USE OF FLY ASH IN AGRICULTURE: INDIAN SCENARIO

Vimal Kumar* & Gopal Krishna Jha**

Abstract

Fly ash a residue of burning of coal / lignite in thermal power plant has traditionally been considered as a waste product. It's generation in the country has increased from 40 Mn T/yr (1994) to about 235 Mn T/yr (2013). It is projected to be 325 Mn T/yr (2016-17), 500 Mn T/yr (2021-22) and 1000 Mn T/yr (2031-32). If not utilized, it would demand large area of land for ash ponds and would pose a threat for air and water pollution. Fly ash utilization has increased from 1 Mn.T/year during 1994 to 130 Mn.T/year during 2013, primarily as an out come of concerted efforts under Fly Ash Mission-India.

It has been proved to be a useful supplement for agricultural application in addition to use in cement, bricks & blocks, road embankments, low lying area filling, mine applications, etc. Fly ash, being a good soil ameliorant & source of secondary plant nutrients as well as micronutrients can significantly improves the physio-chemical properties (like B.D., W.H.C., pH, CEC, free lime etc.). It can efficiently be used as a source of silicon, pesticide carrier, plant growth promoter, etc. Use of fly ash has also been reported for reclamation of degraded/problematic soils & wastelands. It has also been reported to be safe for agriculture application in context of toxicology & radioactivity

Key Words**:** Fly ash, coal ash, mission mode approach, technology, agriculture, forestry.

1.0 Introduction

Power is the key to the prosperity and development of a nation. For electricity generation, India depends mostly (55-60%) on coal-based thermal power plants which annually generates 235 million tonne (2013) fly ash and is projected to exceed 325 million tonne by 2017 and 1000 million ton by 2031-32.

As of now this large volume of fly ash occupies nearly 50,000 ha of land and poses environmental threat, if not managed well. Nearly 2000 MnT of fly ash has been accumulated over a period of time in ash ponds of different thermal plants which have not been utilized.

It was during early 1991 that fly ash caught the attention of Department of Science & Technology, Government of India. In-depth techno-market study was undertaken. The broad objective was to document the status of existing knowledge and technologies about fly ash utilization / safe management, market acceptance levels and the threat that fly ash posses to environment, if not utilized as well as a suggested action plan.

** Adviser, Centre for Fly Ash Research & Management (C-FARM), New Delhi and Former Mission Director & Head, Fly Ash Unit, DST, GoI, Email: dr.vimal.kumar@gmail.com (Cellphone:9818443449)*

***Senior Scientist, Centre for Fly Ash Research & Management (C-FARM), New Delhi*

@ The views expressed are purely of the author and not of the organizations of their current/past affiliation.

Prior to 1990, large numbers of efforts have been made to develop and commercialize technologies for use of fly ash. Academia, national research institutes, private R&D as well as industry have worked in this area. However, most of the work remained confined within the academia / research arena. A few utilizations of fly ash were made primarily in mass concrete, brick / block manufacturing and reclamation of low lying areas.

Ministry of Environment & Forests (MoEF), Ministry of Power (MoP) and a few other agencies took initiatives. National Waste Management Council (NWMC) and a few other groups/committees consisting of senior officials of various Ministries/Departments, State Governments, Research and Development Institutions, etc. were formed. Thermal Power Plants were directed to take actions to enhance ash utilizations and a few fiscal incentives such as rebate on excise duty and sales tax were declared.

It highlighted that only a meagre percentage (less than 3 per cent) of ash was being utilized in the country and the balance was being stored in ash ponds through slurry discharge system. The report brought to fore that the fly ash that is being considered as a waste material, is in fact a useful material and can be put to gainful economic applications.

2.0 Mission Mode Approach

Appreciating the overall concern for environment and the need for safe disposal and gainful utilization of fly ash, the Government of India commissioned Fly Ash Mission during 1994 as a joint activity of Ministry of Environment and Forests, Ministry of Power and Department of Science & Technology with Department of Science & Technology (DST) as the Nodal Agency. The focus is on Technology Demonstration Projects for developing confidence in fly ash technologies towards large scale adaptation. The overall objective was to increase significantly the fly ash utilization in the country from a meagre 3% of 40MnT generation during 1994.

