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Effect of Fly Ash Application on Soil Properties: A Review

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Abstract: *A large amount of fly ash is being generated now-a-days from coal-based thermal power plants. Fly ash is a residue of burning of coal and lignite, the organic sources of energy. Large amount of fly ash production leads to various environmental problems due to lack of its judicious use and proper disposal. Incorporation of fly ash in agricultural soils is best alternate use or way to dispose it. Use of fly ash applications may improves the soil conductivity, organic carbon contents, water holding capacity, microbial activity, soil porosity and contains essential nutrients. Thus, fly ash can be used to reclaim problematic soils and increase crop productivity depending upon the nature of soil and fly ash. The micro and macro nutrients present in coal get generally concentrated in the ash. It is by virtue of this and the ability of fly ash to modify the physical, chemical and biological properties of soils that it works as a soil conditioner. Hence, fly ash applications in agricultural soils have shown promising results with respect to crop production due its high mineral contents and unique physicochemical properties. This review explores the possibilities of using fly ash to improve soil physic-chemical properties and ultimately the crop production and safe environment by its safe consumption in agriculture.*

Keywords: *Fly ash, Agriculture, Essential nutrients and Soil properties.*

1. INTRODUCTION

Progress in technological sector had a great pressure on our valuable natural resources. Coal is one of the important non-renewable resources, which plays a crucial role in meeting the ever increasing demand for fossil fuels across the world. Combustion of coal results in variety of end products such as fly ash, bottom ash, scrubber sludge, coal gasification gas etc. India is producing about 140 million tons of fly ash every year and a very low amount is utilized from this huge quantity. Fly ash is an amorphous mixture of ferroaluminosilicate minerals generated from combustion of coal at a temperature of 400-1500 ^{0}C. Fly ash is composed predominantly of small, glassy, hollow particles with low to medium bulk density ranging from 2.1 to 2.6 g cm^{-3} (Adriano et al., 1980) with an average diameter of <10 µm, high surface area and light texture which are aggregated into micron and sub-micron spherical particles of sizes ranging from 0.01 to 100 mm (Davison et al., 1974), with smaller particles entrapped within large spheres (Fischer et al., 1976). Approximately 90-99% of fly ash consists of Si, Al, Fe, Ca, Mg, Na and K. Major matrix elements in fly ash are Si and Al together with significant percentage of K, Fe, Ca and Mg. Fly ash contains all naturally- occurring elements and is substantially rich in trace elements like lanthanum, terbium, mercury, cobalt, chromium (Adriano et al., 1980). But while considering about the associated problems of environmental pollution and occupation of large area for its disposal seem to be much more alarming in future. So, we have thought about its safe disposal or utilization. Agricultural use can be possibility of its safe consumption due to nutrients and trace elements in flyash. Field and greenhouse studies both indicate that on account of its heterogenous nature fly ash can benefit plant growth and can improve agronomic properties of soil (Sharma et al., 1990). Fly ash has been advocated as a promising material (or amendment) for reclaiming wastelands or mine spoils (Adriano and Weber, 2001). Application of organic manures in combination with fly ash leads improved microbial activities due presence of favorable environment. Fly ash application also leads to higher buildup of nutrient status of soil. But intensive research is required along with field and laboratory experiments in order to identify the side effects of flyash application such as heavy metal pollution.

2. REVIEW OF WORK DONE:

2.1 Physico-chemical properties of fly ash

The mineralogical, physical and chemical properties of fly ash (Carlson and Adriano, 1993) depends on the nature of parent coal, conditions of combustion, type of emission control devices and storage and handling methods. Therefore, ash produced by burning of anthracite, bituminous and lignite coal has different compositions. Fly ash is an amorphous mixture of ferroaluminosilicate minerals generated from the combustion of ground or powdered coal at 400-1500 ^{0}C (Mattigod et al., 1990). 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.

