



e-ISSN No.: 2582-4228

Journal of Indian Association for Environmental Management

Journal homepage: [www.http://op.niscair.res.in/index/php/JIAEM/index](http://op.niscair.res.in/index/php/JIAEM/index)



Emerging Issues and Concerns for Vegetation and Plant Growth Responses to Fly Ash: A Review

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Submitted: 15 January 2024

Revised: 09 September 2024

Accepted: 10 September 2024

Abstract: Coal combustion in thermal power plant, generates a molten mineral residue known as fly ash, which consists of various types of elements such as Se, Sr, Mo, Na, Zn, Ca, Mn, V, Sb, Mg, Fe, S, K and P. Since, fly ash contains macronutrients and trace elements it can be used in agriculture sector to improve the productivity of crops and vegetation. Although it possesses beneficial trace elements and macronutrients, it also possesses heavy metals such as Pb, As, Hg, Cr, Cd, Ni, Co, Cu and Boron. Presence of Boron, As and Hg are of major concern since these heavy metals & Boron impart toxicity to plants and vegetation in long run. Application of fly ash containing few metals such as Ni, As, Cd, Cr, Pb, Zn and Cu shows undesirable growth in plants. However, lower application rate of fly ash application is safe; since high rate of application brings negative impacts such as reduced plant biomass and crop yield. Therefore, only weathered fly ash should be utilized as far as possible for better results of plant growth. In this regard, an exhaustive review is undertaken on issues and concerns for plant and vegetation growth responses to fly ash. This article explores detrimental and beneficial impacts of fly ash application on crops, vegetation and trees along with impacts due to heavy metal toxicity of fly ash on vegetation.

Keywords: fly ash, trace elements, plant growth, vegetation, concerns

I. INTRODUCTION

Fly ash is nothing but the byproduct of coal combustion in thermal power plant (Dzantor et al, 2015), which produces a molten mineral residue. This molten mineral residue generated during combustion of coal constitutes nearly 20-35% of fly ash. Fly ash is basically combination of ferro alumino silicate and different types of trace elements. Fly ash contains oxides, hydroxides, carbonates and silicates (Adriano et al, 1980). Fly ash consists of mainly oxides of Al, Fe, Ca, K and different types of trace elements including toxic heavy metals and is usually alkaline in nature (Dwiwedi et al, 2007).

On an average annually, nearly 700 million tons of fly ash is produced and the production may increase in future (Shaheen et al, 2014). Such a massive production of fly ash if not utilized properly will create deleterious and adverse effects on environment. Several research and development activities have been carried out globally to utilize it in a sustainable manner by various scientific investigators. Majority of scientific reports and literature illustrates utilization of fly ash for plant productivity, since fly ash contain macro nutrients such as N, P,

K, Ca, Mg and S and micronutrients such as Sr, Se, Cu, Fe, Mn, Mo, Na and Zn etc. required for plant growth (Plank and Martens, 1973). Various macro and micronutrients present in fly ash are utilized for different aspects for e.g. Sulfur present in fly ash offers nutritional value for plants (Sale et al., 1996). Besides common trace elements it also possesses other trace elements such as Lanthanum, Terbium and Cobalt (Adriano et al., 1980). Mostly trace elements such as Ca, Mo, S, Se and Sr (Page et al., 1979) in the ash are bound in the very minute ash particles (Adriano et al., 1980). Since fly ash contains plant nutrients required for the growth of plants fly ash should be used as a supplement of plant nutrient. The enriched macro and micronutrient such as K, P, Ca, Mg, Fe & Mo present in fly ash enhances plant growth in nutrient deficient soil due to its efficacy in crop performance and biomass production. (Martens & Beachm, 1978).

Although fly ash boosts plant productivity but, lot of risk is associated with heavy metal accumulation in fly ash ameliorated soil. If such soil is used for crop production and if crops are consumed by grazing animals, it may create toxicity and other issues in animals (Yunusa et al, 2012). Various

reports recommended that approximately 5-10% fly ash application to soil, improves plant growth. Amelioration of fly ash at the rate of 20-30% alters plant metabolism (Narayana et al, 2010). Although, there is alteration in plant metabolism but higher plants protect themselves due to presence of metabolic enzymes and other biochemical components (Sinha et al, 2005). Therefore, while doing fly ash application to soil it is necessary to examine fly ash with respect to heavy metals and Boron toxicity before its use.

