Vol 4 Issue 12 June 2015

ISSN No :2231-5063

# International Multidisciplinary Research Journal

# Golden Research Thoughts

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**RNI MAHMUL/2011/38595** **ISSN No.2231-5063**

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International Recognized Double-Blind Peer Reviewed Multidisciplinary Research Journal
Golden Research Thoughts
ISSN 2231-5063 Impact Factor :3.4052(UIF)
Volume - 4 | Issue - 12 | June - 2015 Available online at www.aygrt.isrj.org

# LIGNITE FLY ASH AND AGRICULTURE: A REVIEW

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## Short Profile

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**ABSTRACT:**
In India, National Thermal Power Plant run more than 70 thermal power plant and subsequently generate about 110 million tonnes of coal-ash and this is predicted to increase up to 170 million tonnes per annum by the year 2012. Fly ash from power generation can be considered either as a waste or as a resource yet to be fully utilized. Huge amounts of fly ash are deposited in adjoining area of the Thermal power plants. These barren fly ash dykes create varied kinds of environmental hazards due to erosion and leachate generation and health hazards to the nearby inhabitants. The present review is focused on application of Lignite fly ash in agriculture. The present review deals with the following topics: Significance of lignite fly ash, Beneficial effects of lignite fly ash, Effect of lignite fly ash on crop growth and yield and Combined effect of lignite fly ash with manures in crop production.

KEYWORDS
*Lignite fly ash, Thermal power plant, Agriculture and Crop yield.*

## 1.INTRODUCTION

Industrial pollution has been and continues to be a major factor causing the degradation of the environment around us, affecting the water we use, the air we breathe and the soil we live on. The exponential increase in industrialization is not only consuming large areas of agriculture lands, but simultaneously causing serious environmental degradation as well as to soil. Water originating from various industries is finding their place in agriculture. The challenge is to properly incorporate the disposal of the wastes in a controlled management programme so that the applied industrial solid wastes do not contribute any problem of pollution to soil, soil microbes and environment.

In India, National Thermal Power Plant run more than 70 thermal power plant and subsequently generate about 110 million tonnes of coal-ash and this is predicted to increase up to 170 million tonnes per annum by the year 2012. Fly ash from power generation can be considered either as a waste or as a resource yet to be fully utilized. Huge amounts of fly ash are deposited in adjoining area of the Thermal power plants. These barren fly ash dykes create varied kinds of environmental hazards due to erosion and leachate generation and health hazards to the nearby inhabitants.

Lignite fly ash has a potential in agriculture and related applications. Physically Lignite fly ash occurs as very fine particles, having an average diameter of < 10 mm, low to medium bulk density, high surface area and very light texture. Chemically the composition of Lignite fly ash varies depending on the quality of coal used and the operating conditions of the Thermal Power Stations. Approximately on an average 95 to 99% of Lignite fly ash consists of oxides of Si, Al, Fe & Ca and about 0.5 to 3.5% consists of Na, P, K and S and the remainder of the ash is composed of trace elements.

Besides many essential macronutrients (P, K, Ca and S) and micronutrients (Fe, Mn, Ni, Cu, Co, B, and Mo), fly ash also contains a number of toxic heavy metals such as Cd, Pb and Se (Rautaray *et al.*, 2003; Adriano *et al.*, 1980). Sometimes, the concentration of trace metals in fly ash exceeds the levels of these metals found in normal soil (Kalra et al., 1996). Various studies concerning the impact of fly ash on soil or plant productivity have been mostly carried out under laboratory conditions (Sinha and Gupta, 2005).