The fine particles are aggregated into micron and sub-micron spherical particles of 0.01 to 100 mm size (Davison et al., 1974). The sub-micron particles are entrapped into large spheres (Fischer et al., 1976). Certain other physical properties of fly ash like shear strength, densification and permeability are also improved which hold importance in civil engineering. Because of the dominance of silt-sized particles in fly ash, this material is often substituted for topsoil in surface mined lands, thereby improving the physical condition of soil, especially water holding capacity. Chemically, 90-99% of fly ash is composed of Si, Al, Fe, Ca, Mg, Na and K with Si and Al forming the major matrix (Adriano et al., 1980). There are mainly two types of ash, i.e: Class F (low lime) and Class C (high lime) based on total amounts of silica, alumina and iron oxide. Al in fly ash is mostly bound in insoluble aluminosilicate structures, which considerably limits its biological toxicity (Page et al., 1979). It is substantially rich in trace elements like lanthanum, terbium, mercury, cobalt and chromium (Adriano et al., 1980). Many trace elements in fly ash like As, B, Ca, Mo, S, Se and Sr are concentrated in the smaller ash particles (Page et al., 1979). The authors opined that oxidation of C and N during combustion drastically reduces their quantities in ash. The pH of fly ash varies from 4.5-12.0 depending largely on the sulphur content of the parent coal (Plank and Martens, 1974) and the type of coal used for combustion affects the sulphur content of fly ash (Page et al., 1979). The solubility of fly ash depends directly on the physicochemical disintegration of the particles, for example indicating that a major portion of total K is localized in the interior glassy matrix while the external glass is enriched with Mg. When the solubility of alkaline fly ash was studied by selective dissolution in mineral acids, it was found that significant quantity of K occurred in the highly refractory magnetic Fe fraction and that the solubility of Mg in acids was much higher (Green and Manahan, 1978).

2.2 Fly ash as a soil-ameliorating agent:

Fly ash for improving soil fertility

Fly ash has immense potential as a soil-ameliorating agent in agriculture, forestry and wasteland reclamation because of its heterogenous nature. Previous work (Reynolds et al., 1999) to determine the feasibility of converting waste disposal problem into a soil benefaction strategy has proven true. Fly ash has been studied as a useful soil-amending agent with agronomic and environmental benefits (Zhang et al., 2004). Studies have been carried out to report the efficacy of fluidized bed combustion (FBC) and flue gas desulfurization (FGD) byproducts, when amended with dairy, swine and broiler litter manures, in reducing phosphorus (P) solubility and potential impact on water quality (Zhang et al., 2004). Pilot scale studies have been conducted on use of fly ash at rates of 100 to 650 tonnes per hectare of land as soil modifier and microfertilizer under field conditions for vegetable crops in Orissa, Madhya Pradesh and Uttar Pradesh, with a positive influence reported on the soil nutrient status as well as on plant growth (Saxena et al., 2005). Influence of fly ash on soil properties has been studied by several workers (Grewal et al., 2001). Fly ash, which can be acidic or alkaline depending on the source, can be used to buffer the soil pH (Phung et al., 1978). The electrical conductivity of soil increases with fly ash application and so does the metal content. Lime in fly ash readily reacts with acidic components in soil and releases nutrients such as S, B and Mo in forms and amounts beneficial to crop plants. Application of fly ash for increasing the pH of acidic soils (Phung et al., 1979) and improving soil texture (Chang et al., 1977) was investigated for agronomic benefits (Adriano et al., 1980) and improving the nutrient status of soil (Elseewi and Page, 1984). Major matrix elements were found to be Al and Si, together with significant percentages of K, Fe, Ca and Mg. The saturation moisture percentage of both the fly ash samples was higher, but the bulk density was lower than that for normal cultivated soils. Calcium was present as the dominant cation of the exchange complex followed by Mg^{2+}, Na^{+} and K^{+} in addition to high sulphur content. A number of studies have shown that addition of alkaline ash can increase the pH of acidic soils (Plank et al., 1975). Fly ash has been observed to have a positive effect on water holding capacity, hydraulic conductivity and pH apart from acting as source of nutrients (Yunusa et al., 2005). Addition of unweathered fly ash up to 8% to calcareous or acidic soils resulted in higher crop yield due to increased availability of S from fly ash (Page et al., 1979). Fly ash applied on acidic strip mine spoils at different places increased the yield of many crops which was attributed to increased availability of Al^{3+} and Mn^{2+} and other metallic ions at the resultant higher pH (Fail and Wochok, 1977).

