FLY ASH: A MATERIAL FOR ANOTHER GREEN REVOLUTION

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ABSTRACT

Fly ash is a residue of burning of coal and lignite, the organic sources of energy. The micro and macro nutrients present in coal get generally concentrated in the ash. It is by virtue of this and the ability of fly ash to modify the physical properties of soils, it works as a soil conditioner enhancing the yield of the crops. Field demonstration projects taken at more than 50 locations by Fly Ash Mission (FAM), now known as Fly Ash Utilisation Programme (FAUP) in varying agro-climatic conditions and different soil - crop combinations supported with laboratory investigations have shown significant increase in yields of edible part as well as biomass without any adverse impact on soil health or crop produce because of any reasons including presence of trace heavy metals and radionuclides in fly ash. The presence of these elements is too low to make any harmful impact. Application of fly ash to agricultural fields enriches the produce with Ca & Fe which are good for human being from nutritional point of view. Detailed investigations on these aspects were undertaken at National Institute of Nutrition (NIN), Hyderabad under direct supervision of Indian Council of Medical Research (ICMR) and at Institute of Physics (IoP), Bhubaneswar, Department of Atomic Energy.

The large scale use of 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 in another green revolution.

Key words: Fly Ash, Agriculture, Wasteland, Food Grain, Green Revolution

1.0 INTRODUCTION

The green revolution which started during sixties increased the national average yield of food grains from 0.75 tonne/ ha (1960-61) to 2.6 tonne/ha (2003-04) & the total production of food grains from 80 million tonne to 213 million tonne during the same period. The impact in the best yields of food grains has been found in states like Punjab, Harayan, Tamil Nadu, West Bengal etc. The average yield of rice increased from 0.9 tonne/ha (1960) to 2.2 tonne/ha (2003-04) and that of wheat increased from 0.8 tonne/ha (1960) to 3 tonne/ha (2003-04). In subsequent years, the application of high doses of NPK, high yielding varieties and excessive irrigation in certain cases have added to the problems of salinity, alkalinity, high water level, etc, adversely affecting the soil properties, restricting further enhancement of crop yields. Though these are not only affecting parameters but the contribution of others has become marginal. These include non- application of micronutrients (Cu, Zn, Mn, Fe, B, Mo) making the soils deficient in such nutrients adversely affecting the crop yield and biological activity of soil.

High water level coupled with local conditions has, in number of cases, led to clinker and salt pan formation in soils. Conventional measures like treatment with gypsum, lime, flooding are being practiced but with limited results. The availability and the affordability of gypsum is limited because of its high cost. The impact of schemes supported / subsidised by India / foreign for reclamation of saline-alkaline soils with gypsum supplied at very low rates has also not resulted in desired results. This can be due to various reasons including management & certain lacunae in implementation mechanisms.

@ The views expressed are that of the authors and not necessarily of the organisation to which the authors have affiliation.

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2.0 MATERIAL FOR ANOTHER GREEN REVOLUTION

Fly ash is a residue of burning of coal and lignite, the organic sources of energy. The macro and micro nutrients present in coal / lignite get generally concentrated in the ash. It is by virtue of this and the ability of fly ash to modify the physical properties of soils, it works as a soil conditioner/ modifier enhancing the yield of the cereals, pulses, oil seeds, sugarcane, vegetables etc. Field demonstration projects1 undertaken at more than 50 locations by Fly Ash Mission (FAM), now known as Fly Ash Utilisation Programme (FAUP) in varying agro-climatic conditions and different soil crop combinations supported with laboratory investigations have shown significant increase in yields of edible part as well as biomass without any adverse impact on soil health or crop produce because of any reasons including presence of trace / heavy metals and radio nuclides in fly ash. The presence of these elements is too low to make any harmful impact. Application of fly ash to agricultural fields enriches the produce with Ca & Fe which are good for human being from nutritional point of view. Detailed investigations on these aspects were undertaken at National Institute of Nutrition (NIN), Hyderabad under direct supervision of Indian Council of Medical Research (ICMR) and at Institute of Physics (IOP), Bhubaneshwar, Department of Atomic Energy.

The large-scale use of 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 in another green revolution.

The details of the work done in farmers' fields in conjunction with laboratory investigations are summarized in subsequent paragraphs. An attempt has also been made to work out the impact that fly ash holds the potential to make on agriculture. The magnitude of possible impact compels the authors to call it another green revolution. 84 utility Thermal Power Stations and about 60 captive Power Stations encompass more than 75% of agricultural land within their economic lead zone of 100KM. The proportion of wasteland falling within this area can also be safely presumed as 75%.

