# Effect Of Fly Ash In Agricultural Field On Soil Properties And Crop Productivity - A Review

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## Abstract

*Fly ash is regularly generated as a by-product by coal or thermal power stations. The potential of fly ash as a resource material in agriculture and related areas is now a well-established fact. The application of fly ash in agriculture because of its favorable physic chemical properties, including appreciable content of essential plant nutrients. While compare to soil, fly-ash consists all the elements except organic carbon and nitrogen. The purpose of this paper is to provide an overview of characterization and utilization of fly ash in agriculture. The effect of fly ash on soil properties, improvement in the crop yields, heavy metal uptake by the plants and ground water contaminations were mentioned.*

## 1. Introduction

In India about 57% of the power generation produced from coal-based thermal power plants. Coal used in the thermal power plants as a fuel , contains high amount of ash upto 40%, sulphur as 0.2 – 6% and heavy metals like Hg, Mn, Cu, Pb, Ni, Fe, Cr and Cd in different concentrations [1].When coal is burnt to generate heat, the residue contains Fly Ash and bottom ash about 80% and 20% respectively [2]. Fly ash is a finely divided residue resulting from the combustion of ground or powdered coal and transported by the fuel gases of boiler fired by pulverized coal. According ASTM C-618 Fly ash can be classified into two class namely class F and class C based on the amount of calcium, silica, alumina, and iron content present in the ash.Normally burning anthracite or bituminous coal produce Class F fly ash while burning sub bituminous or lignite coal produce Class C fly ash. Every year 112 million tons of fly ash is produced, only 38 % utilized. As per the estimates, fly ash generation is expected to increase to about 225 million tons by 2017 [3]. Disposal of fly ash is carried out either by wet slurry process and wet process. In both method, fly ash is dumped in open land, which degrade the soils and enhance the air and water pollution and ultimately affects the human health [4]. It can also contaminate the under-ground water resources with traces of toxic metals present in fly Ash.

[5] Said that fly-ash is a serious problem due to its physical characteristics and sheer volumes generated. Some of the problems are:(a) fly-ash particles both as dry ash and pond ash occupy many hectares of land, due to heavy disposal near the power station.(b) Because of its fineness, it is very difficult to handle fly ash in dry state.(c) It disturbs the ecology through soil, air and water pollution.(d)Various diseases like silicosis, fibrosis of lungs, bronchitis, and pneumonitis were caused due to the long inhalation of fly-ash.(e) Fine particles of fly ash corrode structural surfaces and affect horticulture.[6] conducted a studies with six bituminous, sub-bituminous and lignite coal fired thermal power plants to measure the amount of airborne respirable crystalline silica in the breathing zone of workers engaged in fly-ash-related operations. It was found that the air samples exceeded the threshold limit about 60% which was collected from working areas. Al in fly-ash is mostly bound in insoluble aluminosilicate structures, which greatly confines its biological toxicity [7].

Utilization of fly ash represents a potential for utilities to both reduce costs and increase revenues. Many experiments and studies on the application of fly ash in agricultural has been conducted in universities and research institutes across the country for several years. It can prove beneficial to improve crops yield and enhance the moisture retaining capacity and fertility of soils.

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## 2. Physico- Chemical Properties of Fly ash

The physico-chemical properties of fly ash depends on the quality of coal which used as source, process of combustion, extent of weathering, particle size, collector setup and age of the ash. Fly-ash generally contains 65–90% of silt loam texture with the particles diameter of less than 0.010 mm [8]. The silt loam texture leads to increases the dust formation, which made big issues during the transportation and storing the fly ash. The properties such as pH, Electrical Conductivity (EC), Bulk Density (BD), Water Holding Capacity (WHC), Nitrogen (N), Phosphorus (P), Organic Carbon (OC) of fly ash from different authors were shown in Table 1. The fly ashes have the pH value of 6-11, Electrical Conductivity (EC) 42-450 µS/cm. Most of the fly ash has the Bulk Density (BD) values less than 1 g/cm$^3$, Water Holding Capacity (WHC) 43-66%.