Use of fly ash with organic manure and its effect on soil microbes

The strong correlation between pH correction and nutrient availability in the soil suggests that in fly ash, most elements are associated with the mineral phase. One can therefore expect that interaction between the predominantly inorganic fly ash and organic matter may further enhance its beneficial effect on plant growth in problem soils (Page et al., 1979). Use of swine manure with fly ash increased the availability of Ca and Mg balancing the ratio between monovalent and bivalent cations (Na^{+} + K^{+} / Ca^{2+} + Mg^{2+}), which otherwise proves detrimental to the soil (Giardini, 1991). The ability of calcium to enhance flocculation/aggregation of soil particles, particularly clay, keeps the soils friable, enhances water penetration and allows roots to penetrate hard/compact soil layers. Calcium readily replaces Na at clay exchange sites to enhance soil flocculation and stability. An appreciable change in the soil physicochemical properties, rising of pH and increased rice crop yield was obtained by mixed application of fly ash and paper factory sludge and farmyard manure (Molliner and Street, 1982). Menon (1993) studied the effect of mixed application of fly ash and organic compost on soil and availability and uptake of elements by various plant species. Co-utilization of 'slash,' a mixture of fly ash, sewage sludge and lime in the ratio of 60:30:10 had beneficial soil ameliorating effect (Reynolds et al., 1999). Incorporation of 'slash' in soil had positive effect on soil pH and Ca, Mg and P content and reduction in the translocation of Ni and Cd (Rethman et al., 2001) and enhanced growth of corn, potatoes and beans in pot trials. The mine spoils could be revegetated by enhancing the activities of various enzymes such as dehydrogenase, phosphatase and nitrogenase upon inoculation with arbuscular mycorrhizal fungi Glomus mosseae (Rao and Tak, 2001). Very little is known regarding the effect of fly ash amendment on soil biological properties (Schutter and Fuhrmann, 2001). Fly ash was mixed with organic matter in the form of cow dung at 1:3, 1:1 and 3:1 ratio and incubated with and without epigeic earthworm (Eisenia fetida) for 50 days which resulted in a significant increase in the population of phosphate-solubilizing bacteria and increased bioavailability of phosphorus and nutrients by vermicomposting (Bhattacharya and Chattopadhyay, 2002). Studies on CO_2 evolution and enzyme activities (dehydrogenase, protease and amylase) of fly ash amended soil in the presence and absence of earthworms under laboratory conditions for two months at 50 % water holding capacity, showed stimulation of soil respiration and microbial activities in the presence of fly ash up to 5% (Pati and Sahu, 2003). Fly ash composted with wheat straw and 2% rock phosphate (w/w) for 90 days had an encouraging effect on chemical and microbiological parameters of the compost and fly ash up to 40-60% did not exert any detrimental effect on either C:N ratio or microbial population (Gaind and Gaur, 2003). The soil conductivity, available P, and organic matter increased significantly by 32, 48 and 29% respectively. (Sarangi et al., 2001). Alkaline coal fly ash and lime were tested for their effectiveness in pathogen removal from biosolids (Wong et al., 2001). Application of fly ash at 40 t/ ha in conjunction with phosphate solubilizer, Pseudomonas striata improved the bean yield and phosphorus uptake by grain and fly ash did not exert any detrimental effect on the population of P. striata in soil (Gaind and Gaur, 2002). Amendment of Class F bituminous fly ash to soil at a rate of 505 Mg/ha did not show any detrimental effect on soil microbial communities. Analysis of community fatty acids indicated elevated populations of fungi, including arbuscular mycorrhizal fungi and Gram-negative bacteria (Schutter and Fuhrmann, 2001).