As is evident from the work done in the farmers' fields over last 10 years, the yield increase of rice and wheat is generally in the range of 8-15%. Taking the conservative average yield increase of 10% and transportation cost [@ Rs.200 per tonne fly ash for 100 KM distance, @ Rs.150 per tonne fly ash for 50 KM distance and @ Rs.100 per tonne flyash upto 20 KM distance from thermal power stations], its pay back period [3 crops for 100km distant farmers, 2 crops for 50KM distant farmer and 1.33 crops for 20KM distant farmers] would be 1 to 1.5 years. The impact of one time application of flyash @ 40t/ha dose could continue to yield the same result for 6-8 years. The impact is more prominent and lasting in case of black cotton soils and red lateritic soils wherein the change in the physical properties of soil plays a dominant role.

3.0 NATURE AND PROPERTIES OF FLY ASH

Fly ash, the residue of combustion of coal, originally a mixture of vegetation, clay and rocks, comprises a wide range of inorganic matters. Physically, flyash occurs as very fine spherical particles, having diameter in the range from few μ to 100μ, low to medium bulk density, high surface area and sandy silt to silty loam texture. Chemically, flyash is amorphous ferro-alumino silicate mineral with major matrix elements like, Si, Al, Fe together with significant amount of Ca, Mg, K, P, S. The concentration of total and available trace/ heavy metals and radionuclides in fly ash samples is in traces and their availability/ leachability is negligible. The texture and physico-chemical properties including trace/ heavy metals and radioactivity closely resemble with most of the field soils. The range of physico-chemical properties including trace/ heavy metals and radionuclide in flyash samples are given in **Tables 1 to 5**:

Table 1: Physical properties of fly ash

Parameters	Fly ash
pH	6.0 - 10.0
Specific gravity	1.66 - 2.55
Bulk density (g/cc)	0.85 - 1.2
Grain size distribution	Sandy silt to Silty loam
Porosity (%)	45 – 55
Water holding capacity (%)	45 – 60
Electrical conductivity (dS/m)	0.15 - 0.45

Table 2: Chemical properties of fly ash

Parameters	%
SiO2	38-63
Al2O3	27-44
TiO2	0.4 -1.8
Fe2O3	3.3-6.4
MnO	0.1-0.5
MgO	0.01-0.5
CaO	0.2-8.0
K2O	0.04-0.9
Na2O	0.07-0.43
L.O.I.	0.2-3.4

Table 3: Total and available micronutrients in fly ash

Parameters	Total	Available (ppm)
Cu	40-80	0.5-1.6
Zn	50-150	0.4-1.8
Mn	500-750	0.9-1.5
Fe	3.3-6.4*	10-15
B	17–38	0.5-0.8
Mo	2.2 – 6.7	0.1-0.6

* Percent

Table 4: Total and available trace / heavy metal in fly ash

Parameters	Total	Available (ppm)
Se	0.6 – 2.6	0.1-0.4
Cr	50-150	0.3-0.6
Pb	10-70	BDL
Co	10-50	0.05-0.15
Ni	50-150	0.15-0.25
Cd	5-10	0.03-0.07
As	1.0 – 4.0	BDL
Hg*	BDL	BDL

* below detectable limit (BDL)

Table 5: Radioactivity levels in fly ash

Parameters	Bq Kg^{-1}
226Ra	30-110
228Ac	30-110
40K	180-500

4.0 WORK DONE

4.1 Laboratory Evaluation:

Laboratory work with detailed analyses and evaluation of fly ash for its various constituents & their likely impact as compared to field soils was taken up before field trials & large-scale application in farmers' fields. In addition, laboratory and post demonstration work have been done for studying the impact of fly ash on seed germination, sapling raising, dehydrogenase activity, biological activities in the root zone, & impact on root mass, proliferation of root, crust formation, water holding capacity, hydraulic conductivity, etc. These were undertaken alongwith optimization of fly ash doze, based on number of treatments taken up for study with & without other amendments.

4.2 Farmers' field activities under Technology Demonstration Projects (TDP) of Fly Ash Mission

Large-scale field demonstration/ application of use of fly ash in agriculture has been taken up at more than 50 project sites under 15 Fly Ash Mission Technology Demonstration Projects along with different R&D institutes / Universities and farmers' across the country in different agro-climatic conditions with varying soil-crop combinations during 1994-2004.

