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FLY ASH BASED BIOPESTICIDES: A COMPREHENSIVE REVIEW

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ABSTRACT

Fly ash (FA), the notorious waste product of coal based thermal power plants, known for its ill effects on agricultural land, may now come as an aid for the farming community. Because of its great availability and low cost, further possibility of its usage should be investigated. Fly ash from both coal and lignite- acts as a good carrier for bio pesticides. It is used as a conditioner to arrest soil erosion, and to induce plant resistance against diseases. However, several studies proposed that FA can be used to improve physical, chemical and biological properties of the degraded soils and is a source of easily available and cheaper micro, macro-nutrients for crops. Thus use of fly-ash is an effective way of utilization of problematic fly-ash waste in a useful manner. In this study, the review covers the sources, merits and applications of fly ash and fly ash based biopesticides and fertilizers in agriculture. This study also discusses the case studies and scientific reports about the use of fly ash.

KEYWORDS: *Fly ash, coal, Agriculture, bio pesticides, soil, crops*

INTRODUCTION

Humans are using traditional and folkative cultivation methods in their agriculture to minimize pest and increase crop yield since ancient time. The current millennium demands that the pest management studies should be bio-intensive. One of the methods in recent years that have gained increased attention is the use of bio pesticides in order to develop environmentally friendly, safe and integrated crop management (IPM) compatible approaches and tactics of pest management. Biopesticides are naturally occurring substances that control pests by nontoxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the harmful as well as useful pests. Biopesticides are considered eco-friendly and easy to use. Biopesticides are receiving much practical attention as a means to reduce the load of synthetic chemical products being used to control plant diseases.

Biopesticides fall into three major classes:

1. Microbial pesticides

It consists of a microorganism (e.g., a bacterium, fungus, virus or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pest. The most widely used microbial pesticides are subspecies and strains of *Bacillus thuringiensis*, or Bt. Each strain of this bacterium produces a different mix of proteins, and specifically kills one or a few related species of insect larvae. While some Bt's control moth larvae found on plants, other Bt's are specific for larvae of flies and mosquitoes. The target insect species are determined by whether the particular Bt produces a protein that can bind to a larval gut receptor, thereby causing the insect larvae to starve.

2. Plant-Incorporated-Protectants (PIPs)

These are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists can take the gene for the Bt pesticidal protein, and introduce the gene into the plant's own genetic material. Then the plant, instead of the Bt bacterium, manufactures the substance that destroys the pest.

3. Biochemical pesticides

These are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest. Biochemical pesticides include substances, such as insect sex pheromones, that interfere with mating, as well as various scented plant extracts that attract insect pests to traps.

Fly ash (FA)

Fly ash (FA) (also known as a coal combustion product CCP) is the finely divided mineral residue resulting from the combustion of powdered coal in electric generating plants. Fly ash consists of inorganic, incombustible matter present in the coal that has been fused during combustion into a glassy, amorphous structure. Coal can range in ash content from 2%-30%, and of this around 85% becomes fly ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now require that it can be captured prior to release. Internationally, fly ash has been used in many applications [1, 2] for several years.

Harmful Effects of fly ash to Environment

1. Fly ash being light mixes with air water and pollutes the environment.
2. Fly ash corrodes structural surface and its deposition affects horticulture.
3. Slurry disposal lagoons/ settling tanks become a breeding ground for mosquitoes and bacteria. In addition, they contaminate underground water with traces of toxic metals.
4. Fly ash disposal in rivers/ sea destroys aquatic life.
5. 2 % of the cost of thermal power plants goes towards fly ash disposal system.
6. Annual expenditure on the road transport for dumping fly ash is Rs 50 crore.