## 2. LIGNITE FLY ASH

Production of electricity in India is mainly dependent on coal fired thermal power plants. Lignite fly ash (LFA) is a by-product from thermal power stations. Fly ash, a by-product of coal fired thermal power industries, amounts to about 35 - 40% of the coal used by the thermal power plant. In other words, generation of one MW of electricity from coal requires about one acre of land for disposal of fly ash (Sahu *et al.*, 1994). In India Fly ash production was about 112 million tones during 2005 - 2006 and it is expected to be about 150-170 million tones per annum by the year end of 2012 (MOEF, 2007; Pandey et al., 2009). However, such large scale production of fly ash by thermal power industries would pose a formidable environmental challenge regarding its disposal and overall impact on environment.

Lignite Fly ash (LFA) which is a by-product of thermal power unit, called as a waste material can be beneficially utilized for increasing agriculture production. Large quantity of LFA was accumulated annually, and only a small quantity of the LFA is supplied to cement factories for use in the production of cement. The disposal of LFA is done through land fill and such practice consumed more valuable land areas and the ground water gets contaminated due to leaching of elements in the industrial wastes like

LFA. Agriculture is the only way and means of utilizing the industrial wastes like LFA, in a controlled manner by combining with organic manures, pressmud and crop residues, so that the microbial population will not be affected (Kumarimanimuthu Veeral, 2010). LFA contains heavy metals, some heavy metals are considered as essential plant nutrients, hence its rate of application could be minimized (Raghupathy, 1988). For the purpose of agricultural use, the transport of LFA to far-away places may cost more. So utilization near the generation source is much beneficial. Hence, the disposal of lignite fly ash is one of the major solid waste management problems in the Neyveli thermal power station.

## 3. SIGNIFICANCE OF LIGNITE FLYASH

In India, about 100 million tones of Lignite flyash is being generated by the combustion of coal in over 82 thermal power plants. Its generation is estimated to cross over 140 million tones by 2020, considering 10 per cent annual growth in power generation through thermal power plants. The huge quantity of Lignite flyash poses problem for its storage, requiring around 30,000 hectares of land for its safe disposal. Although concerted efforts are being made to develop technologies for the gainful utilization of Lignite flyash for different purposes, the present consumption is hardly around 13 per cent of the total generation in the country (Samra *et al.*, 2003). Therefore, it is necessary to establish regular utilization avenues of Lignite flyash. Agriculture is one of the avenues where it can be used for gainful purpose.

The bulk density of Lignite Flyash is 1.39 Mg m-3 which indicates that it has very good porosity due to the presence of lighter particles. It contains more than 60 per cent of particles having a size of less than 0.25 mm. it has got a maximum water holding capacity of heavy clayey soils and sandy soils (Mahalingam, 1995). Lignite flyash is a material having high water retention capacity and rich in essential nutrients. Therefore, it may support better plant growth in arid and semi and regions where soils are generally poor in fertility (Kansal *et al.,* 1995).

Lignite Flyash is one of the furnace residues produced, when polverised coal or lignite was burnt in electric power generating plants Maiti *et al*., (1990). Raghupathy (1990) and Poonkodi (1999) explored the use of Flyash in agriculture. Flyash is an amorphous ferro alumino silicate product from coal fired power stations. The analysis of flyash collected from different thermal power station resealed that it contains moderate amounts of P,K, Zn Fe and B and appreciable amounts of Si, Ca, Mg and S and traces of heavy metals viz., Cr, Cd and Pb (Baskar and Selvakumar, 2001). Vimal Kumar *et al*., (2001) found that Flyash contained all naturally existing elements.

Percentage lignite Flyash utilization of the total ash generated in different countries amount to more than 85% in west Germany, 100% in Denmark, 85% in France, 50% in UK, 45% in china and 38% In India, Kalra *et al*. (1997) have reported that lignite Flyash production in India will exceed 140 million tons by 2020. Lignite Flyash production depends on the quality of the coal, which contains a relatively high proportion of ash that leads to 10.30% Flyash formation (Singh and Siffiqui, 2003).

The Lignite Flyash (LFA) contains a high concentration of toxic heavy metals such a Cu, Zn, Cd, Pb, Ni, Cr, etc. (Ravtaray *et al.*, 2003; Lee et al., 2006; Tiwari *et al*., 2008) along with low nitrogen and phosphorus content and pH ranged from 4.5 to 12.0 depending on the S-content of parental coal.