The details of the Technology Demonstration Projects carried out in **agriculture sector**, **wasteland development** & reclamation of saline-alkali soil / eroded land / ash pond and **quality assessment** of soil health, crop produce and field water are summarized below:

4.2.1 Technology Demonstration Projects undertaken at various sites in the area of Agriculture Sector are given below in Table - 6:

Table 6: 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	Executed by
1	Alluvial Soil	0-200 t/ha	Rice, wheat (2)	Farakka	CFRI, Dhanbad
2	Alluvial Soil	0-100 t/ha	Mustard, jute (1)	Farakka	CFRI, Dhanbad
3	Laterite Soil	0-200 t/ha	Rice, wheat (4)	Bakreshwar	CFRI, Dhanbad
4	Laterite Soil	0-100 t/ha	Mustard, Potato,Lentil (1)	Bakreshwar	CFRI, Dhanbad
5	Black Soil	0-50 t/ha	Sugarcane	Chidambaram	Annamalai University
6	Laterite Soil	0-150 t/ha	Groundnut	Neyveli	Annamalai University
7	Laterite Soil	0-100 t/ha	Sugarcane	Neyveli	Annamalai University
8	Black Soil	0-150 t/ha	Rice-Green Gram (1)	Sathamangalam	Annamalai University
9	Black Soil	0-120 t/ha	Cotton-Rice (1)	Vellampudugai	Annamalai University
10	Lateritic Soil	0-10 t/ha	Rice-Groundnut (3)	Kharagpur	IIT-Kharagpur
11	Lateritic Soil	0-20 t/ha	Rice, Groundnut-Mustard (1)	Kharagpur	IIT-Kharagpur
12	Lateritic Soil	0-30 t/ha	Mustard-Rice (1)	Kharagpur	IIT-Kharagpur
13	Lateritic Soil	0-10 t/ha	Rice (2) –Mustard, Groundnut, Potato (1)	Balarampur, Gholghoria, Burari	IIT-Kharagpur
14	Lateritic Soil	0-80 t/ha	Sunflower-Groundnut	Raichur	CAS, Raichur

	(Red)		(2)		
15	Black Soil	0-80 t/ha	Sunflower-Maize (2)	Raichur	CAS, 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	RRL, Bhopal
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	RRL, Bhopal
18	Alluvial Soil	0-40/0-80 t/ha	Rice-Wheat (1), Cotton-Wheat (1), Sunflower-Maize (1) Wheat-Rice (1)	Ropar, Bhatinda	PAU Ludhaina
19	Alluvial Soil	0-12 t/ha	Wheat	Ropar (Astalpur)	PAU Ludhaina
20	Alluvial Soil	100% ash body with 7.5 cm soil cover	Arhar-Wheat (1)	Bhatinda	PAU Ludhaina
21	Black Soil	0-640 t/ha (Residual Effect)	Wheat-Maize, Soyabean-Maize, Lemon Grass (1)	Sarni	RRL, Bhopal
22	Alluvial Soil	0-640 t/ha	Maize-Onion, Rice-Sunflower (1)	Angul	RRL, Bhopal

4.2.1.1 Impact of fly ash on crop yield

The results on the yield of different crops grown with fly ash in various soil types are included in Table 7. It is evident from the results that the addition of fly ash (10 - 200 tonne per ha) increased the yield of different crops from 10-40%. Thus the use of fly ash in agriculture has proved to be economically rewarding.

Table 7: Effect of fly ash application on Yield of various Crops at different locations

Soil Group	Location	Application rate	Crops	Percent yield increase
Alluvial Soil	Dadri (UP) &IARI (Delhi)	10-20 t/ha	Wheat, Mustard, Rice, Maize	6-18
Alluvial Soil	Hissar (Haryana)	20% soil: ash (w/w)	Pearl Millet, Wheat	32
Alluvial Soil	Murshidabad (W. B.)	200 t/ha/3yrs (one time application)	Wheat, Rice	29
Black Soil	Vidarbha Region (Maharashtra)	10-15 t/ha	Seed Cotton, Sorghum, Gram, Soybean, Summer Groundnut, Wheat	10-46
Red Soil	Raichur (Karnataka)	30-60 t/ha/3yrs (one time application	Sunflower, Groundnut	10-26
Black Soil	Raichur (Karnataka)	30-60 t/ha/3yrs (one time application	Sunflower, Maize	22-42
Red lateritic Soil	Coimbatore & Vridhichalam (Tamilnadu)	40 t/ha	Rice, Groundnut	14-25
Lateritic Soil	Kharagpur (W. B.)	10 t/ha	Kharif Rice, Mustard	12
Red Soil	Birbhum (W. B.)	200 t/ha/3yrs (one time application	Kharif & Boro Paddy, Potato	31

4.2.1.2 Economic Evaluation:

The economic evaluation of application of fly ash in few farmers' fields at Raichur (Karnataka) & Birbhum (West Bengal) has been made and is given in **Tables 8 & 9.**

The benefit-cost ratio **(Table 8)** and net profit **(Table 9)** have been found to be quite favorable / sustainable for farming community due to use of fly ash in agriculture.