Table.1 Physico chemical properties of fly ash

| Reference | pH | EC(µS/cm) | BD (g/cm$^3$) | WHC (%) | N (%) | P (%) | OC (%) |
|---|---|---|---|---|---|---|---|
| [9] | 8.28 | - | 0.93 | 59.3 | 0.04 | 0.29 | - |
| [10] | 8.25 | 150 | - | 43.5 | 0.003 | - | 0.30 |
| [4] | 6.98 | 650 | 1.01 | - | - | 0.04-0.8 | 0.36 |
| [11] | 9.30 | 750 | 0.94 | 45.2 | - | - | - |
| [12] | - | - | <1 | 35-40 | - | - | - |
| [13] | 9.67 | 220 | 0.96 | 74.5 | - | - | - |
| [14] | - | 42-429 | 0.93 - 1.05 | 43.90 –57 | - | - | - |
| [15] | 7.96 | 414 | 0.99 | 50.444 | - | - | 0.15 |
| [16] | 8.8± 0.4 | 761.0±28 | - | - | 0.02 ± 0.001 | 0.14 ± 0.006 | 1.17 ± 0.59 |
| [17] | 9.2 | 82 | 0.95 | - | - | - | - |
| [18] | 6.9 | 108 | - | 66 | - | - | - |
| [19] | 11.07 | 1550 | 1.55 | - | - | - | - |
| [20] | 6-10 | 150-450 | 1.26 | 45-60 | - | - | - |

Fly-ash consists about 95–99% of Si, Al, Fe and Ca and about 0.5–3.5% consists of Na, P, K and S and the remaining of the ash is composed of trace elements like lanthanum, terbium, mercury, cobalt and chromium which are found in Below Detection Limit (BDL). While compare to soil, fly-ash consists all the elements except organic carbon and nitrogen [21]. The amount of trace and heavy metals content presents in the fly ash were mention in the Table.2. It also contains natural radio nuclides such as $U^{238}$, Th $^{232}$, $K^{40}$ [22].The application of fly ash in agriculture and forestry because of its favorable physicochemical properties, including appreciable content of essential plant nutrients [23].

Table.2 Metal content in Fly ash

| Elements | Range (mg/kg) |
|---|---|
| Cu | 0.92-2.17 |
| Zn | 0.77-2.09 |
| Mn | 0.68-19.3 |
| Fe | 5.90-62.7 |
| Pb | 0.06-3.10 |
| Ni | 0.43-4.90 |
| Co | 0.03-0.46 |
| Cr | BDL-0.54 |
| Cd | BDL-0.28 |
| As | <0.05 |
| Hg | BDL |

## 3. Influence of fly ash in soil properties

Physico-chemical and biological properties of soil vary due to fly-ash amendment according to the original properties of soil and fly ash. The effect of fly ash on soil properties have been studied by several workers ([8],[10],[11],[24]- [30])

### 3.1. Physico-chemical properties

[8] found that the fly ash in soil influence to reduce bulk density and hydraulic conductivity and increase the water holding capacity. The experimental results conclude that the hydraulic conductivity is reducing when fly ash is amended greater than 10% to the acidic soils. And also observed that among five soil types, Reyes silty clay showed an increase in bulk density from 0.89 to 1.01 g/cm$^3$ and a marked decrease in soils having bulk density varying between 1.25 and 1.60 g/cm$^3$ when the corresponding rates of fly ash amendment increased from 0% to 100%.

[31] revealed that the fly ash contain several elements namely Si, Fe, Al, Ca, K, Mg and Na concentration of 17%, 11%, 9.8%, 6.4%, 1.4%, 1.2% and 0.4% respectively and also the concentration of heavy metals such as Mn, Ni, Co, Cr and Mo were reported as 582 mg/kg, 53 mg/kg, 34 mg/kg, 67 mg/kg, and 20 mg/kg respectively. We conclude from this result that the fly ash can be used in agriculture field as valuable fertilizer.[26] Investigates the effect of soil chemical properties on the application of the coal ash

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mixture. He resulted that the application of coal ash mixture in an increase of soil pH when compared to the control. Also the comparison of the application of the two different types of coal ash at the same rate among treatments suggests that fly ash has a higher potential to increase pH than clinker ash. He concluded that may be due to theirs particle size and fine fly ash fraction that was more effective than the coarse one.

[11] Studied bulk density of soils were lower, while WHC and porosity were higher than the soil, silt content of both the ashes was higher than the soil. [19] Observed Electrical conductivity of soil increased gradually with increase in percentage of fly ash. The highest electrical conductivity was observed 75%. It varied significantly between the treatments but there was no significant difference between the days. [27] Also observed increase in EC of soil from 0.467 to 0.746 as the proportion of fly ash increased. [32] Founded that bulk density increased as fly ash addition increased to 25%, and then decreasing with additional fly ash.