## 4. BENEFICIAL EFFECTS OF LIGNITE FLY ASH

### 4.1. Role of Lignite fly ash in Agriculture

The large scale use of Lignite fly ash in agriculture and wasteland development holds a potential to increase on an average 15% yield of grains, oil seeds, sugarcane, cotton and about 25-30% of vegetables resulting another green revolution. Fly ash is the residue obtained when pulverized coal or brown coal (lignite) undergoes combustion in electric power generating plant. Use of Lignite fly ash in agriculture has been suggested by Martens (1971) and Fail and Wochok (1977).

### 4.2. Nutrient status of lignite fly ash

The LFA of NLC has been reported to be alkaline (pH, 10-12; Ca, 8-12%), and its cementitious property is useful in improving the water storage capacity of sany soils while providing a source of plant nutrients (CARD, 1997). Mishra and Shukla (1986) observed that the major fraction of Lignite fly ash consists of silt and sand sized particles, while the particle size of Lignite fly ash ranged from 0.01 to 110 µm. According to Kene *et al*. (1991) coal Lignite fly ash has bulk density of 1390 kg $m^{-3}$ and electrical conductivity of 0.35 $dsm^{-1}$. Waramble et al. (1992) found that Lignite fly ash constituted particles of size less than 0.25 mm upto 60.96 per cent and 28.79 per cent particles of size > 0.25 m.

In addition, it also serves as supplementary source of essential plant nutrient viz., Ca, Mg, K, P, S, Cu, Zn, Mu, Fe, B and Mo (Raghupathy 1990; Manoharan *et al*., 2004). The studies have shown that Lignite fly ash has position effects as a liming agent, a soil conditioner, and a source of essential plant nutrients and is also effective in the reclamation of waste, degraded land, and mine spoil (Singh et al., 1997; Ram *et al*., 2006). Lignite fly ash also contains environmental toxins in significant amounts, including arsenic; barium; beryllium; boron; Cadmium; Chromium; Chromium VI; Cobalt; Copper; fluorine; lead; manganese; nickel; selenium; strontium; thallium; and zinc (NRC and NA, 2006).

### 4.3. Effect of Lignite fly ash on physico-chemical properties of soil

Addition of Lignite fly ash has been found to alter the texture of sandy and clayey soil to loamy (Fail and Wochock, 1977). Application of Lignite fly ash at 0, 5, 10 and 15% by weight in clay soil significantly reduced the bulk density and improved the soil structure, which in turn improves porosity, work ability, rood penetration and moisture-retention capacity of the soil (Kene *et al.,* 1991). He also stated that lignite fly ash acts as a better soil conditioner for clay and sandy soil and it may also be used as carrier material of micronutrients to rectify their deficiencies. Similar inferences were earlier documented by Rama Subramonian and Chandrasekaran (2001).

Page et al. (1980) showed that application of Lignite fly ash to variety of agricultural soil resulted in improved soil porosity, workability of the soil, root penetration and the moisture retention capacity. In contract the field studies conducted by Raman *et al.* (1996) revealed that the addition of lignite fly ash did not have any significant effect on soil pH or EC.

Application of Lignite fly ash @ 10 t $ha^{-1}$ decreased the bulk density and maximum water holding capacity of soil, while no marked effect on pH, EC, CEC and lime content of soil was noticed. The available NPK and micronutrients viz., Cu, Fe, Zn, Mn and exchangeable Ca and Mg were increased with fly ash application (Anjali Deshmukh et al., 2000).

Among the lignite fly ash ashes tested, Elamvaluthi (2001) observed that dry lignite fly ash has more effect on p adsorption than wet lignite fly ash in Vertisol. Selvakumar *et al.* (2001) stated that continuous addition of lignite fly ash resulted in a significant increase in pH, EC and exchangeable Na in the post harvest soil. The results also revealed that even after continuous addition of lignite fly ash for three seasons, there was no hazardous level of heavy metal content that otherwise would affect soil health and crop production.