The overall complexity of technology development, transfer, infrastructure support, inter-institutional linkages, development of market, orientation of Government policies to promote and support fly ash utilization were the challenge. Further, as no single utilization held the potential to provide a solution to this mammoth task of safe disposal and gainful utilization of fly ash, a judicious mix of a number of applications was to be evolved (considering impact timeframe, investment requirement, technical and infrastructure inputs requirements by fly ash utilization, potential and expected returns, etc.). The large numbers of demonstration projects were undertaken to build the confidence of potential user and decision makers, especially to develop a critical mass for replication. Use of fly ash in agriculture including forestry, horticulture & floriculture was an important & integral part of the program. The formulation of national standards, code of practices / guidelines, legislations and facilitating mechanisms were essential to get wider acceptance on self sustaining principle.

Over a period of last twenty years, the image of fly ash has completely been changed from a “Polluting Waste” to “Resource Material”. The utilization in the country has increased to about 130 MnT during 2013. Simultaneously generation has increased to 235 MnT/year. The

focused thrust being provided by Fly Ash Mission (FAM) is being continued through Fly Ash Unit (FAU), Department of Science & Technology (DST).

The achievements of Fly Ash Mission are acclaimed across the globe including import of technology, know how & managerial expertise by Federation of Russia to establish Fly Ash Mission-Siberian Region on similar lines of FAM-India.

3.0 Relevance of Fly Ash for Agriculture

The ashes are good sources of available secondary (Ca, Mg and S) and micronutrients (Zn, Fe, Cu and Mn), The texture being sandy silt to silty loam improves water holding capacity and percolation in sandy as well as clay soils for beneficial effects.

Laboratory & field research as well as large scale field demonstration projects have shown encouraging results in terms of 10 to 25% increased yield, improvement in WHC, aeration, tillage, control of soil borne pests, crust formation & use efficiency of fertilizers, etc.

India is also working hard to improve it's agriculture out put from the available cultivable area to meet the growing needs. Fly ash can play a important role in this context.

4.0 Results of application of fly ash in Agriculture

FAM undertook 16 R&D technology demonstration projects at 55 project sites in the country during 1994-2004 and 10 field demonstration projects. Thereafter a large number of replication projects & actual use by farmers are happening. The detailed results are presented below:

The spread of FAM projects over variety of crops in different soils across the country is summarized in Table 1 and 2, below:

Table 1: Numbers of project sites that have addressed to various agricultural practices investigated with fly ash in arable soils, ash filled areas and problematic/degraded soils.

Sl. no.	Agricultural practices	Group			
		Arable soils	Ash filled areas	Problematic/degraded soils	Total
1.	Cereals	97	2	2	101
2.	Pulses	12	0	1	13
3.	Oil seeds	39	3	2	44
4.	Horticulture	19	3	0	22
5.	Cash crops	19	1	0	20
6.	Fodder	2	0	0	2
7.	Floriculture	0	4	0	4
8.	Forestry	0	6	4	10

Table 2: Field crops & vegetables grown with fly ash in different soil types at various project sites

Sr. No	Soil	Fly ash doses range	Crops & No. of Sites	Location
1	Alluvial Soil	0-200 t/ha	Rice, wheat (2)	Farakka
2	Alluvial Soil	0-100 t/ha	Mustard, jute (1)	Farakka
3	Laterite Soil	0-200 t/ha	Rice, wheat (4)	Bakreshwar
4	Laterite Soil	0-100 t/ha	Mustard, Potato,Lentil (1)	Bakreshwar
5	Black Soil	0-50 t/ha	Sugarcane (1)	Chidambaram
6	Laterite Soil	0-150 t/ha	Groundnut (1)	Neyveli
7	Laterite Soil	0-100 t/ha	Sugarcane (1)	Neyveli
8	Black Soil	0-150 t/ha	Rice-Green Gram (1)	Sathamangalam
9	Black Soil	0-120 t/ha	Cotton-Rice (1)	Vellampudugai
10	Lateritic Soil	0-10 t/ha	Rice-Groundnut (3)	Kharagpur
11	Lateritic Soil	0-20 t/ha	Rice, Groundnut-Mustard (1)	Kharagpur
12	Lateritic Soil	0-30 t/ha	Mustard-Rice (1)	Kharagpur
13	Lateritic Soil	0-10 t/ha	Rice (2) –Mustard, Groundnut, Potato (1)	Balarampur, Gholghoria, Burari
14	Lateritic Soil (Red)	0-80 t/ha	Sunflower-Groundnut (2)	Raichur
15	Black Soil	0-80 t/ha	Sunflower-Maize (2)	Raichur
16	Alluvial Soil	0-650 t/ha	Tomato (1), Cabbage (1), Potato (1), wheat (2), Pea (1) – Maize (6), Wheat-Maize (2)	Dhodhar, Nilgiri, Rihand Nagar
17	Alluvial Soil	0-650 t/ha	Sunflower (1), tomato (1), Potato (1), Wheat (1), Berseem (1), Red Gram (1), Maize (1), Rice (1)	Nilgiri, Rihand Nagar
18	Alluvial Soil	0-40/0-80 t/ha	Rice-Wheat (1), Cotton-Wheat (1), Sunflower-Maize (1) Wheat-Rice (1)	Ropar, Bhatinda
19	Alluvial Soil	0-12 t/ha	Wheat (1)	Ropar (Astalpur)
20	Alluvial Soil	100% ash body with 7.5 cm soil cover	Arhar-Wheat (1)	Bhatinda
21	Black Soil	0-640 t/ha (Residual Effect)	Wheat-Maize, Soyabean-Maize, Lemon Grass (1)	Sarni
22	Alluvial Soil	0-640 t/ha	Maize-Onion, Rice-Sunflower (1)	Angul