### 3.2. Biological properties

The effects of fly-ash amendment on soils were affect biological properties of soil. The microbes mediated processes in the soil disturbs by the application of pollutants such as fly ash leads to the imbalance of ecosystem [33]. [34] Resulted that increased content of fly ash decrease the total bacteria, actinomycetes, fungal species and also the enzyme in soil such as phosphatase, sulphatase, dehydrogenase and invertase.Several laboratory experiments [35]-[38] resulted that application of fly-ash particularly to sandy soil greatly inhibited the microbial respiration, enzymatic activity and soil N cycling processes like nitrification and N mineralization.

[39] Reported that the application of lignite fly-ash reduced the growth of seven soil borne pathogenic microorganisms, whereas the population of Rhizobium sp. and P-solubilizing bacteria were increased under the soil amended with either farmyard manure or fly-ash individually or in combination [40]. [41] observed that there was no impact on agriculture soil on amendment of fly ash up to 100 tons/ha. It found at 400 – 700 tons/ha will cause adverse affect on microbial activity on soil. [35] founded that 20% fly ash decreased bacteria, actinomycetes and fungi by 57, 80 and 86%, respectively. [42] Founded that the application of fly ash up to 15 t ha/year increase the activity of invertase, amylase, dehydrogenase and protease activity but decreased with higher levels of fly ash application which improves the crop productivity.

## 4. Influence of fly ash in Agriculture

Fly Ash has a potential in agriculture and related applications. The Indian Fly Ash is alkaline and as such improves soil quality. In fact, Fly Ash consists of all elements present in soil except organic carbon and nitrogen [3]. Presence of micro and macro nutrients such as Potassium, Boron, Calcium, Zinc etc. improves the fertility of soil. CPRI Bengaluru has developed porous and hollow globules from Fly Ash. These globules if buried around crop, absorbs the water and retain it for longer period by resisting evaporation. This application helps to widen the gap between two watering cycles. It can also be used as insecticide and if used along with bio-waste, it significantly supplements the utility of chemical fertilizers.

### 4.1 Improve crops yield

Several researchers [43]-[51 have investigated with fly ash to increase the crop yield. For their experiments different crop species of wheat (Tritiucm aestivum), alfalfa (Medicago sativa), barley (Hordeum vulgare), bermuda grass (Cynodon dactylon), Sabai grass (Eulaiopsis binata), mung (Vigna unguiculata) and white clover (Trifolium repens) were used.

[52] Observed that rice yield is improved from 1.02 to 3.83 t/ha in 1979 and 4.65 t/ha in 1980 with the amendment of fly-ash at 10 and20 t/ha. Similarly, wheat yield was improved from 0.57 t/ha to 2.53 t/ha in 1979 and 2.85 t/ha during 1980s. According to [53] application of 10 t/ha fly-ash and 25:50:0 NPK kg/ha resulted in better growth and yield attributes which led to the highest pod yield of groundnut.[11] Studied the bulk application of fly ash application at 30-40 t/ha recommended dose of NPK fertilizers alone or along with FYM @ 20 t/ha was used for cultivation of sunflower maize crops. The results indicated that the total yield of 35.7 q/ha was recorded and concluded that the application of either pond ash or fly ash increased the grain yield of both sunflower and maize significantly.

[54] observed the fly ash amendment on soil with different concentration using three species namely wheat (*Triticum aestivum*), mung bean(*Vigna radiata)* and urad beans (*Vigna mungo)* and found that the application of fly ash improves the seed germination rate where as in yhe absence of fly ash the seed germination rate was very slow. The maximum yield of wheat, mung bean and urad beans were at 60%, 10-20% and 20% of fly ash admixture respectively. [55] Studied an experiment with brinjal (Solanum melongena). The result indicates the plant growths

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were better in the fly ash amendments when compared to control and the maximum field at 180 t/ha fly ash amendments on soil. [56] experiment resulted that amendments of fly ash in soil using *Allium Cepa* species increase the trend of each growth parameters such as root number, root length, shoot length, leaf number, till 5t/h but decrease at higher doses like 10 and 15 t/h. Contents of both chlorophyll a and b of *Allium Cepa* leaves had increasing trends with increasing FA amendments up to 5t/h but at higher level of FA Chlorophyll steadily decreased. Carotene content decreased in all concentration.

[57] Shown the crops yield percentage with the application of fly ash in different soil crop combination and it is mentioned in Table 3.