Table: 8 Economics of fly ash application to sunflower-groundnut cropping sequence in red soil under irrigated conditions, Raichur, Karnataka

Treatment	Total cost (A) (Rs/ha)	Total cost (B) (Rs/ha)	Net returns (A) (Rs/ha)	Net returns (B) (Rs/ha)	Gross returns** (Rs/ha)	Benefit: Cost Ratio (A)	Benefit: Cost Ratio (B)
Recommended Fertilizer Dose (RDF)	14380	14380	13730	13730	28110	1.95	1.95
RDF + Fly ash @ 30t/ha/yr	20080	15580	17690	22190	37770	1.88	2.42
RDF + Fly ash @ 30t/ha/yr + FYM@ 20t/ha/yr	22480*	16480	19100	25100	41580	1.84	2.52
RDF + Fly ash @ 40t/ha/yr	21980	15980	15620	21610	37590	1.71	2.35
RDF + Fly ash @ 30t/ha once in 3 years	15060	13060	19500	21500	34560	2.29	2.64
RDF + Pond ash @ 30t/ha/yr	20080	15580	19190	20080	39270	1.96	2.52
RDF + Pond ash @ 30t/ha/yr + FYM@ 20t/ha/yr	22480*	16480	18920	24920	41400	1.84	2.51
RDF + Pond ash @ 40t/ha/yr	21980	15980	16660	22660	38640	1.76	2.41
RDF + Pond ash @ 30t/ha once in 3 years	15060	13060	20190	22190	35250	2.34	2.69

** The market value of sunflower seeds: Rs. 1200/q and groundnut pods: Rs. 1500/q

* Inclusive of cost of FYM @ Rs 100/tonne

A = Inclusive of transportation cost of fly ash from RTPS Shaktinagar to Raichur (20 Km distance) @ Rs. 150/tonne

B = Excluding the transportation cost of fly ash

Labour cost for spreading fly ash/pond ash/FYM was taken as Rs 20/tonne

Table 9: Economics of one time application of pond ash (@ 100 t/ha) on farmer's field at Bhabghati, Birbhum, (W. B.)

Crops grown year	Yield of control plots (q/ha)	Yield of fly ash treated plots (q/ha)	Difference (q/ha)	% increase over control	Profit Rs/ha
Kharif paddy-96	43.07	49.90	6.83	15.86	4098.00
Potato 96-97	250.00	300.00	50.00	20.00	10,000.00
Boro Paddy-97	69.78	78.44	8.66	12.45	5,196.00
Kharif Paddy-97	50.57	53.38	2.81	5.50	1686.00
Potato 97-98	256.70	283.70	27.00	10.52	5400.00
Boro Paddy-98	67.50	72.30	4.80	7.11	2880.00
Kharif Paddy-98	48.50	52.40	3.90	8.04	2340.00
Potato 98-99	260.00	290.00	30.00	11.00	6000.00
Boro Paddy-99	43.60	51.20	7.60	17.43	4560.00
Potato 99-00	275.00	304.00	29.00	10.54	5800.00
Boro Paddy-00	49.00	51.40	2.40	4.90	1440.00
Gross Profit					**49400.00**
Cost of Transportation and Application of 100 t PA @ Rs. 1/t/Km.					**4000.00**
Net profit/ha					**45400.00**

The selling prices of Paddy and Potato Rs. 600 and Rs. 200/q, respectively.

4.2.1.3 Other Impacts:

In addition to increase in the yield of produce, significant increase in biomass yield has also been found. Farmers have also reported that the size of grains and their lustre get improved with application of fly ash, resulting in better quality marketing assessment inter-alia better realization. The significant improvement has been reported by farmers regarding pest control especially in case of rice & sugarcane, due to fly ash application. A number of farmers reported that there was no soil born pest attack due to fly ash application. The presence of calcium, magnesium, sulphur, iron and other nutrients in most of the fly ash samples was found to improve the quality of crop produce in respect of protein and oil content.