Indian scenario of fly ash

India generates around 112 million tonnes of bituminous wastes from coal and lignite based thermal power plants annually [3]. Power plants generally dispose it in ash pond which further contaminates ground and surrounding water bodies. This has adverse effect on public health and environment. 120 million tonnes/ year fly ash is produced in India. In a number of investigations on the aspect of utilization of fly ash for agricultural purposes, It has been reported that FA (Fly Ash) acts as a source of micro-nutrients essential for plant life and agricultural crops as well as in correcting the deficiency of several micronutrients and preventing the toxicity of some metal ions through the neutralization of soil acidity. The effect of fly ash addition on the uptake or enrichment of various nutrients and heavy trace elements in soil as well as various crops has been investigated with safe use of crop produce for human consumption [4, 5]. Application of fly ash to soils would increase the available water content of soil [6, 7]. Percentage ash utilization of the total ash generated in different countries is investigated to be more than 85% in West Germany, 100% in Denmark, 85% in France, 50% in UK, 45% in China and 38% in India. It is reported that FA production in India will exceed 140 million tons by 2020 [8].The disposal of such a huge amount of FA is one of the major problems of developing countries .

Methodology of preparation of the fly ash pesticide at lab scale

Dust formulation of fly ash and plant products of finer fraction are obtained through grinding, filtration, and then blended. The products are then stored in sealed containers 'FA-based biopesticide' (FBP). Dust formulation of the pesticides applied over the leaves using the laboratory FA duster. The leaves were sprayed with water prior to dusting for easy adhering of the dust and then air dried. Insects are then allowed to feed on the treated leaves placed over a moist filter paper, and kept in a Petri dish replicated three times. Observations on the symptoms of poisoning and eventual mortality, if any, are recorded every 24h after treatment. Other physiological alteration in the insect's body system is also recorded. In order to ravel the mechanisms of action of the FBP on insects, the feeding organs of the insects are examined for any disfiguration.

Merits of fly ash (FA) based biopesticides and biofertilizers

The field demonstration experiments carried out under varied agro-climatic conditions and soil types across the country by various R & D Institutes / Universities on the cultivation of different field crops (cereals, pulses, oil seeds, sugar cane, vegetables, etc.) and forestry species with different doses of fly ash and pond ash as soil modifier /source of economical plant nutrients with and without organic manure bio-fertilizer and chemical fertilizers in respect to crop yield, soil health, quality of crop produce, uptake of nutrients and toxic heavy metals, ground water quality etc. have revealed the following merits (**Table 1**).

Table 1.Merits of fly ash based biopesticides and biofertilizers

Sr. No.	Merits
1	It improves permeability status of soil
2	Improves fertility status of soil (soil health) / crop yield
3	Improves soil texture
4	Reduces bulk density of soil
5	Improves water holding capacity / porosity
6	Optimizes pH value
7	Improves soil aeration
8	Reduces crust formation
9	Provides micro nutrients like Fe, Zn, Cu, Mo, B, Mn, etc.
10	Provides macro nutrients like K, P, Ca, Mg, S etc.
11	Works as a part substitute of gypsum for reclamation of saline alkali soil and lime for reclamation of acidic soils
12	Surface cover of bio reclaimed vegetated ash pond get stabilized and can be used as recreational park
13	Ash ponds provides suitable conditions and essential nutrients for plant growth, helps improve t economic condition of local inhabitants
14	Works as a liming agent
15	Helps in early maturity of crop
16	Improves the nutritional quality of food crop
17	Reduces pest incidence
18	Conserves plant nutrients / water
19	Carryover of trace & heavy metals & radioactivity is insignificant
20	Crops grown on fly ash amended soil are safe for human consumption & Groundwater quality is not affected.

Radio nuclides and heavy metals

Fly ash Mission had shown that grains, seeds and vegetables harvested from the crop applied with tonnes of fly ash were found negligible amount of heavy metals. Institute of Nutrition, Hyderabad, found no harmful effects in animals or humans. There have been several reports in the literature on the presence of radionuclides in fly ash but studies on their impact have been few[9]. The radiochemical pollution of Uranium and Thorium series is always present in fly ash [10]. Scientists at Bhabha Atomic Research Centre, Mumbai say most Indian coals have very low levels of radioactivity, well below the hazardous limit. Hence radioactivity of fly ash may not be the limiting factor for its application in agriculture. Central Fuel Research Institute, Dhanbad, observed that there is no significant uptake of radioactive elements by plants. Also, there is negligible cumulative build up of these contaminants in soil when fly ash is used in agriculture. Thus this pesticide is a real time boon for industry, agriculture, animals and we human being.