Effect of fly ash on soil quality

Soil quality, which determines the soil health, manifests into soil productivity and has far reaching effect on the soil ecosystem. While the health of soil depends on inorganic and organic matter content, processes like erosion, salinization and chemical contamination has a direct bearing on groundwater contamination, land use and management practices (Acton and Gregorich, 1995). Natusch and Wallace (1974) observed that 5 to 30% of toxic elements especially Cd, Cu and Pb are leachable. The activity levels of some natural radionuclides and Cs 137 in the surface soil layer (0-5 cm) within and outside three recultivated coal fly ash disposal sites have been determined by -ray spectrometry with an REGe detector. 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 two disposal sites (Bem et al., 1998). Adriano et al. (1978) reported that at higher levels of fly ash, some heavy metals might become more active and hinder microbial activity. These metals form complexes, which undergo transformation, influenced by various factors like pH, moisture, cation exchange and microbial activity (Milovsky and Kononov, 1992). Effect on the soil quality and crop establishment after incorporation of flue gas desulfurization sludge in soils was assessed on mesocosm studies @ 0.2, 5.0, 7.5 and 10% FGD residues (Punshon et al., 2001). Fly ash added at 0, 5, 10 and 20% (w/w) to field lysimeters containing sandy soils and planted with rhizomes of *Cynodon dactylon* (L.) was observed to reduce leaching of nitrate, ammonium and phosphorus alongwith an increase in extractable phosphorus by 2.5 to 4.5 fold thereby indicating its potential as a tool for improved management of sandy soils (Pathan et al., 2003). Four cultivars of sunflower (Helianthus annus) were grown on sandy loam soil amended with graded fly ash from 0-100% (v/v) and it resulted in an improvement in nutrient status and physical properties of soil. In the seeds except Fe, Pb, Mn, Zn and other heavy metals remain untraced upto 40% fly ash above which their level increased but within permissible limits (Siddiqui et al., 2004) .