4.2.2 Use of fly ash in wasteland development

Table 10: Projects undertaken at various sites in the area of forestry sector for wasteland management & reclamation of Saline-Alkali Soil/Eroded Land/Ash Pond

S.N.	Soil/Land Type	Fly ash doses range	Tree Species & No. of Sites	Location	Executed by
1	Laterite Soil	0-240 t/ha	Eucalyptus (1)	Chaudwar , Cuttak	TCRDC, Patiala
2	Laterite Soil	0-24% of pit volume	Eucalyptus, Acacia auriculiformis, Casurina equisetifolia, Acacia mangium (1)	Durga Prasad, Cuttack	TCRDC, Patiala
3	Alkali-Saline Eroded land (in Arid Zone)	0-20% v/w	Eucalyptus, Zizyphus, Jojoba (1)	Jaipur	TERI, New Delhi
	Ash Pond	-	Melia azadirach, Delbergia Sisso, Eucalyptus sp., Populus deltoides (1)	Badarpur	TERI, New Delhi
5	Low Fertile Soil	1/3 Pit volume	Ceiba pentandra, Melia azadirach, Cassia siamea, Erythrina indica, Cassia glauca, Bauhinia purpurea, Putranjiva, Pongamia glabra, Thevetia elifera (1)	New Delhi	TERI, New Delhi

S.N.	Soil/ Land Type	Fly ash doses range	Crops	Location	No. of Sites	Executed by
6	Usar	0-5%	Rice-Wheat	Dailapur	1	IFFCO, Phulpur
7	Usar	0-5%	Rice-Wheat	Tardih	1	IFFCO, Phulpur
8	Usar	0-5%	Rice-Wheat	Yakubpur	1	IFFCO, Phulpur
9	Usar	0-6%	Rice-Wheat	Purisudi	1	IFFCO, Phulpur
10	Usar	0-6%	Rice-Wheat	Parasinpur	1	IFFCO, Phulpur
11	Usar	0-6%	Rice-Wheat	Mobarukpur	1	IFFCO, Phulpur

Soil degradation in India is a serious problem needing urgent attention. Large area of land is affected by soil & wind erosion and by desertification. The results obtained from the above field demonstration sites have shown that fly ash works as an excellent soil conditioner/ modifier and helps to a great extent for restoration of degraded land into agriculture land wherein different types of crops / forestry species/ horticulture species could be grown on sustainable basis.

The effect of fly ash on growth and height of Eucalyptus, grown at Chaudhwar site (Orissa), can be perused from the results included in **Table 11**.

Table 11: Effect of fly ash on growth and annual increment (AI) in height of Eucalyptus at Chaudhwar, Cuttak Site (cm)

Treatment	Jan 1999	Jan2000	Jan 2001	Jan 2002
Plot 1 (Control)	135	160	35	170
Plot 2 (80 tonne FA ha $^{-1}$)	140	172	38	180
Plot 3 (160 tonne FA ha $^{-1}$)	137	189	40	185
Plot 4 (240 tonne FA ha $^{-1}$)	146	211	65	201

It is quite evident from the above results that the annual increment (AI) in height of eucalyptus was maximum in the plot (partially degraded) amended with 240 tonne per ha fly ash. The girth of plants at breast height (GBH) also increased significantly. Fly ash application was found to improve the texture, fertility status and biological activity of soil without any adverse impact due to heavy metals / radioactivity on plant growth and soil health. Similar results have also been found at other sites (Jaipur) on cultivation of different forestry species, Zizyphus, Jojoba, etc. The bare abandoned ash pond at Badarpur Thermal Power Station amended with mycorrhizal organo-fertilizer & FYM was found to be suitable for cultivation of different forestry species and herbaceous and flowering plants

Use of flyash, for reclamation of saline-alkali (usar) soils of Phulpur, IFFCO (up to 75% part-substitute of gypsum), and its use along with mycorrhiza for reclamation of eroded impervious alkaline-saline soils/ threatened land in arid zone (Jaipur) has been successfully demonstrated. Fly ash also enhances growth of commercial as well as conventional forestry species.

As such huge quantity of fly ash can be gainfully utilized for reclamation of wastelands/ commercial forestry. The economic returns, in addition to environment protection / regeneration, would be enormous. Fly ash may be included as one of the amendments in cultivation of Jatropha, being undertaken in the country on large scale for bio-diesel production.

4.2.3 Quality Assessment

The apprehensions regarding the possible negative impacts on presence of heavy metals and radionuclides (in traces) in fly ash have been addressed through in-depth scientific studies with detailed analyses and evaluation on these accounts.

4.2.3.1 Assessment of impact of heavy metals

Samples of hopper ash as well as pond ash were analyzed from a large number of thermal power stations for total and available heavy metals content and their leachability/ availability. The detailed analyses and evaluation (Table-4) clearly indicate that the concentration of metals present in fly ashes and their leachability/ availability is too small to make any significant impact on soil-cropping system.