Table.3 Crops Yield Increase on Amendment of fly ash

| Crops | Yield increase in % |
|---|---|
| Banana | 30 |
| Paddy, Potato | 31 |
| Pearl Millet | 32 |
| Seed cotton, Sorghum, Gram, Soybean | 10-46 |
| Sunflower, Groundnut | 10-26 |
| Sugarcane | 22 |
| Wheat, Mustard, Rice, Maize, | 6-18 |
| Vegetables | 15 |

[58] Conducted a study on Fly ash application in soil using *Solanum nigrum*.. They founded up to concentrations of 30% fly ash there will be a improved the growth of *Solanum nigrum* plant. But further increase in the fly ash concentration caused deleterious effects on the plant growth, biomass, and leaf area, number of leaf per plant and leaf photosynthetic pigments.[59] Revealed that the fly ash could be beneficial in improving the soil quality and plant growth. The most suitable treatment for improved plant growth and crop yield for oil yielding plant *Brassica juncea* is 40%, fly ash with soil as it gives the maximum crop yield.

## 4.2 Metal contents in plant

[27] Revealed that elements like K, Na, Zn, Ca, Mg and Fe in fly-ash increases the yield of agricultural crops at high concentration. But the application of fly-ash may have a tendency of accumulating elements such as B, Mo, Se and Al reduce the crop yields and also affect animal and human health at toxic level. [17] studied the application of fly ash, Cd and Pb were not accumulated in wheat (*Triticum aestivum*), mung bean(*Vigna radiata)* and urad beans (*Vigna mungo)* and also Cu, Mn and Ni were accumulated in very low concentration. Fe, Mg and Zn were accumulated in higher concentration but not above the permissible level of Indian Standards and WHO and concluded that upto 10-20% use of fly ash mixture in agriculture is safe for crops wheat (*Triticum aestivum*), mung bean (*Vigna radiata)* and urad beans (*Vigna mungo).*

[55] concluded that the amendment of fly ash will not affect the vigor of plant. The accumulation of toxic heavy metals such as Cr and Ni at 120t/ha & 180t/ha amendment indicates safe utilization for human consumption. The essential metals Zn and Cu relatively accumulate in high level and beneficial for consumption. [43] Studied the heavy metal content in grain and straw of rice. There was a marginal increase in content of Se, Cd under different treatments and no increment in Ni content. They concluded that these marginal variations does not affect the plant and remains safe for human consumption.[56] Conducted the experiment with *Allium cepa L* and found that the amendment of fly ash increases the content of contaminating elements such as Pb, Cr and Cd and the Fe content of soil remained almost same. [60] Experimental data revel that when soil and water get contaminated with fly ash, all the heavy metal as Cu, Ni, Co, Pb, Zn, Cd and Cr become highly reactive and get easily absorb into the plant body. Fly ash treated soil sample becomes enriched with the presence of different heavy metals which in due course makes the medium reactive.

## 4.3 Impact on ground water

[61] Laboratory experiments revealed that 5–30% of toxic elements especially Cd, Cu and Pb are leachable. Moreover, the concentration of these elements in fly-ash is very low; hence, the chance for leaching of these elements to ground water is negligible.[62] studied the fly ash had initially high pH and calcium concentrations that declined as the water column took up CO2 and contribute to leaching of arsenic and chromium to surface water and groundwater in addition to contaminating the nearby soils.[63] studied the leaching of fly ash and the concentrations of all the heavy metals under study in the leachates were invariably well below the permissible limits for discharge of effluents as per the Indian standard near the ash ponds and at the

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surrounding villages shows that the concentration of heavy metals is within the permissible limits of Indian standard IS: 10500 and WHO limits for drinking water quality.

[64] Identified the presence of these heavy metals ground water samples of the ash pond. They revealed the concentration of Zn was found in higher side while Ni concentration was very less and Cr was below detectable limit. No ash pond lining is employed in the construction of the ash pond; hence leaching of heavy metals is possible. [65] Investigation the underground and surface water samples were collected and the result shows that, concentration of certain heavy metals were above permissible limit. The heavy metals like As, Hg and Zn shows highest concentration, while metals such as Cu, Cd and Pb shows low concentration from the surrounding areas of fly ash dumping site near Parli Thermal Power Station (PTPS).

## 5. Conclusion

The applications of fly ash in agricultural usage were differ from the characteristics of fly and soil type. The high concentration of micro nutrient and macronutrient presents in fly ash increases the yield of many crops in agricultural field. The physic chemical properties and biological properties of soil were improved by fly ash at proper amendment leads to improve the productivity. At the same time some toxic metal at higher level reduce the productivity of yield and make contamination of ground water. If we make proper knowledge of fly ash creates significant benefits in terms of yield saving as well as environment.

## 6. References

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