Fly ash amendment to soil enriches soil with trace elements and improves the crop production and crop yields (Ram et al, 2006). Fly ash can be utilized for various types of vegetables production also such as Pumpkin (Ahmad et al, 2021) Chickpea (Upadhyay et al, 2021), Turnip, Onion, Garlic and Potato (Tripathi et al, 2010). Utilization of fly ash at the rate of 30% for Pumpkin production showed increased growth and yield of Pumpkin (Upadhyay et al, 2021). Fly ash application at the rate of 30-40% was reported to be suitable for the growth & production of Indian mustard (Shakeel et al, 2019). The yield of rice was found good when fly ash was applied at the rate of 50% (Bisoil et al, 2017). From these studies and findings it is revealed that fly ash helps to improve crop production but there are certain limitations for fly ash application to crops as it is observed that at higher concentration, fly ash may create toxicity to plants in long run, especially Arsenic, Boron and Mercury toxicity.

Until now, lot of research work is done on fly ash utilization to soil to boost the plant & crop productivity. But very few research works is done on its toxicity threshold levels application to check what rates of fly ash application are proper for plant growth. Whether, weathered fly ash application to soil is safe or unweathered fly ash application. The aim of the review article is to discuss the various issues such as heavy metals toxicity and other concerns such as utilization of weathered or unweathered fly ash application to soil is appropriate or not and the recommendations thereof for its safe utilization for vegetation and plant growth.

II. MATERIALS AND METHODS

Characteristics of Fly Ash

Physical Characteristics of Fly Ash

Fly Ash contains very small particles with diameter of 10µm, combined to sphere shaped smaller particles of 0.01-100 µm sizes. (Jala & Goyal, 2006) as depicted in Table1. Physically, it is minute glass like structure having average diameter of less than 10 mm. Fly ash possesses silt loam texture. The bulk density in fly ash was found to be ranging from 0.92 to 1.56 g cm⁻³. (Rautaray et al, 2003 & Tekade et al, 2013). Fly ash maintains moisture when applied to soil. Fly ash is generally grey in colour. The colour of fly ash is mainly based upon Fe₂O₃ and carbon contents. If fly ash possesses high concentration of Fe₂O₃ fly ash appears darker in colour (Alonso & Wesche, 1991). Physical properties of fly ash are depicted in Table1.

TABLE 1
Physical Properties of Fly Ash

Physical properties	Concentration
Color	Grey to black (Nyambura et al., 2011)
Texture	Silty loam (Yeledhalli et al., 2007)
Porosity	44.01-56.78% (Juwarkar & Jambhulkar, 2008)
Bulk Density	0.92 to 1.56 g cm ⁻³ . (Rautaray et al, 2003)
Maximum water holding capacity	40-60% (Nyambura et al., 2011)
Specific gravity	1.6 to 2.6 g/cm ³ (Nyambura et al., 2011)
Particle diameter	0.01-100 µm (Jala & Goyal, 2006)

Chemical Characteristics of Fly Ash

The nature, category and composition of coal used, play an important role for determining chemical characteristics of fly ash. The principal ingredients of fly ash are Silica, Alumina and Iron oxides. Besides this, it also possesses trace elements like La, Tb, Hg, Co and Cr. The pH in fly ash depends on CaO & Sulphur contents and also on coal composition. The pH in fly ash was found to be ranging between 5.0 to 12.0. (Riehl et al, 2010). Fly ash having high amount of anthracite usually is rich in Sulphur content and is acidic in nature. While fly ash which is produced from lignite is usually low in Sulphur content and high in Calcium content and is alkaline in nature. Generally, Indian coal is low in Sulphur content and its ash content was found to be 40% but in United States, coal is high in Sulphur content (2%) and contains 4-12% ash (Jala & Goyal, 2006). Coals produced from anthracite are high in Sulphur content bears acidic ash especially Eastern US coals. Coals produced from lignite are low in Sulphur content and generates alkaline ash especially Western US coals. Fly ash generally contain Sulphur content varying from 0.1 - 1.5% (Page et al, 1979). Chemical properties of fly ash are depicted in Table 2.