The above is further validated by detailed analyses & evaluation of field soil samples of control plots as well as fly ash treated plots. The analytical results are given in **Table - 12 (a) & 12 (b)**:

Table 12(a): Effect of application of fly ash on concentration of available heavy metals (ppm) in Control Soil and Fly ash Treated Plots after harvest of paddy & wheat during 1996-2002: Site-Bakreshwar (W.B)

Lead		Nickel		Selenium		Chromium	
Control	FA (200T/ha)	Control	FA (200T/ha)	Control	FA (200T/ha)	Control	FA (200T/ha)
3.60	3.70	0.50	0.65	0.15	0.20	0.20	0.20

Table 12(b): Effect of application of fly ash on concentration of available heavy metals (ppm) in Control Soil and Fly ash Treated Plots after harvest of paddy & wheat during 1996-2002: Site-Bakreshwar (W.B)

Cadmium		Arsenic		Mercury		Cobalt	
Control	FA (200T/ha)	Control	FA (200T/ha)	Control	FA (200T/ha)	Control	FA (200T/ha)
0.03	0.03	BDL	BDL	BDL	BDL	0.04	0.06

BDL - Below Detectable Limit

The result of field water samples of control plots and fly ash treated plots, given in **Table 13**, also validate the above findings.

Table 13: Effect of application of fly ash on concentration (ppm) of available heavy metals in Ground Water before start of the experiment (250 m away from the experimental site) and Final Water Samples after completion of the Project, i.e. after harvest of last crop: Site-Bakreshwar(W.B) & Regional Research Station(RRS), Bhatinda

	Lead		Nickel		Selenium		Chromium	
	Initial water	Final water	Initial water	Final water	Initial water	Final water	Initial water	Final water
Bakareshwar (WB) 200 tonne FA/ha	BDL	BDL	0.21	0.23	0.05	0.05	0.2	0.2
RRS, Bhatinda (Punjab) 80 tonne FA/ha	0.04	0.06	0.004	0.008	BDL	BDL	0.006	0.009

	Cadmium		Arsenic		Mercury		Cobalt	
	Initial water	Final water	Initial water	Final water	Initial water	Final water	Initial water	Final water
Bakareshwar (WB) 200 tonne FA/ha	0.02	0.02	BDL	BDL	BDL	BDL	0.03	0.04
RRS, Bhatinda (Punjab) 80 tonne FA/ha	0.001	0.002	BDL	BDL	0.004	0.006	0.05	0.04

To study the impact of heavy metals uptake in the produce as well as in the biomass, which might go in the food chain through grazing / cattle feed, samples were analysed for these heavy metals and the results presented in Tables 14(a) & (b) once again conclude that the presence of heavy metals in fly ash does not give any significant impact on the produce as well as the biomass.

Table 14 (a) : Effect of application of fly ash (FA) on concentration (range) of heavy metals in Grains & Straw (ppm): Site-Bakreshwar (W.B)

	Lead		**Nickel**		**Selenium**		**Chromium**	
	Control	FA (200T/ha)	Control	FA (200T/ha)	Control	FA (200T/ha)	Control	FA (200T/ha)
Paddy (96-2002)								
Grain	0.6-0.8	0.7-0.9	0.4-0.6	0.6-0.8	0.4-0.5	0.6-0.7	0.7-0.8	0.7-0.9
traw	0.7-0.9	0.8-0.9	0.7-0.8	0.8-1.0	0.2-0.3	0.3-0.4	0.7-0.9	0.7-0.9
Wheat (96-2002)								
Grain	0.2-0.3	0.2-0.3	0.2-0.3	0.3-0.4	BDL-0.2	BDL-0.3	0.4-0.5	0.4-0.6
Straw	0.2-0.4	0.3-0.4	0.2-0.3	0.3-0.4	BDL-0.1	BDL-0.2	0.4-0.5	0.4-0.5

Table 14 (b): Effect of application of fly ash on concentration (range) of Heavy Metals in Grain and Straw (ppm): Site Bakreshwar (W.B)

	Cadmium		**Arsenic**		**Mercury**		**Cobalt**	
	Control	FA (200T/ha)	Control	FA (200T/ha)	Control	FA (200T/ha)	Control	FA (200T/ha)
Paddy(96-2002)								
Grain	< 0.5	< 0.5	BDL	BDL	BDL	BDL	BDL-0.04	BDL-0.05
Straw	< 0.5	< 0.5	BDL	BDL	BDL	BDL	0.03-0.05	0.04-0.06
Wheat (96-2002)								
Grain	< 0.5	< 0.5	BDL	BDL	BDL	BDL	BDL-0.04	BDL-0.04
Straw	< 0.5	< 0.5	BDL	BDL	BDL	BDL	BDL	BDL