Agriculture

Agricultural utilization of fly ash has been proposed because of its considerable content of K, Ca, Mg, S and P (Singh et al., 1997). Fly ash addition generally results in consistently favourable impact on plant growth and nutrient uptake (Aitken et al., 1984). Research in England dealing with the establishment of successful vegetative covers on fly ash deposits have indicated that plant growth is conditioned by the amount of total soluble salts, pH and available B in the ash and by the physical characteristics of the ash deposits (Hodgson and Townsend, 1973). Fly ash procured from thermal power plant, Dadri was used in field experiments up to 50t/ha to study its effect on the soil properties and yield of wheat (*Triticum aestivum* L.), mustard (*Brassica juncea* L.), rice (*Oryza sativa* L.) and maize (*Zea mays*, L.). The yield of wheat increased for 20t/ha fly ash while paddy and mustard were observed to survive well in soil amended with 10t/ha of fly ash, all three crop plants showed improved growth over control (Kalra et al., 2003). The availability of B in fly ash to alfalfa was shown by Plank and Martens (1974) to be essentially equal to that of sodium borate-B. Application of 5-20 % fly ash on w/w basis in the plough layer (0-15 cm) increased both grain and straw yield of pearlmillet (*Sorghum* *vulgare*) followed by wheat (Grewal et al., 2001). The amino acid content in soybean *(Glycine max)* was found to show an increase when grown in fly ash-amended soils in pot cultures (Goyal et al., 2002). Fly ash applied at 25% showed higher yield of brinjal (*Solanum melongena*), tomato and cabbage. Oil seed crops like sunflower (Helianthus sp.) and groundnut (*Arachis hypogaea*) also responded favourably to fly ash amendment. Medicinal plants such as cornmint (*Mentha arvensis*) and vetiver (*Vetiver zizanoides*) were successfully planted in fly ash used in conjunction with 20 % farmyard manure (FYM) and mycorrhiza (Sharma et al., 2001 a). Tomato cultivars grown on fly ash amended soils had higher tolerance to wilt fungus *Fusarium oxysporum* (Khan and Singh, 2001). Growth and nutrient uptake of two arbuscular mycorrhizal fungi, *Glomus mosseae* (Nicol. and Gerd.) Gerdemann and Trappe and *Glomus versiforme* (Karsten) Berch, grown on soil admixed with fly ash showed good growth and better nutrient uptake by maize (Bi et al., 2003). Effect of fly ash and Helminthosporium oryzae on growth and yield of three cultivars of rice Pusa Basmati, Pant dhan-4 and Pant dhan-10 was observed in a 120-day old greenhouse experiment where fly ash amendment up to 40% (v/v) showed an increase in growth and yield respectively (Singh and Siddiqui, 2003). An integrated plant nutrition system was developed utilizing fly ash, paper factory sludge, farmyard manure, crop residues and chemical fertilizers for rice-peanut cropping system (Mittra et al., 2003). Fly ash applied at 10 t ha^{-1} in combination with organic sources was found to increase the grain yield of rice, pod yield of peanut and equivalent yield of both crops by 31, 24 and 26% respectively as compared to chemical fertilizers alone (Mittra et al., 2003). Studies were conducted on sandy loam acid lateritic soils to observe direct effect of fly ash, organic wastes and chemical fertilizers on rice (*Oryza sativa*) and their residual effects on mustard (*Brassica napus* var *glauca*) grown in sequence. The integrated use of all the three amendments was observed to show an increase in rice-mustard yield by 14%, compared to use with fertilizers 10% and fly ash alone at 3%, respectively (Rautaray et al., 2003). Field studies have evaluated environmental and technical parameters associated with coal combustion byproduct (CCBP)-organic waste utilization as growth media in bermudagrass sod production (Schlossberg et al., 2004). Studies were carried out to determine feasibility of CCBP, organic waste and a sand compost control for use as growth media of selected horticultural ornamentals and turfgrass sod. Fly ash from thermal power plant Kasimpur, India was found to have a positive influence on plant growth parameters of bottle gourd by helping in reducing infection by root rot fungus, *Rhizoctonia solani* by 25% at concentration of 10% (Shamim et al., 2004). Alkaline fly ash with pH higher than 8 from Illinois has been reported to be beneficial for growth of turfgrass (*Cynodon dactylon*) and (*Lycopersicon esculentum*) at 12.5% with the nutrient content within permissible limits in soil and plants (Chou et al., 2005). Yeledhalli et. al. (2008) reported that ash application @ 30-40 t/ha (one time and repeat application) with recommended dose of NPK fertilizers alone or along with FYM @ 20 t/ha was used and the total yield of 35.7 q/ha was recorded in treatment receiving pond ash @ 40 t/ha along with FYM @ 20 t/ha followed by fly ash @ 30 t/ha. Nilesh et. al. (2012) reported that the application of fly ash enhances the seed germination rate considerably, whereas in the absence of fly ash (control) rate of seed germination was very slow. The use of fly ash as an admixture in agriculture up to 60% for the wheat (*Triticum aestivum*), 10-20% for mung bean (*Vigna radiata*), and 20% for urad beans (*Vigna mungo*) is suitable for maximum growth and yield. Cd, Cu, Fe, Mn, Mg Ni, Pb, and Zn were accumulated in the plants under study, but at very low concentrations and below the permissible limits pro-vided for human consumption.

3. CONCLUSION

The beneficial effect of fly ash on improvement of soil health in respect of physico-chemical parameters, nutritional status and microbial population may be due to the cumulative effect of improvement in individual physico-chemical characteristics. Due to the presence of CaSi minerals, having pozzolanic properties its addition to soil likely to improve physical properties. The fly ash brings about improvement in various physico-chemical properties such as Bulk Density, porosity, Water Holding Capacity, hydraulic conductivity etc. of soil.

REFRENCES

[1] Acton, D.F. and Gregorich, L.J. The health of our soils: Toward sustainable agriculture in Canada. Centre for Land and Biological Resources Res., *Research Branch Agriculture and Agri-Food Canada Publ.* 1995, 1906/E.

[2] Adriano, D.C., Page, A.L., Elseewi, A.A., Chang, A.C. and Straughan, I. Utilization and disposal of fly ash and other coal residues in terrestrial ecosystems: A review. *J. Environ. Qual*. 9, 1980, 333-344.

[3] Adriano, D.C. and Weber, J.T., 2001. Influence of fly ash on soil physical properties and turfgrass establishment. *J. Environ. Qual. 30*, 596-601.