TABLE 2
Chemical Properties of Fly Ash

Chemical properties	Concentration
pH	5.0 -12 (Riehl et al, 2010).
Electrical conductivity	4.20 mS/cm (Juwarkar and Jambhulkar, 2008)
Organic carbon %	1.12 (Juwarkar and Jambhulkar, 2008)
CEC (Cmol/kg)	6.60 (Singh & Tewary, 2004)

Composition of Fly Ash

Chemically, 95 percent of fly ash consists of Si as the major element. Besides this, it also contains Al and Fe along with other trace elements. The elemental composition of fly ash depends on the nature of the parent coal. Nitrogen in fly ash is present in negligible quantities. Phosphorus in fly ash can vary widely and the concentration varies from 0.0002 to 1.08%. Calcium, Potassium and Magnesium are available in abundance in fly ash. Trace elements such as Cu, Fe, Mn, Mo and Zn occur in fly ash in abundance and are helpful for plant growth. Besides trace elements it also contains oxides of Sulphur, Iron, Aluminium, Calcium, Magnesium, Potassium, Sodium and Silicon.

Beneficial Impacts of Fly Ash Application on Crops, Vegetables and Trees

Crops

Fly ash can be utilized to boost the productivity of soil for growing crops. (Fig.1). Various investigators have used fly ash for the growth of crops and found certain beneficial impacts of fly ash application on crops. In an experimental study it was found that amelioration of 2 to 4% fly ash to soil enhanced the Ca, Na, S and Fe concentration in rice (*Oryza sativa*) plant (Sikka and Kansal, 1995). Wong & Wong 1990, observed that when *B. parachinensis* were grown in pots in a sandy textured soil while *B. chinensis* were grown in sandy loam textured soil and both were treated with 0, 3, 6 and 12 percent fly ash. It was found that crop yields were highest with application of 3 percent fly ash in *B. chinensis* in sandy loam textured soil, but when only *B. parachinensis* were grown on sandy loam textured soil, it was observed that yield was highest with application of 12 percent fly ash. It is concluded that yield of both the crops were higher in sandy loam textured soil than in the sandy textured soil. From these studies it is apparent that texture of soil plays an important role in crop productivity. Various investigators have reported its advantageous impacts on crop yield when it is used with some fertilizer and farm yard manure (FYM).

Western US unweathered fly ash when amended to acidic soil at the rate of 8% (w/w) showed good growth and high yield in agronomic crops. Application of 5 to 25% fly ash in the 0 - 15 cm layer of soil increased growth of Pearl millet crop (*Pennisetum* sp). Amelioration of fly ash with 2 to 5% application rate on soil showed positive response on production and yield of rice (Sikka & Kansal, 1995). However, higher fly ash application rate at the rate of 30% had adverse effects on crop productivity (Singh et al, 1997). Experiment conducted with combination of garden soil ameliorated with fly ash application at the rate of fly ash 0, 25, 50 and 100%, using *Cajanus cajan* crop, showed 25% application have positive effect with respect to crop yield of *Cajanus cajan* (Pandey et al, 2009). Also, it was observed that 25% application rate was suitable for *C. cajan* cultivation. Yet, the yield of *Cajanus cajan* was badly affected at higher rates of application i.e. 50 & 100% as compared to the control. Favorable crop response depends, directly on proper amendments of fly ash and other factors such as its application technique, soil types and types of plants (Cervelli, 1989). If all conditions such as soil texture, climatic conditions and pH of soil etc. are suitable for crop

production, then fly ash brings encouraging results for that particular crop (Cervelli, 1989).