Fly ash improve crop growth, yield and soil fertility

Use of fly ash as pesticide or carrier of insecticide is well known [11, 12]. Though limited quantity could be utilized for this purpose, the dust formulation prepared using this fly ash is cost effective. Since the readymade formulation based on *P. nigrum* is not available, a simple low cost dust formulation was made using fly ash as filler and tested against rice bug [13]. Fly ash was used as a filler against the serious storage pest of pulses, pulse beetle *Callosobruchus maculates* as a safe and cheap insecticide to manage the stored product insects [14]. Arnold Schumann and Malcolm Sumner (2000) revealed that the plant nutrient supply from fly ash and bio solids might have enhanced their agricultural use and crop fertility [15]. Now-a-days bio-fertilizers are gaining importance in agriculture. The application of fly ash at 20 and 40 t per hectare increased the groundnut pod yield and rice yield grain significantly [16]. In Australian soils, application of fine fly ash (20 micron meter) to the sandy soil found to reduce the hydraulic conductivity by 25% and so improve the water holding capacity [17]. The application of fly ash in two paddy soils increased the available phosphorus significantly [18]. Fly ash and its different combinations with soil (w/w) were tested to explore its possible use as a potential carrier for diazotrophs and phosphobacteria[19]. In a research *Azotobacter chroococcum, Azospirillum brasilense* and *Bacillus circulans* showed their maximum viability in fly ash alone whereas *Pseudomonas striata* proliferated most in soil: fly ash (1:1) combination. *P. nigrum* dust formulation (Pn10D) was prepared by K. Govindan et al 2010 by mixing pulverized seed powder of *P. nigrum* (10%) and fly ash (90%). Pn10D was tested against pulse beetle *Callosobruchus maculatus* (F.) .Pn10D at 4.00 percent caused mortality of *C.maculatus* after 72 hr the treatment. Thus Fly ash was used as excellent filler for black pepper, *Piper nigrum* dust formulation against *Callosobruchus maculatus* [20].

Fly ash contains considerable content of K, Ca, Mg, S and P hence its agricultural use has been proposed [21]. Higher Selenium was found in the grains of winter wheat (*Triticum aestivum*) grown on a deep bed of fly ash[22].The mechanism of plant growth and nutrition uptake was found to be enhanced by use of fly ash based pesticides[23]. Besides, fly ash increased crop yield of alfalfa (*Medicago sativa*), barley (*Hordeum vulgare*), Bermuda grass (*Cynodon dactylon*) and white clover (*Trifolium repens*)[24]. Greenhouse experiments conducted showed that application of 2-4% fly ash significantly increased N, S, Ca, Na and Fe content of rice (*Oryza sativa*) plants [25]. The foliar application of fly ash also exhibited enhancement in the growth and metabolic rates, as well as increasing the photosynthetic pigments of crops like maize and soybean[26]. In a research, tomato yield was increased by 81% [27]. Integrated use of fly-ash, organic and inorganic fertilizers saved N, P and K fertilizers to the range of 45.8, 33.5 and 69.6%, respectively and gave higher FUE (fertilizer use efficiency) than chemical fertilizers alone or combined use of organic and chemical fertilizers in a rice-groundnut cropping system[28].

Fly-ash utilization program (FAUP) has been undertaking various projects/activities for technology development/demonstration, disseminating the information, creating awareness, facilitating multiplier effects, providing inputs for policy interventions etc. in the area of safe management & gainful utilization of fly ash[29]. Vimal Kumar et al. (2005) reported that the large scaled filed application of fly ash in agriculture had been taken up at more than 50 project sites under 15 fly ash mission demonstration projects across the country in different agro-climatic conditions with varying soil crop combinations during 1994-2004 [30]. Arivazhagan K. conducted show case project on utilization of fly ash in agriculture in and around thermal power station areas NTPC-Simhadri, Dadri, Talcher Thermal and Vindhyachal in the farmers holding. These trials revealed that the application of fly ash at 50 tonne per hectare increased the yield of paddy wheat, maize, ragi, red gram, mustard, sugarcane and banana and potato crops [31]. **Table 2**.