[4] Adriano, D.C., Woodford, T.A. and Ciravolo, T.G. Growth and elemental composition of corn and bean seedlings as influenced by soil application of coal ash. *J. Environ. Qual*. 7, 1978, 416-421.

[5] Aitken, R.L., Campbell, D.J. and Bell, L.C. Properties of Australian fly ash relevant to their agronomic utilization. *Aust. J. Soil Res*. 22, 1984, 443-453.

[6] Bem, E.M., Bem, H. and Wieczorkowski, P. Studies of radionuclide concentrations in surface soil in and around fly ash disposal sites. *Sci. Tot. Environ*. 220, 1998, 215-222.

[7] Bhattacharya, S.S. and Chattopadhyay, G.N. Increased Bioavailability of Phosphorous from Fly Ash through Vermicomposting. *J. Environ. Qual*. 31, 2002, 2116-2119.

[8] Bi, Y.L., Li, X.L., Christie, P., Hu, Z.Q. and Wong, M.H. Growth and nutrient uptake of arbuscular mycorrhizal maize in different

depths of soil overlying coal fly ash. *Chemosphere*, 50, 2003, 863-869.

[9] Carlson, C.L. and Adriano, D.C. Environmental impacts of coal combustion residues. *J. Environ. Qual.* 22, 1993, 227-247.

[10] Chang, A.C., Lund, L.J., Page, A.L. and Warneke, J.E. Physical properties of fly ash amended soils. *J. Environ. Qual*. 6 (3), 1977, 267-270.

[11] Chou, S.F.J., Chou, M.I.M., Joseph, W.S., Warnock, D., Chemler, J.A. and Peppie, M.A. Plant growth in sandy soil/compost mixture and commercial peat moss both amended with Illinois coal fly ash. 2005, http://www.fly ash.info/2003/206 cho.pdf.

[12] Davison, R.L., Natusch, D.F.S., Wallace, J.R. and Evans, C.A. Trace elements in fly ash: Dependence of concentration on particle size. *Environ. Sci. Technol.* 8, 1974, 1107-1113.

[13] Elseewi, A.A. and Page, A.L. 1984. Molybdenum enrichment of plants grown on fly ash treated soils. *J. Environ. Qual*.13, 394-398.

[14] Fail, J.L. and Wochok, Z.S. Soyabean growth on fly ash amended strip mine spoils. *Plant and Soil*, 48, 1977, 473-484.

[15] Fischer, G.L., Chang D.P.Y. and Brummer, M. Fly ash collected from electrostatic precipitator. Microcrystalline structures and the mystery of the spheres. *Science*, 19, 1976, 553.

[16] Gaind, S. and Gaur, A.C. 2002. Impact of fly ash and phosphate solubilising bacteria on soybean productivity. *Bioresour. Technol*. 85, 313-315.

[17] Gaind, S. and Gaur, A.C. Quality assessment of compost prepared from fly ash and crop residues. *Bioresour. Technol*. 87, 2003, 125-127.

[18] Giardini, L. Aspetti agronomici della gestione dei reflui zootecnici. Rivista di Ingegnaria Agraria 12, 1991, 679-89.

[19] Goyal, D., Kaur, K., Garg, R., Vijayan, V., Nanda, S.K., Nioding, A., Khanna, S and Ramamurthy, V. Industrial fly ash as a soil amendment agent for raising forestry plantations. In 2002 EPD Congress and Fundamental of Advanced Materials for Energy Conversion. Ed. by Patrick R Taylor; TMS Publication. Warrendale, Pennsylvenia, 2002, pp. 251-260.

[20] Green, J.B. and Manahan, S.E. Determination of acid base and solubility behaviour of lignite fly ash by selective dissolution in mineral acids. *Anal. Chem*. 50, 1978, 1975-80.

[21] Grewal, K.S., Yadav, P.S., Mehta, S.C. and Oswal, M.C. Direct and residual effect of fly ash application to soil on crop yield and soil properties. *Crop Res.* 21, 2001, 60-65.

[22] Hodgson, D.R. and Townsend, W.N. The amelioration and revegetation of pulverized fuel ash. p. 247-270. In R.J., Hutnik and G. Davis (ed.) Ecology and reclamation of devastated land. Vol. 2. 1973, Gordon and Breech, London.