Vegetables

Singh et al, 1994 recommended the use of 2 percent w/w fly ash to soil, is suitable and safe for sugar beet production. Application of fly ash for growing vegetables like Brinjal, Tomato and Cabbage at the rate of 25% revealed a sufficient yield of Brinjal, Tomato and Cabbage. Singh et al, 1991 observed maximum growth of Tomato plants and availability of most of the nutrient elements in soil increased with addition of fly ash at the rate of 500 t/ha. Khan and Khan 1996 suggested 40 percent fly ash addition to soil is the most suitable dose for plant growth. This increased the yield of Tomato fruits by 30 to 81 percent respectively. Singh et al, 1991 studied an experiment with fly ash application on Brinjal (*Solanum melongena*). The result of the study indicated that the plant growth was good in the fly ash amendments in contrast to control and the better yield was found at 180 t/ha fly ash amendment on soil. Similarly fly ash application to *Allium Cepa* showed that the amendment of fly ash at the rate of 5 t/ha in soil to *Allium Cepa* increase the different growth parameter with respect to root, shoot and leaf.

When fly ash and soil was used for *Solanum nigrum* plant at the rate of 30% it was noted that 30% application rate was better for growth of *Solanum nigrum* plant. However, higher than 30% rate plant was showing negative response to fly ash application and undesirable effects on plant growth (Singh et al, 1994). In another experiment on fly ash application on Soybean, fly ash was treated with silt loam textured soil at the rate of 80 T/ha for 2 years, it was observed that Soybean yield improved (Kim et al, 1994). An experiment was conducted by Singh & Agrawal (2010) to study the impact of fly ash application on yield of three varieties of Mung bean (*Vigna radiata*) on a soil ameliorated with various proportions of fly ash 0, 5, 10 and 20% w/w respectively. In this experiment positive response was found in all the three varieties tested at 10% application rate. Therefore, it is concluded that lower dose of application of fly ash is better option for improving productivity of different types of vegetables. Further, the productivity of vegetables also depends on soil texture and climatic conditions prevailing at that site.

Trees (forestry species)

Different types of forestry plants namely *Delbergiasisoo*, *Albizia lebbek*, *Eucalyptus hybrida*, *Acacia nilotica* and *Tamirudus indica* responded well with fly ash amended soils for recovery of fly ash dump sites and were found to be growing on fly ash dump luxuriantly. (Jala and Goyal, 2006). In an experiment, studies were conducted at fly ash dump at Khaperkheda Thermal Power Plant in India; on 10 hectare area ash dump, where commercially and ecologically and economically important species like *Azadirachta indica*, *Cassia siamea*, *Eucalyptus hybrida*, *Pongamia pinnata*, *Tectona grandis*, *Dendrocalamus strictus*, *Delbergia sissoo* etc. were grown using farm yard manure and cultures of Biofertilizers to remediate the fly ash dump (Juwarkar and

Jambhulkar, 2008). Similarly 20 types of tree species were planted in the ash pond filled with garden soil and farm yard manure (FYM) and reported 99 -100 % survival after two years for all the species (Singh et al,1992). Pot culture study was carried out with fly ash and acid soil using five plants namely, Subabul (*Leucaena leucocephala*,) Chakundi (*Cassiasiamia*), Black siras (*Albezia lebbek*), Shishum (*Delbergiasissoo*) and Gamhar (*Amelia arborea*) and the response on different growth parameters was observed. Out of the five plants, Subabul (*Leucaena leucocephala*,) Chakundi (*Cassiasiamia*), Black siras (*Albezia lebbek*), Shishum (*Delbergiasissoo*) are nitrogen fixing plants and the Gamhar (*Amelia arboreal*) is timber yielding plant. It was found that different growth parameters such as number of tillers, leaves and height of all the species showed good response when 20 percent fly ash was added to acid soil (Pandey et al, 1996).