Table 2. Effect of fly ash application on yield of various crops at different locations in India

Sr. no.	Soil Group	Location	Application Rate	Crops	Percent Yield Increase
1	Alluvial soil	Dadri (UP) and IARI(Delhi)	10-20 t/ha	Wheat,Mastard,Rice,Maize	6-18 %
2	Alluvial soil	Hissar (Haryana)	20% soil: ash (w/w)	Pearl Millet, Wheat	32 %
3	Alluvial soil	Murshidabad (West Bengal)	200t/ha/3yrs (onetime application)	Wheat, Rice	29 %

4	Black Soil	Vidarbha Region (Maharashtra)	10-15t/ha	Seed Cotton, Sorghum, Gram, Soyabean , Summer Groundnut, Wheat	10-46 %
5	Red soil	Raichur (Karnataka)	30-60/ha/3yrs (one time application)	Sunflower, Groundnut	10-26%
6	Black Soil	Raichur (Karnataka)	30-60/ha/3yrs (one time application)	Sunflower, Maize	22-42%
7	Red lateritic soil	Coimbatore & Vridhachalam (Tamilnadu)	40t/ha	Kharif Rice, Groundnut	14-25%
8	lateritic soil	Kharagpur (West Bengal)	10t/ha	Kharif Rice, Mustard	12 %
9	Red soil	Birbhum (West Bengal)	200t/ha/3yrs (one time apl)	Kharif & Boro Paddy, Potato	31 %

Further it is evident from the results, that the addition of fly ash (10-200 tonne per ha) increased the yield of different crops from 10 to 40 percent in various fields studied over India. Thus, the use of fly ash in agriculture proved to be economically rewarding.

Effect of fly ash on Biological Properties of Soil

There is very less information available on soil biological properties of fly ash [32]. The concentration of soluble salts and other trace elements was found to decrease due to weathering of fly-ash during natural leaching[33]. In a study, 20% fly ash decreased bacteria, actinomycetes and fungi by 57, 80 and 86%, respectively[34]. Invertase, amylase, dehydrogenase and protease activity was found to be increased with increasing application of fly ash up to 15 t ha y^{-1}, but decreased with higher levels of fly ash application [35]. Fly ash composted with wheat straw and 2% rock phosphate (w/w) for 90 days enhanced chemical and microbiological properties of the compost[36]. In advance fly ash was also found as an enhancer in the improvement of physical and chemical properties of soil [37, 38, 39, 40, 41, 42, 43, and 44].

DISCUSSION

Although there are many ways to consume the fly ash generated from thermal power plants but the steps taken in this direction is poor. In the present review it is discussed to explore utilization of fly-ash as carrier in bio-fertilizer, biopesticide formulations. Use of fly-ash as carrier in these formulations is expected to be an effective way of utilization of problematic fly-ash waste in a useful manner. The fly ash generation is expected to grow further as coal would continue to remain as major source of energy at least for next 25 years. The fly ash, which is a resource material, if not managed well, may pose environmental challenges. Nature has designed and provided a circular loop for regular flow of nutrients for sustainability of agriculture. But urbanization and industrialization have broken loop and encouraged a linear flow. Further, with the shrinking cultivable land resources, the demand to produce more and more food per unit area has resulted agriculture becoming heavily dependent on chemical inputs *viz.* chemical fertilizers as source for plant nutrients. Indiscriminately use of chemical fertilizers may affect soil health and may lead to a negative impact on soil productivity by destroying so many microorganisms which were beneficial to farmers. Hence for sustainable agriculture, all our efforts should be stream lined to protect and maintain soil health.

CONCLUSION

Fly ash (FA) is regularly generated as a by-product by any established 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. Fly ash based bio pesticides are effective in controlling various insect pests independently. These Bio-pesticides which would be less expensive than conventional products could be used by the bottom level farmers. Although fly ash cannot completely fulfill the need of chemical fertilizers or organic manure it can be

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used in combination with these for improvement of biological, physical and chemical properties of soil. Though appearance of heavy metals and radioactive materials in fly ash to be not much ground for concern; however their critical levels for human health in plant parts and soil should be investigated. With growing threat of degradation of environment due to excessive use of chemical fertilizers for pest control and nutrient management; fly ash based bio pesticides and bio fertilizers have emerged as safe and effective alternatives. Their use in Integrated Pest Management (IPM) and Integrated Nutrient Management (INM) programs of the country is being increasingly recommended / promoted.

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