The Ca in Lignite Flyash readily replaces Na at clay exchange sites and thereby enhances flocculation of soil clay particles, keeps the soils friable, enhances water penetration and allows roots to penetrate compact soil layers (Jala and Goyal, 2006). Fly ash is considered to be a rich source of Si and application of LFA in Si-deficient soils has been demonstrated to improve the Si content of rice plants as well as their growth (Lee *et al*., 2006).

## 4.4. Effect of Lignite fly ash on biological properties of soil

Information regarding the effect of Lignite fly ash amendment on soil biological properties is very scanty (Schutter and Fuhrmann, 2001). Sarangi *et al.* (2001) reported that invertase, amylase, dehydrogenase and protease activity increased with increasing application of Lignite fly ash upto 15 t $ha^{-1}$ but decreased with higher level of its application. Kumar *et al.* (2008) isolated metal tolerant plant growth promoting bacteria (Enterobacter sp.) from LFA contaminated soils and found that the strain Enterobacter sp. and its siderophore over producing mutant are capable of stimulating plant biomass and enhance phytoextraction of metals from LFA by metal accumulating plant i.e., Brassica juncea. However, LFA amendment without VAM inoculation was also found to enhance the growth of plants as compared to control plants.

Ray and Adholeya (2008) presented a correlation between organic acid exudation and metal uptake by ectomycorrhizal fungi grown on pond ash in vitro and this finding supports the widespread role of low molecular weight organic acid as a function of tolerance, when exposed to metals in vitro.

Hrynkiewiez *et al.* (2009) evaluated the use of inoculation with a mycorrhiza-associated bacterial strain (Sphingomonas sp.) to promote mycorrhiza formation and plant growth of three willow clones (Salix sp.) on Lignite fly ash from an overburdened dump in a pot experiment.

## 4.5. Impact of Lignite fly ash on soil fertility

Industrial wastes like lignite fly ash as a source of sulphur could also be used in agriculture (Maiti *et al.*, 1990; Ganesan, 1992). Gurunathan (1990) reported that the application of lignite fly ash enhanced the crop yield and yield attributes of groundnut. It increased the P, K, Ca and Mg content in haulm, kernel and shell of groundnut. The uptake of N, P, K, Ca and Mg, by pod and haulm was also increased with lignite fly ash application. Soil properties as influenced by lignite fly ash application have been studied by several workers (Inam, 2007) for utilizing this industrial waste as an agronomic amendment.

## 5. EFFECT OF LIGNITE FLY ASH ON CROP GROWTH AND YIELD

Several workers reported the beneficial effect of lignite fly ash combined with pressmud and inorganic fertilizers. High availability of nutrients due to the combined application of lignite fly ash substantially increase in the availability of N, K, Ca, Mn, and Zn in soil due to the combined application of pressmud (Prasad, 2005) and increase in pod yield and finally net return.

Sulphur is the most essential plant nutrient for enhanced development of pod number, pod size and kernel colour. It is the only nutrient directly involved in bio-synthesis of oil and in formation of Protein, vitamins and amino acids. Enhancement of the availability of essential plant nutrients viz., Ca, Mg, S., K, P, Cu, Zn, Mn, Fe, B and Mo in soil stratum (Chang et al., 1977). The groundnut crop might have exploited the available nutrients to a maximum extent and resulted in better root initiation, proliferation and better crop growth. Further, Ca and S present in good proportion in LFA might be responsible for increased root nodulation and nitrogen fixation (Raja Rao, 1978), which in turn might have promoted growth and development.

Adriano *et al*. (1978) noticed a significant increase in contents of soil available N, P, K and S with application of LFA. Favorable improvement of soil physico-chemical characteristics and increased availability of both secondary and micronutrients to the crop as evidenced by the uptake studies might be the reasons for increased pod yields. Lignite fly ash addition generally increases plant growth and nutrient uptake.