4.2.3.2. Toxicological Studies

The detailed laboratory and clinical studies have been taken up at National Institute of Nutrition (NIN), Hyderabad, under Indian Council of Medical Research (ICMR), Ministry of Health, GOI, to evaluate the produce grown on fly ash treated plots for the toxicological impact. The laboratory analyses reaffirm the earlier findings of insignificant impact of fly ash in respect of heavy metal contents in agricultural produce. Clinical evaluation has also been done through haematological and histopathological studies. Two groups each of 12 rats (weanling WNIN) & 12 mice were taken for the study, as per WHO protocol. The test groups were fed with produce grown on fly ash treated soil and the control group of animals were fed with same composition of food from control plot. The physiological data regarding weight, growth, etc were recorded at regular intervals. Blood & tissue samples were tested as per the protocol. Animals were scarified and various organs tested. The tests & evaluation revealed

that there is no toxicological impact to any of the organs of both rats and mice fed on crop produce grown with fly ash.

The photographs/ scan of brains, kidney, liver, heart of animals fed with crop produce grown on fly ash treated soils, placed below, do not show any change / impact.

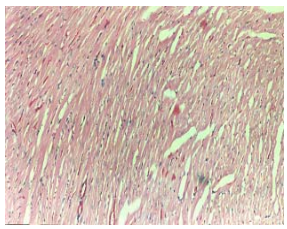


Fig. 1: NORMAL HEART - SHOWING MUSLCLE FIBRES ARRANGED LONGITUDINALLY H & E X 100

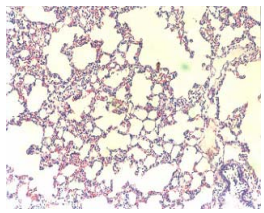


FIG.2: NORMAL LUNGS - SHOWING BRONCHIOLE AND NORMAL ALVEOLI H & E X 100

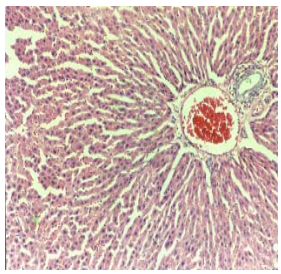
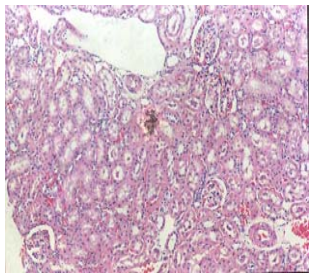


FIG. 3: NORMAL LIVER - SHOWING HEPATOCYTES AND PORTAL TRIAD - H & E X 100



NORMAL KIDNEY - SHOWING GLOMERULI AND TUBULES - H & E X 100

4.2.3.3 Nutritional Evaluation

Evaluation of nutritional value of agricultural produce grown on fly ash treated soils and in the control plots was also taken up at NIN, Hyderabad. The results, presented in Table 15(a), 15(b) & 15(c), indicate that there is no adverse effect of addition of fly ash, on the contrary there is an advantage; the protein, iron & calcium contents are higher in the produce of fly ash treated plots and trace/ heavy metal concentrations in the produce is not at all affected by fly ash addition. This is desirable as it is good for human being.

Table 15(a): Effect of fly ash on proximate composition (Mean value) of Mustard, Rice & Wheat (g%)

Parameters	Mustard (Phulpur)		Rice (Raichur)		Wheat (Rihandnagar)	
	No Fly Ash	Highest dose of fly ash	No Fly Ash	Highest dose of fly ash	No Fly Ash	Highest dose of fly ash
Fat	36.25 (1.00)	35.76 1.39)	0.40 (0.09)	0.54 (0.10)**	1.99 (0.18)	1.85 (0.09)**
Moisture	6.62 (1.46)	6.95 (1.34)	10.16 (0.49)	9.80 (0.44)**	7.78 (0.51)	7.69 (0.31)
Protein	22.86 (1.15)	23.85 (0.90)**	9.95 (0.50)	10.04 (0.43)	11.46 (0.60)	11.55 (0.53)
Ash	4.46 (0.18)	4.44 (0.08)	0.53 (0.06)	0.51 (0.05)	1.44 (0.07)	1.47 (0.07)
Crude Fibre	3.79 (0.49)	3.26 ((0.45)**	0.10 (0.02)	0.11 ((0.02)	1.36 (0.26)	1.57 (0.13)**
Carbo-Hydrate	26.02 (26.02)	25.74 ((1.59)	78.86 (0.77)	79.00 (0.46)	75.97 (0.95)	75.88 ((0.61)
Energy (Kcals/100 gms.)	521.75 (8.48)	520.17 (11.08)	358.89 (1.83)	361.06 (2.20) **	367.67 (2.39)	366.42 (1.50)**

* Significant at 5% level vis-a-vis no fly ash
** Significant at 1% level vis-a-vis no fly ash