Albizia procera and *Acacia nilotica* were treated with fly ash amended soil in 10, 20 & 30% ratio respectively and it was noted that in 10% fly ash amended soil both the trees were growing luxuriantly while in 30% fly ash amended soil trees were showing undesirable effects (Tripathi and Tripathi, 1998, Sikka and Kansal, 1994). Experiment was conducted using different trees and were planted in fly ash landfill and found that survival rate varied from 10 to 85%. (Scanlon and Duggan, 1979). When fly ash was used for growing leguminous trees the growth response was good in terms of different growth parameters (Rai et al, 2002). When *Cassia siamea* plant was grown using pressmud in combination with fly ash it was reported that the plant possess metal detoxification potential as well as antioxidants properties (Kumar et al, 2002). Therefore, it can be concluded that lower application rate of fly ash along with organic amendments such as press mud and farm yard manure are helpful in boosting the productivity of trees (forest species). (Fig.1)

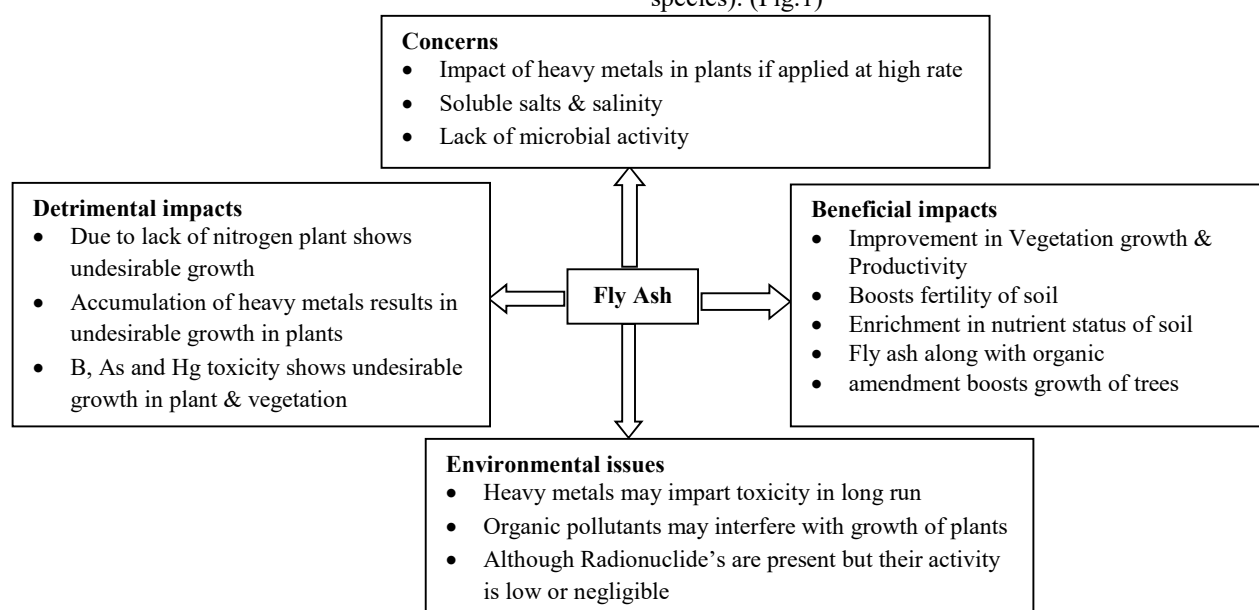


Fig. 1 Environmental issues and concerns of fly ash utilization

Detrimental Impacts of Fly Ash Application on Plant Growth and Vegetation

When fly ash disperses in air, fly ash dust; stick to the leaves and causes injuries to the plant. Sometimes brown spots are also observed on shoot of different types of vegetables (Singh & Yunus, 2000). Application of fly ash to soil showed lot of changes in soil properties affecting the soil micro flora and ultimately roots of plants. Higher application rate of fly ash at the rate of 20 to 25% showed undesirable and unfavorable impacts on the growth of plants. When *Beta vulgaris* plant was cultivated in soil with fly ash it was found that fly ash application at the rate of 4 & 8% was inhibitory for the growth of *Beta vulgaris* plant (Singh & Yunus, 2000).