Weinstein *et al*. (1989) reported that fly ash increased crop yield of groundnut. Balanced nutrition to any crop at critical stages of crop growth results in greater accumulation of photosynthates in source and effective translocation of the assimilates to sink. This may be also the reason for increased number of pods plant-$^{1}$, shelling percent and kernels weight.

Ganesan (1992) reported that the application of lignite fly ash enhanced the crop growth, yield attributes and yield of groundnut. He also obtained enhanced growth attributes of groundnut viz., plant height, leaf area index, effective nodules plant-1 and dry matter production with the incorporation of lignite fly ash in groundnut.

According to Balu (1993), the application of lignite fly ash at 2.5 t ha-1 in combination with bio-digested pressmud at the rate of 12.5 t ha$^{-1}$ significantly enhanced the pod yield, yield attributes viz., number of pods plant$^{-1}$, hundred kernel weight, shelling percentage and also the protein content of groundnut.

Kuppuswamy *et al*. (1995) noticed that addition of LFA @ 5 t ha$^{-1}$ along with pressmud @ 20 t ha$^{-1}$ registered an additional yield of 598 kg ha-1 compared with control in groundnut. Sankar *et al*. (1995) reported that lignite fly ash could be used as on effective source of plant nutrients like Ca, Mg and K etc. Among levels of fly ash tried, 10 t ha$^{-1}$ was found to be optimum in improving the yields of pod and haulm and nutrient uptake by groundnut.

Singh and Tripathi (1996) noticed that the application of lignite fly ash improves the growth and yield characteristics with respect to plant height, branching respect to plant height, branching, leaf area, root nodulation, early flowering and maturity. Julia Banumathi and Kuppusamy (1996) record high concentration of nutrients along with admirable physico-chemical properties with LFA grades.

Arvindkumar et al. (1999) reported that fly ash incorporation in soil increased the grain yield of both soybean and wheat corps. Percent increase in grain yield with graded levels of fly ash (4 to 16%) ranged from 55 to 90 in soybean. Similarly, significant increase in yield was observed with 2nd and 3rd crop of groundnut with the application @ 10 t ha$^{-1}$ of LFA itself.

Vimal Kumar *et al.* (2001) also obtained higher monetary returns from groundnut through the application of fly ash compared to gypsum and NPK applications. He also reported significant reduction in pod and haulm yield of groundnut under NPK alone compared to application of lignite fly ash + NPK. Anu Mary John *et al.* (2001) also reported increased availability of soil nutrients and their high uptake by groundnut through addition of lignite fly ash.

Poonkodi (2003) also obtained higher monetary returns in groundnut with the application of LFA compared to gypsum and NPK application. She concluded that the application of LFA @ 4 t ha$^{-1}$ significantly increased the pod and haulm yield of groundnut and also increased the soil available N, P, K, Ca and S contents. Ram et al. (2003) recorded the highest yield with the application of 200 t ha$^{-1}$ LFA along with 10 t ha$^{-1}$ of pressmud. The groundnut pod yield increased by 24.8 per cent with the application of LFA at 40 t ha$^{-1}$; the increase in yields with lignite fly ash addition could be attributed to improvement in physical characteristics and availability of nutrients like P, K, S, Ca, Mg, Si and Na.

Manoharan *et al.* (2004) also obtained significant increment in groundnut oil content through application LFA. Lignite fly ash application has made the oil to become specialized grade suitable for human consumption without any toxic effects. The results on the yield of different crops grown with lignite fly ash in various soil types are included in black soil region 10-15 t ha$^{-1}$ seed cotton, sorghum, gram, soybean, groundnut, wheat 10-46% yield increases and red soil 30- 60 t ha$^{-1}$ sunflower, groundnut 10-26 percent yield increases. It is evident from the results that the addition of fly ash increased the yield of different crops from 10-40 %. Thus the use of fly ash in agriculture has proved to be economically rewarding.