4.1 Impact on yield

Yield increase has been reported for all crops with application of fly ash. The crops include cereals, pulses, oil seeds, cotton, sugarcane, fodder crops, horticultural crops, ornamental & medicinal plants. The increase in yield of cereal crops have been reported 10-15%, in case of pulses and oil seeds 20-25% and in vegetable as well as in other crops up to 40%. Table 3 provides the yield increase data for various crops.

Table 3: Per cent yield increase over control for various crops

Crop	Increase Over Control (Common range, %)	Soil Type	FA/PA Dose t/ha*
Paddy	10-15	Alluvial	200 t/ha
Wheat	15-20	Laterite	200 t/ha
Maize	10-15	Black	30 t/ha
Lentil	15-20	Laterite	100 t/ha
Green Gram	20-25	Black	150 t/ha
Groundnut	25-30	Black	30 t/ha
Sunflower	20-25	Red	60 t/ha
Mustard	15-20	Laterite	10t/ha
Tomato	35-40	Landfill	650 t/ha
Cabbage	30-35	Landfill	650 t/ha

FA: Fly Ash **PA: Pond Ash** **LANDFILL: Area filled with fly ash**

* Other inputs viz. NPK and FYM dose have been applied as per normal package & practices of Agriculture.

4.2 Impact on soil health

It has been observed that the addition of fly ash to the soil results in multi-beneficial effects including (i) improvement in the available N, available P_2O_5 and available K_2O, as also in the contents of available secondary nutrients like Ca^{++} & Mg^{++} and available micronutrients such as Zn, Mn, Cu, in soil, and (ii) significant improvement in the physico-chemical properties (like bulk density, maximum water holding capacity, pH, electrical conductivity, etc.) of various kind of soils resulting in better soil health. Impacts of fly ash on physio-chemical properties of different soils of some of the project sites are placed in Table 4, below:

Table 4: Physio-chemical properties of soils at the start (s) and completion (c)

Proj. Site	Soil type	FA dose t/ha	start/ completion	pH	EC dS/m	BD gm/Cm^2	WHC %	N %	P %	K %	Ca %	Mg %	S %	TDA mg/kg/ 24 hr
1	Alluvial sandy loam	PA 200	s	7.99	1.04	1.52	42.88	0.109	0.068	0.975	0.003	0.002	0.352	68.73
			c	8.06	0.12	1.42	48.55	0.114	0.075	0.908	0.003	0.002	0.032	78.3
2	Acidic Red sandy loam	PA 200	s	5.01	0.05	1.63	30.92	0.051	0.013	0.768	-	-	0.057	Nil
			c	5.39	0.04	1.52	44.73	0.016	0.001	0.01	-	-	0.005	12
3	Acid Laterite sandy clay loam	DFA 10	s	5.32	0.02	1.67	34.20	-	-	-	-	-	-	-
			c	5.88	0.03	1.52	37.90	-	-	-	-	-	-	-
3	Acid Laterite sandy clay loam	PA 10	s	4.99	0.02	1.52	35.30	0.047	0.52	0.17	-	0.049	-	-
			c	5.55	0.03	1.49	39.50	0.062	0.06	0.188	-	0.055	-	-
4	Alluvial clay loam	PA 30	s	9.40	1.97	1.16	49.11	4.7 ppm	11.2 ppm	390.0 ppm	-	-	1.5	2.58
			c	9.50	1.87	1.14	51.79	57.8 ppm	15.67 ppm	530 ppm	-	-	26.6 ppm	6.1