If fly ash is highly alkaline, the high pH can be dangerous to the micro flora present in the rhizosphere of plants. These rhizospheric microorganisms help to keep the soil in healthy condition. For example *Rhizobium* present in soil helps in nitrogen fixation. High pH in fly ash has adverse effects on root

growth in plants and delay in root nodulation was observed. Trace elements and metals such as B, As, Se, Mo, V, Al and Cd are considered to be dangerous to plants. Different types of heavy metals such as Hg, As and B present in fly ash may be taken up by plants and can bioaccumulate in plants. Boron can be taken up by plants from unweathered (fresh) fly ash application (Elseewi et al, 1978). Experiment was conducted using fly ash amelioration with farm yard manure; press mud and garden soil and plants were grown on this. It was observed that few metals such as Cu, Fe, Zn and Ni were found in abundance. This may be attributed to low pH availability after the addition of press mud and cow dung manure (Tripathi et al, 2000).

Higher plants contain defensive mechanisms within the cell therefore metal ions present in plant parts undergo complementary impacts with the toxic metals of fly ash. At first toxic metals come in contact with roots followed by other aerial parts (Mishra & Shukla 1986). Some chemical compounds, namely dibenzofuran and dibenzo-p-dioxin mixture (Sawyer et

al, 1983) and metals namely Ni, As, Cd, Cr, Pb, Se, Zn, Cu etc. are likely to be present in fly ash which causes undesirable growth in plants (Mayer 1981). Fly ash do not possess Nitrogen and even if it is present, it is present in negligible quantities; therefore its application in soil causes severe deficiency in soil as well as plant which are grown on such fly ash amended soil. Ultimately, such plants show undesirable growth.

Impact of Fly Ash on Heavy Metal uptake by Plants & Vegetation

When Basil, Tomato, Zucchini & Sunflower were potted in soil ameliorated with fly ash at the rate 5%, 10% and 20% fly ash, it was noted that there are lots of variations in uptake of different metals by these plants (Brake et al, 2004). As the fly ash amelioration rates were increased the As uptake rate also increased; Arsenic was reported to cross the toxic level in Basil and Zucchini by 7 ppm. Similarly, application of fly ash on productivity of wheat (*Triticum aestivum*), Mung bean (*Vigna radiate*) and Urad beans (*Vigna mungo*) was studied and it was observed that Cd and Pb were not accumulated in wheat (*Triticum aestivum*), Mung bean (*Vigna radiate*) and Urad beans (*Vigna mungo*) while Cu, Mn and Ni were accumulated less in all.

Heavy metal translocation in vegetation & plants is generally based on fly ash application rates. An experimental study was conducted using *Cajanus cajan* L, with fly ash amendment at lower application rate and observed that heavy metal accumulation in *Cajanus cajan* L, was negligible. (Pandey et al. 2009). Incorporation of fly ash with 25% application rate revealed that the plant was growing luxuriantly and the yield was also better than the control. Therefore, it is assumed that 25% application rate of fly ash is the most responsive one in terms of yield of *Cajanus cajan* L, and it is safe; since the translocation of heavy metals in different edible parts were found to be within permissible limits (Pandey et al. 2009). An experimental study was conducted with fly ash application on *Vigna radiata* plant with respect to accumulation of heavy metals in root & shoot, and it was noted that the metal accretion increased as the fly ash application is increased. More accumulation of heavy metal was observed in shoots comparatively to roots. *Cassia. siamea* and *Pisum sativum*, both Leguminous vegetation, were used with different combinations of fly ash such as 25, 50, 75 and 100% respectively & were applied to soil and it was observed that both the plants translocate Zn, Cu, Ni and Fe within permissible limits with 25% treatment (Tripathi et al, 2000). It can be concluded that lower application rates of fly ash to soil is safe since the translocation of heavy metals in most of the plant parts was found within permissible limits.