Kumar Ghosh and Singh (2012) reported the potential of coal fly ash, a waste from thermal power stations, for retaining soil applied metolachlor and atrazine within the application zone. Both the fly ashes were highly effective in reducing the leaching losses of metolachlor and atrazine and at 2% and 5% fly ash amendment levels the herbicides were retained in the top 15 cm profile of the column. However, fly ashes varied in their capacity in reducing the downward mobility of herbicides, as the Inderprastha fly ash was more effective than the Badarpur fly ash. Although, fly ash contained heavy metals like Cr, Cu or Pb, but they were not detected in the leachate. Also, concentration of other metals like Zn, Mn and Fe in leachate decreased after fly ash amendment.

Annual fly ash production ranges from 2 MT in the Netherlands to 112 MT in India, whereas fly ash utilization ranges from 100% in the Netherlands to 38% in India. 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. Reviews on fly ash in agriculture are scarce. The potential of fly ash as a resource material is due to its specific physical properties such as texture, water holding capacity, bulk density, and pH. Moreover fly ash contains almost all essential plant nutrients. Fly ash can be used as an amendment in soil. Fly ash can improve soils physical and chemical properties, reduce pest on crops and increase crop yields. The amount and method of fly ash application to soil depend on the type of soil, the crop grown and fly ash characteristics. Besides positive effects fly ash may contain also toxic metals and radionuclides. Therefore, use of fly ash should be done with care, notably by taking into account the uptake of metals by plants (Amit Gupta et al., 2012).

## 6. COMBINED EFFECT OF LFA WITH MANURES IN CROP PRODUCTION

The significantly increased yield for groundnut and maize, even up to the final crop that is the overall beneficial effect of LFA application with other amendments was an indirect indicator of improvement in soil fertility. As was found in another investigation (Narayanaswamy and Nambirajan, 2000), there were fewer pest in LFA- amended plots, particularly polyphagus pests such as Helicoverpa armigera and Spodoptera litura, a circumstance that also enhanced crop yield.

According to Mittra *et al.* (2003), integrated use of flyash, organic and inorganic fertilizer saved N, P and K fertilizers to the range of 45.8, 33.5 and 69.6%, respectively and gave higher FUE than chemical fertilizers alone or combined use of organic and chemical fertilizers in a rice-groundnut cropping system.

With one-time and repeat applications of LFA (with and without pressmud), yield increased significantly (7.0-98.0 %) in relation to the control crop. The pressmud enhanced the yield (3.0-15.0 %) with different LFA applications. The highest yield LFA dose was 200 t /ha for one time and repeat applications, the maximum yield being with crop III (combination treatment). One-time and repeat application of LFA (alone and in combination with pressmud) improved soil quality and the nutrient content of the produce (Lal et al., 2007).

Beneficial Effects improve soil texture, reduces bulk density of soil, improves water holding capacity, optimizes p+1 value, increases soil buffering capacity, improves soil aeration, percolation and water retention in the treated zone (due to dominance of silt-size particles in LFA, reduces crust formation, provides micro-nutrients like Fe, Zn, Cu, Mo, B etc., provides macro-nutrients like K, P Ca, etc. reduces the consumption of soil ameliorants (fertilizer lime), LFA can also be used as insecticidal purposes, and decreases the metal mobility and availability in soil. Harmful effects Reduction in bioavailability of some nutrients due to high pH (generally from 8 to 12, high salinity and high content of phytotoxic elements, especially boron (Pramkishor et al., 2011).

## 7. CONCLUSION

The above literature shows that industrial wastes particularly sugar mill wastes, compost mixtures and lignite fly ash is highly beneficial for various agricultural crops. From this reviews, it was clear that the sugar mill industrial wastes and lignite fly ash not only increased the yield of agricultural crops and it also maintains the soil fertility in agricultural fields.

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