[23] Kalra, N., Jain, M.C., Joshi, H.C., Choudhary, R., Kumar, S., Pathak, H., Sharma, S.K., Kumar, V., Kumar, R., Harit, R.C., Khan, S.A., Hussain, M.Z., Soil properties and crop productivity as influenced by fly ash incorporation in soil. *Environ. Monit. Assess*. 87 (1), 2003, 93-109.

[24] Khan, M.R. and Singh W.N. Effects of soil application of fly ash on the fusarial wilt of tomato cultivars. *Intl. J. Pest Mng*. 47 (4), 2001, 293-297.

[25] Mattigod, S.V., Rai, D., Eary, L.E. and Ainsworth C.C. Geochemical factors controlling the mobilization of inorganic constituents from fossil fuel combustion residues: I.Review of the major elements. *J. Environ. Qual.* 19, 1990, 188-201.

[26] Menon, M.P. Elements in coal and coal ash residues and their potential for agricultural crops. Trace elements in coal and coal combustion residues. Lewis Publishers, Florida, USA, 1993, pp. 259-285.

[27] Milovsky, A.V. and Kononov, O.V. Mineralogy. (ed) Savostin, P. Zpflanzenernaehr Bodent. Mir Publishers, Moscow 1132, 1992, pp. 37-45.

[28] Mittra, B.N., Karmakar, S., Swain, D.K. and Ghosh, B.C. Fly ash- a potential source of soil amendment and a component of integrated plant nutrient supply system. 2003, http:// www.Fly ash.info./2003/28 mit.pdf.

[29] Molliner, A.M. and Street, J.J. Effect of fly ash and lime on growth and composition of corn (*Zea mays* L.) on acid sandy soils. *Proc. Soil Crop Sci. Soc.*, Florida, 41, 1982, 217-220.

[30] Natusch, D.S.F. and Wallace, J.R. Urban aerosol toxicity: the influence of particle size. *Science*, 186, 1974, 695-701.

[31] Page, A.L., Elseewi, A.A. and Straughan I.R. Physical and Chemical properties of fly ash from coal-fired power plants with special reference to environmental impacts. *Residue Rev.* 71, 1979, 83-120.

[32] Pathan, S.M., Aylmore, L.A.G. and Colmer, T.D. Soil properties and turf growth on a sandy soil amended with fly ash. Plant and Soil. 256 (1), 2003, 103-114.

[33] Pati, S.S. and Sahu, S.K. CO_2 evolution and enzyme activities (dehydrogenase, protease and amylase) of fly ash amended soil in the presence and absence of earthworms (Drawida willsi Michaelson) under laboratory conditions. Geoderma (2003).

[34] Phung, H.T., Lam, H.V., Lund L.J. and Page, A.L. The practice of leaching Boron and salts from fly ash amended soils. *Water, Air and Soil Pollut*. 12, 1979, 247-254.

[35] Plank, C.O. and Martens D.C. Boron availability as influenced by application of fly ash to soil. *Soil Sci. Soc. Am. Proc*. 38, 1974, 974-977.

[36] Plank, C.O., Martens D.C. and Hallock, D.L. Effect of soil application of fly ash on chemical composition and yield of corn (*Zea mays* L.) and on chemical composition of displaced soil solutions. *Plant and Soil*, 42, 1975, 465-476.

[37] Punshon, T., Adriano, D.C. and Weber, J.T. Effect of flue gas desulfurization residue on plant establishment and soil and leachate quality. J. Environ. Qual. 30 (3), 2001, 1071-1080.

[38] Rao, A.V. and Tak, R. Growth of different tree species and their nutrient uptake in limestone mine spoil as influenced by arbuscular mycorrhizal (AM)-fungi in Indian arid zone. *J. Arid Environ*. 2001, 113-119.

[39] Rautaray, S.K., Ghosh, B.C. and Mittra, B.N. Effect of fly ash, organic wastes and chemical fertilizers on yield, nutrient uptake, heavy metal content and residual fertility in a rice-mustard cropping sequence under acid lateritic soils. *Bioresour. Technol*. 90 (93), 2003, 275-283.