5	Alluvial sandy loam	PA 1170	s	6.40	0.12	1.30	27.40	0.25	0.06	1.7	-	-	0.015	NA
			c	7.40	0.21	1.25	40.00	0.059	0.076	6.7	-	-	0.373	2.4
6	Alluvial sandy loam	PA 80	s	7.66	0.55	0.92	-	-	399 ppm	2102 ppm	7105	2708	89.5	-
			c	8.85	0.28	1.33	-	-	485 ppm	2193 ppm	1075 5ppm	3204 ppm	135 ppm	-
7	Alluvial clay	PA 300	s	7.80	0.46	1.10	64.60	-	-	-	380	72	NA	-
			c	8.40	0.25	1.31	55.00	150 ppm	40 ppm	170 ppm	2435 ppm	403 ppm	12 ppm	-

4.3 Impact of radioactivity and heavy metal

Detailed study of radio nuclides and heavy metals content in fly ashes and their impact on agriculture use has been undertaken in association with Dept. of Atomic Energy, Govt. of India and Indian Council of Medical Research, Govt. of India. Chemical as well as biological studies are conducted. It concludes that the levels of radio nuclides and heavy metals content in fly ashes, fly ash admixed soil and crop produce are within safe/normal range. The magnitude values can be seen at Table 5, below:

Table 5: Impact of radioactivity & heavy metal content in fly ash, soil and produce

Sample	Radioactivity(Bq/kg)			Trace & Heavy metals (ppm)			
	^{40}K	^{226}Ra	^{228}Ac	B	Mo	As	Se
ESP fly ash	280-432.5	43.6-115.4	55-129	17.1-28.0	2.5-6.7	1.0-4.0	1.6-2.6
Pond ash	280-353	69-92	77-108	18.3-23.1	2.6-5.3	1.4-3.6	1.2-2.3
Soil	160-326	30-58.8	37-80	13-17	0-4.8	1.9-2.9	2.4-4.0
Grain	9-95	0.29-0.75	0.60-1.60	0.2-1.6	0-1.2	0-0.45	0.10-1.0
Straw	8.4-10.9	039-0.72	078-1.00	0.29-0.42	0-0.67	0-.40	018-0.55
Vegetables	0.6-85	0.1-0.5	0.4-0.8	0.72-1.3	0.2-0.06	0.10-0.50	0-0.14
Oil seeds	60-110	0.3-0.8	0.6-1.0	0.1-1.3	0.2-0.6	0.3-0.4	0.10-1.06
Normal range in soil	4000*	1000*	1000*	2-100**	0.1-40**	5-100**	0.1-10**

*Source: Atomic Energy Regulatory Board, Radiological Safety Division, Dept. of Atomic Energy, Govt. of India letter no AERD/RSD/28/2002/6007 on dated. July 26, 2002

**Source: P.C Srivastava and U.C. Gupta (1996): trace element in crop production, oxford and IBH publishing Co. Pvt. Ltd., New Delhi.

It is also observed that the measured levels of radio nuclides in Indian fly ash are below the limits specified, in environmental point of view. The grains, straws and vegetables produced from fly ash applied soils are safe for human and animal consumption. Therefore, in India fly ash has a great potential for utilization in agriculture.

The daily intakes of radio nuclides due to consumption of the agricultural produce grown in fly ash treated soils have also been calculated. It is found that the consumption of such eatables is also within safe limits as is evident from the Table 6, below:

Table 6: Daily intake ratio of radio nuclides through eatables grown with fly ash

Food Items	Daily consumption (gm)	Max[m] radionuclide level (Bq/kg)		
		^{40}K	^{226}Ra	^{228}Ac
Grain	400	95	0.75	1.0
Vegetable	200	85	0.50	0.8
Daily intake of radionuclide (Bq/kg)				
Grain	-	38	0.30	0.4
Vegetable	-	17	0.10	0.16
Total	-	**55**	**0.40**	**0.56**
Safe limit:	-			
- Daily intake (Bq)*	-	104	0.61	2.2
- (Bq/kg)[@]		173.34	1.00	3.67

* IOP, a constituent laboratory of BARC, Dept. of Atomic Energy, Govt. of India.
[@] Calculation based on * and daily consumption of grain/vegetables.