Impact of fly ash due to Boron, Arsenic and Mercury Toxicity on Plant Growth & Vegetation

Boron

Fly ash is rich in Boron, Arsenic and Mercury. These metals impart toxicity to plant if they are present in soluble state. Boron in fly ash is basically generated from coal because coal contains 5 to 250 ppm of B and fly ash contains 22 to 60 ppm of Boron (Haynes, 2009). Reported literature suggests that the concentration of Boron in coal varies significantly and it depends on the nature of coal. Sometimes, Boron in fly ash occurs in insoluble form. If the Boron occurs in insoluble form it is not taken up by the plant. Boron concentrations higher than 30 ppm are highly sensitive to plant species (Haynes, 2009). If the plant is affected with Boron toxicity then necrotic lesions will appear on the leaves leading to premature shedding of the leaves. Sometimes leaves become yellow & brown in colour. Boron is mostly taken up by plants in the form of Boric acid & Borate ions.

Arsenic

Coal pyrite contains lot of Arsenic. And since fly ash is produced from burning of coal, Arsenic is bound to be there. Arsenic occurs as Arsenic trioxide. Generally, it was found to range from 4 to 440 ppm (Huggins et al, 2007). Sometimes the concentration may reach beyond 440 ppm also which may be a serious concern for plant growth and vegetation.

Mercury

Coal based thermal power plants generally contain Mercury. Coal possesses 0.272 ppm of mercury (Jambhulkar et al, 2018). Reported literature suggests that Mercury is emitted from flue gases of thermal power plant and may enter into hydrological system. From there it is absorbed by aquatic plants (hydrophytes) growing in aquatic ecosystem. This methylated mercury may enter in food chain also affecting the life of aquatic animals.

Impact of fly ash due to Radioactive Elements on Plant Growth & Vegetation

Coal contains many trace elements. Some of them are radioactive in nature, which include Uranium, Thorium and Radium. These elements are chemically less toxic and do not have any detrimental impacts to plants and vegetation, but comparatively few elements and metals such as Boron, Mercury and Arsenic are supposed to be dangerous for plant growth since they impart detrimental impacts to plants and vegetation. Fly ash does not contain much concentration of these radioactive elements. Reported literature suggests that generally fly ash contain Uranium and Thorium. Uranium in fly ash varies from 15 to 110 ppm and Thorium is about 10 to 25 ppm (Jambhulkar et al, 2018). Experiments on radioactive elements uptake by plants revealed that plants were not much affected by radioactive elements since the radioactivity level in fly ash was within safe limits. The radioactive elements in Indian fly ash occur at low concentration. Since no toxicity with respect to radioactive elements was observed, therefore fly ash can be used as an amendment for plant and vegetation growth.

Application of fly ash Utilization in Agriculture

As fly ash is rich in majority of plant nutrients therefore it can be used mainly in agriculture sector. Fly ash also contain different types of Oxides, Hydroxides, therefore it is approved to use for crop and vegetation productivity. Alkaline fly ash is used to maintain the pH of acidic soil (Matsi and Keramidis, 1999). Fly ash boosts crop productivity on degraded soil and wastelands. Fly ash amelioration helps to alter soil pH, improvement in soil texture and also support for trees productivity. (Bilski et al, 1995). Gora, 1982 suggested that all types of fly ash could be put to agriculture use, except those containing Mercury, Arsenic, Boron and Beryllium. Field and green house studies conducted revealed that different types of trace elements of fly ash support for plant productivity (Chang et al, 1977).

Bioremediation of fly ash Landfills

When fly ash landfills were irrigated with application of blue green algal inoculants, it was observed that the algal inoculants help to improve the productivity of fly ash landfills thereby improving different parameters of fly ash such as pH, electrical conductivity, CEC, total N, available P and organic carbon. In an experiment, when the alga *Anabaena doliolum* was applied, it was noticed that the alga could reduce the concentration of different metals present in fly ash through bioaccumulation in its tissues (Rai et al, 2000). In an experiment fly ash lagoon was amended with nitrogen fixers and non nitrogen fixers for two plant species namely *Acaiaauriculiformis* and *Leucaena leucocephala* (Cheung et al, 2000). In another experiment it was found that, plant *Morus alba* was well established in fly ash amended soil and could grow well along with alga *Anabaena doliolum* (Rai et al, 2000). In an experiment *Brassica juncea* plant was cultivated on fly ash landfill using Cyanobacteria as a green manure and positive results were observed with respect to the survival and growth of *Brassica juncea* plant (Banerjee et al, 1999), due to the presence of trace elements and nutrients in fly ash which boosted the growth of Cyanobacteria (Furr et al, 1978). Inoculation of Biofertilizer to *Cassia surattensis* plant showed positive results in terms of survival and was growing well (Vajpayee et al, 2000).