[40] Rethman, N.F.G. and Truter, W.F. Plant responses on soils ameliorated with waste products. 16th National Meeting of ASSMR, Albuquerque, New Mexico, U.S.A. 2001, pp. 425.

[41] Reynolds, K.A., Kruger, R.A. and Rethman, N.F.G. The manufacture and evaluation of an artificial soil prepared from fly ash and sewage sludge. Proc. Intl. Ash Utiliz. Sympos. Lexington, Kentucky, U.S.A. 1999, pp. 378-385.

[42] Sarangi, P.K., Mahakur, D. and Mishra, P.C. Soil biochemical activity and growth response of rice *Oryza sativa* in fly ash amended soil. *Bioresour. Technol.* 76 (3), 2001, 199-205.

[43] Saxena, M., Asokan, P. and Murali, S. Pilot scale demonstration study on impact of fly ash on soil fertility and crop yield. International Conference on Energy Environment and Disasters-INCEED2005, Charlotte, NC, U.S.A, 2005, July 24 to 30.

[44] Schlosssberg M.J., Vanags, C.P. and Miller, W.P. Bermudagrass sod growth and metal uptake in coal combustion by-product amended media. *J. Environ. Qual*. 33 (2), 2004, 740-748.

[45] Schutter, M.E. and Fuhrmann, J.J. Soil microbial community responses to fly ash amendment as revealed by analyses of whole soils and bacterial isolates. *Soil Biol. Biochem.* 33, 2001, 1947-1958.

[46] Shamim, A., Azam, M.F. and Tiyagi, S.A. Utilization of fly ash for the management of *Rhizoctonia solani* infesting bottle gourd. *Phytopathol. Plnt. Protec.,* 37, 2004, 269-274.

[47] Sharma, B.M., Aggarwal, R.K. and Kumar, P. Water retention and nutrient availability in a fly ash amended desert sandy soil: A study in vitro. Arid Soil Res. Rehab. 4, 1990, 53-58.

[48] Sharma, M.P., Tanu, U. and Adholeya, A. Growth and yield of *Cymbopogon martinii* as influenced by fly ash, AM fungi inoculation and farmyard manure application. *In 7th International Symposium on Soil and Plant analysis, Edmonton, Alberta, Canada,* 2001a.

[49] Siddiqui, S., Ahmed, A. and Hayat, S. The fly ash influenced the heavy metal status of the soil and the seeds of sunflower. A case study. *J. Environ. Biol*. 25 (1), 2004, 59-63.

[50] Singh, L.P. and Siddiqui, Z.A. Effects of fly ash and Helminthosporium oryzae on growth and yield of three cultivars of rice. Bioresour. Tech. 86, 2003, 73-78.

[51] Singh, S.N., Kulshreshtha, K. and Ahmad, K.J. Impact of fly ash soil amendment on seed germination, seedling growth and metal composition of *Vicia faba* L. *Ecol. Engg*. 9, 1997, 203-208.

[52] Wong, J.W.C., Fang, M. and Jiang, R., Persistency of Bacterial indicators in Biosolids Stabilization with Coal Fly ash and Lime. *Water Environ. Res*. 73 (5), 2001, 607-610.

[53] Zhang, G.Y., Dou, Z., Toth J.D. and Ferguson, J. Use of fly ash as environmental and agronomic amendments. *Environ. Geochem. Health*. 26, 2004, 129-134.

[54] Yeledhalli, N.A, Prakash, S.S, Ravi, M.V and Narayana R. Long-Term Effect of Fly Ash on Crop Yield and Soil Properties. *Karnataka J. Agric. Sci.,* 21(4), 2008, 507-512.

[55] Nilesh K.M., Sachin D.P., Dhananjay B.S. and Sanjay B.A. Effect of Fly Ash as an Admixture in Agriculture and the Study of Heavy Metal Accumulation in Wheat (*Triticum aestivum*), Mung Bean (*Vigna radiata*), and Urad Beans (*Vigna mungo*). *Pol. J. Environ. Stud.* Vol. 21, No. 6, 2012, 1713-1719.