4.4 Other Impacts

It has been observed that in last two decades number of R&D has been undertaken in India on use of fly ash in various aspects including agriculture. Fly ash has emerged as a very resourceful material for agriculture and reclamation of problematic/degraded soils. Some of the impacts are dealt herewith:

4.4.1 Fly ash as a source of silicon

The fly ash in general reacts with soil and releases Si which can be effectively used as a source of nutrient for crops. The benefit of Si was highlighted by scientists as spotlight wherever the Si sources of material viz., rice straw, rice hull ash, sugarcane baggasse ash and other available industrial bye products. In recent years the importance of Si fertilization has been realized in view of intensive cultivation of crops where depletion of Si occurs in rice soils which responded to Si sources.

4.4.2 Fly ash as a water conserver

One of the study showed that fine pond fly ash when incorporated@ of 25t/ha in a highly percolating sandy loam soil increased the average grain yield of rice and wheat by 3.9% and 4.12% respectively over the control. Cultivation of rice required 14 to 17% less irrigation whereas in case of wheat it required 14 to 20% less irrigation water.

Owing to more fineness of pond fly ash incorporated in upper layer of soil in leaching columns, flow rate of irrigation water applied in rice and wheat seasons decreased significantly over the control that resulted in significant reduction in leaching losses of NO_3^- and K^+.

4.4.3 Fly ash as an insecticide and pesticide carrier

Extensive studies made so far in India have concluded that the fly ash could be a good insecticide and an active carrier in chemical and herbal insecticides for use against various kinds of pests infesting different crops like, rice, vegetables, oil seeds, fruit plants including

store grains. There is also scope for application of the fly ash as a carrier in developing insecticides to check house-hold pests like, cockroaches etc.

Morphological analyses of the fly ash particles revealed spherical shape containing mostly of Silica as Silicon–di- oxide (SiO_2) which is present in two forms: amorphous which is rounded and smooth and crystalline which is sharp and pointed. These differently shaped particles of the fly ash could adhere to the body skin of the insects firmly as the body morphology is contained with variety of structures like, hairs, scales, spine-like processes, nodules, pustules, vesicles etc. When the fly ashes are delivered in the field as dusts through mechanical dusters, they reach the targets namely the foliage of the plants, cling to it and remain for considerably long time to check the pest damage. These morphological features of the fly ash revealed that there was better dispersion of the filler in the synthesis of chemical and herbal insecticides while incorporating carrier – value to the fly ash.

4.4.4 Vermin composted fly ash

Among different methods of composting of organic materials, vermin composting technology is recently emerging as an important one owing to simplicity as well as high efficiency of this technology in producing better quality compost, as compared to traditional methods of composting. Use of fly ash with organic and mineral wastes will not only help in extracting more amount of plant nutrients into available forms from insoluble mineral fractions in fly ash, but will also enrich the material with organic matter for improving the soil health. The organic materials, excreted by the earthworms in half digested forms, contain micro organisms and enzymes in high concentrations, which help in rapid aerobic decomposition of these excreted organic materials resulting in the production of good quality compost in lesser period of time along with multiplication of different beneficial micro organisms. In addition, the solubility of various heavy metals in fly ash also declined on vermin composting due to formation of complex like metallothionene by the earthworms. These beneficial effects of vermin composting of fly ash have been observed in field levels also. Use of vermin composted fly ash resulted in substantial yield increments in case of rice, potato and tomato.

5.0 Use of Fly ash in Forestry & reclamation of problematic/degraded soils

5.1 Use of fly ash in forest plantation

Results of field demonstrations in forest plantation by the various agencies under the aegis of Fly ash Mission as well as of other scientific bodies envisaged that application of fly ash in forest plantation would create remarkable benefits. The bio-metric parameters such as germination rate, height and girth of the plant and sapling grades of various species grown with fly ash have found significantly improved as compared to control without exhibiting any adverse effect.