Recommendations for Fly Ash Utilization for Vegetation & Plant Growth

- Fly Ash should be used along with soil for growing commercially important plant species since fly ash possesses trace elements required for plant growth and development. So utilization of fly ash for commercially important plant production should be considered as the most effective way of fly ash utilization.
- Fly ashes dumps and fly ash landfills makes the nearby ecosystem polluted by leaching heavy metals and other pollutants. Such dumps should be reclaimed using Phytoremediation technique which minimizes the chances of leaching of heavy metals and groundwater contamination

to nearby ecosystem. Hence, phytoremediation technique should be adopted for fly ash landfills & fly ash dumps.

- Cultivation of plants on degraded land, wastelands and mined lands with fly ash utilization at lower rates, makes the best usage of wastelands with concomitant benefits to the environment.
- Phytoremediation of fly ash dumps helps to immobilize the metal and their migration to nearby ecosystem. So, phytoremediation of fly ash dump should be implemented in practice.
- Native plants suitable to existing climatic conditions should be selected for cultivating on fly ash landfills. Selected plant species should tolerate metal toxicity, hence rehabilitation of fly ash landfills should be done using proper plant species especially economic and ecologically important plant species should be considered rather than edible one.
- Before utilization of fly ash for growing plants, it is necessary to check fly ash to soil to be used for experimental purpose and test it with the existing environmental conditions.
- Application of fly ash at lower rate is suitable for the growth of crops, vegetables and forestry species while higher rates show inhibitory effects. Hence, lower doses of fly ash should be considered in order to achieve maximum benefit.
- Weathered (old) fly ash should be used for its utilization as an amendment for better yield of crops and vegetation.
- Utilization of unweathered (fresh) fly ash should strictly be avoided for crop growth since unweathered (fresh) fly ash possess soluble salts which may result in increased level of salinity and will hamper crop growth.
- Before application of fly ash, fly ash should be checked carefully with respect to metal toxicity such as Arsenic, Mercury and trace element Boron; other pollutants and other toxic compounds if any.

III. CONCLUSION

Fly ash application at lower rate brings encouraging impacts in agriculture such as increased yields of crops and vegetation. Similarly, soil texture also plays an important role in crop yield. High rate of fly ash application brings negative impacts such as reduced plant biomass and crop yield. However, responses to yield showed differences with respect to types of plant species, soil texture and climatic conditions. Responses to yield also depend on what type of fly ash is used whether the weathered (old) fly ash or unweathered (fresh) fly ash. For better yield of crops only weathered fly ash should be utilized. When fly ash is applied at lower concentration, uptake of metals by plants (crops) is lower. However, detrimental impacts on crops were observed when fly ash is applied at higher concentration; resulting into stunted growth and other issues in crops. Fly Ash can be directly used with soil for growing plants of ecologic and economic benefits as well as plants that have commercial value. Besides this, fly ash can also be utilized for bioremediation of fly ash landfills. Although fly ash is helpful for growing plants

and vegetation but still its utilization is limited to certain extent as fly ash creates toxicity with respect to Arsenic, Mercury, and Boron in long run. So, considering metal toxicity as the only limitation for its application, use of fly ash can be done in a safe way to protect the environment being getting polluted. This approach of fly ash utilization will conserve the environment and will minimize the chances of land getting eroded and degraded.

Acknowledgment

The author acknowledges the kind support and encouragement extended by Dr. Atul Vaidya, Director, NEERI, Nagpur. KRC number provided by the Institute is CSIR-NEERI/KRC/2023/MAY/EISD/2.

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