mogazi *et al*., 1988) [13]. Elevated concentrations of B, Se, As, Mo, Sr and S are commonly reported for plants growing in fly ash or fly ash-amended soil (Adriano *et al*., 1980; Carlson and Adriano, 1993) [2, 9].

Conclusion

fly ash having almost all the essential plant nutrients i.e., macronutrients including P, K, Ca, Mg and S and micronutrients like Fe, Mn, Zn, Cu, Co, B and Mo, except organic carbon and nitrogen. (ii) Its application also increases the soil pH, water holding capacity etc. This will certainly reduce the availability of heavy metals in the soil.

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