5.1.1 Impact of fly ash on survival & growth of planted species

The growth and vigour of the planted species with fly ash have found improved over control i.e. without fly ash. The mortality rate of various spp. have found reduced except shisham. The girth of the planted species except karanj (*Pongamia pinnata*) have found increased by 20-30%. Similarly, in most of the planted species plant height and number of branches have found increased over control. Results are placed at Table 7, below:

Table 7: Effect of different dose of fly ash on survival rate (%), girth* (cm) & height* (cm) of diff. plant species (4th year of plantation)

Plant species	Survival			Plant girth			Plant height		
	Control	25% FA	50% FA	Control	25% FA	50% FA	Control	25% FA	50% FA
Teak	78	92	96	27.5	35.5	42.0	218.5	228.0	294.0
Acacia	85	85	86	17.5	18.0	27.5	232.0	230.5	241.0
Radhachura	82	90	85	35.5	42.5	46.5	230.0	241.0	266.0
Chhattiyan	72	84	90	28.5	32.5	36.0	268.0	274.0	264.0
Karanj	90	86	96	27.0	22.5	26.0	240.0	284.5	295.0
Shisham	82	86	80	28.5	33.0	39.5	247.5	256.0	274.0
Anwla	85	86	96	21.0	27.5	29.5	222.0	232.4	271.0

* mean of 20 replications

5.1.2 Impact on soil

The impact in control soil and fly ash admixed soil at different treatment level varied markedly. Addition of fly ash in latertic soil improved the soil physical properties like texture, bulk density (B.D.), water holding capacity (W.H.C.) and porosity. The concentration of major nutrients such as nitrogen, phosphorus and potassium are slightly increased in treated soils as compared to control. The results are given in Table 8, below;

Table 8: Effect of diff. dose of fly ash on physio-chemical properties of soil (3rd yr of plantation)

Parameters	Fly ash	Soil (Initial)	T0 (Control)	T1 (25% Fly ash)	T2 (50% Fly ash)
Soil Texture					
Sand (%)	38.4	72.8	70.4	62.2	56.2
Silt (%)	49.5	19.4	18.2	24.5	32.8
Clay (%)	12.1	7.8	11.4	13.3	11.0
B.D. (G/CC)	0.98	1.82	1.65	1.58	1.54
WHC (%)	64.60	42.4	44.7	54.0	52.4
POROSITY (%)	40.25	34.9	36.2	38.2	36.0
Chemical Properties					
pH	7.8	5.4	5.5	5.8	5.6
OC (%)	0.57	0.25	0.38	0.42	0.44
Total N (ppm)	0.076	145	166	172	168
Av. P (ppm)	24.6	34.0	36.6	38.0	41.0
Av. K (ppm)	130.0	194.0	184.4	178.8	188.0

5.2 Use of fly ash in forest nursery

Findings of the field demonstrations carried out for raising of forest nursery envisaged that plant saplings grown in 50% pond ash and soil (v/v) mixture in poly tubes along with control

beds (without pond ash) has better growth. The grade of various plant saplings which is the major criteria from its economic point of view has been observed to have increased by 20-25% over control.

5.3 Use of fly ash for reclamation of sodic soil

Fly ash has also been successfully demonstrated for reclamation of sodic soil. The effect of pond ash alone and in combination with other amendments on eradication of sodicity is found suitable for replacement of gypsum at much lower cost. The application of fly ash and gypsum either alone or with farm yard manure had a synergistic positive effect in increasing the yield of paddy, wheat and mustard in highly sodic soil. Results of all the fields' experiment/trials indicate that based on the degree of alkalinity/salinity pond ash can effectively substitute 50% gypsum requirement. Application of pond ash at 1.5% (30t/ha) can substitute 50% gypsum requirement and about 6% (120t/ha) pond ash can replace 100% gypsum requirement.

6.0 Conclusion

Fly ash has been found to be good soil ameliorant as well as a source of micronutrients. Application of fly ash also improves WHC (reducing irrigation requirement by about 10-15%), improves texture, aeration and reduces crust formation. Fly ash is also a good amendment for sodic and saline soils as well as for reclamation of other degraded/problematic soils.

One time field application of fly ash/pond have shown sustained improvement in yield and soil quality up to 7-8 years without showing any adverse effect on soil or crop produce quality either due to chemical or other properties of fly ash.