Table 15(b): Effect of fly ash on Concentration (Mean value) of Macro and Micro Elements in Mustard, Rice & Wheat (mg/100g)

Parameters	Mustard (Phulpur)		Rice (Raichur)		Wheat (Rihand Nagar)	
	No Fly Ash	Highest dose of fly ash	No Fly Ash	Highest dose of fly ash	No Fly Ash	Highest dose of fly ash
Ca	489.03 (28.75)	498.33 (32.04)	10.4 (2.44)	9.28 (1.15)*	32.61 (1.70)	33.52 (1.65)*
P	623.06 (23.97)	606.89 (36.56)	115.61 (10.79)	117.36 (8.22)	227.36 (29.13)	211.53 16.97)**
Mg	300.24 (22.77)	299.33 (16.70)	25.33 (3.73)	28.64 (2.16)**	113.25 (7.35)	112.50 (7.14)
Fe	14.30 (3.33)	13.64 (2.58)	1.14 (0.37)	1.73 (0.29)	4.11 (0.87)	4.39 (0.54)
Mn	2.31 (0.15)	2.34 (0.14)	1.09 (0.12)	1.13 (0.10)	4.56 (0.27)	4.69 (0.33)
Cu	0.70 (0.07)	0.75 (0.11)*	0.36 (0.10)	0.30 (0.07)	0.55 (0.07)	0.59 (0.11)*
Zn	4.54 (0.20)	4.60 (0.34)	1.32 (0.17)	1.23 (0.14)*	-	-

* Significant at 5% level vis-a-vis no fly ash
** Significant at 1% level vis-a-vis no fly ash

Table 15(c): Effect of fly ash on Concentration (Mean value) of Trace and Heavy Metals in Mustard, Rice & Wheat (mg/100 g)

Trace/ heavy metals	Mustard (Phulpur)		Rice (Raichur)		Wheat (Rihandnagar)	
	No Fly Ash	Highest dose of fly ash	No Fly Ash	Highest dose of fly ash	No Fly Ash	Highest dose of fly ash
Pb	0.10 (0.22)	0.00 (0.00)	0.27 (0.30)	0.19 (0.30)	0.58 (1.09)	0.04 (0.10)**
Cd	0.03 (0.15)	0.01 (0.02)	0.04 (0.08)	0.01 (0.02)*	0.00 (0.00)	0.00 (0.00)
As	0.30 (0.89)	0.40 (1.15)	0.00 (0.00)	0.19 (0.54)	0.94 (1.92)	0.29 (0.92)
Cr	0.47 (0.47)	0.21 (0.10)**	0.21 (0.07)	0.20 (0.04)	0.22 (0.22)	0.21 (0.21)

* Significant at 5% level vis-a-vis no fly ash
** Significant at 1% level vis-a-vis no fly ash

4.2.3.4 Evaluation of Radioactivity

Samples of fly ash, soil, grain and biomass from fly ash treated plots as well as the control plots under the projects undertaken/ supported by FAM/ FAUP have been evaluated for their radionuclide contents at Institute Of Physics (IOP), Bhubaneshwar, Department of Atomic Energy, GOI. The results presented in Tables 16 & 17 clearly show that application of fly ash has no significant impact on field soil, and agricultural produce and biomass.

Table 16: Activity Levels (Range) of gamma emitting radionuclides in flyash, field soils and flyash amended soils (Bq Kg-1)

	^{40}K	^{226}Ra	^{228}AC
Dry fly ash	290-350	70-90	90-110
Pond ash	280-320	65-85	80-100
Field soil	170-200	30-50	40-60
Fly ash amended soil	200-300	40-60	50-70

Table 17: Activity levels (Range) of gamma emitting radio-nuclides in grains & straw of paddy & wheat crops (Bq Kg-1): Site: Bakreshwar, (W.B)

Period	Treatment	Activity		
		^{40}K	^{236}Ra	^{238}AC
Paddy & wheat Grain (1996-2002)	T1	60-90	0.3-0.4	0.5-0.7
	T4	65-100	0.4-0.7	0.7-1.0
	T7	67-100	0.4-0.7	0.7-1.0
Paddy & wheat straw (1996-2002)	T1	10-25	03.04	0.6-0.7
	T4	15-30	05.07	0.7-0.9
	T7	15.30	0.5-0.7	0.7-0.9

Note: T1: Control (without fly ash), T4 : Fly ash application @ 200 t/ha (one time),
T7 : Pond ash application @200 t/ha (one time)

Table 18: Estimated daily intake of radionuclides

Food item	Daily Consumption (gm)	Daily intake(Bq)		
		^{40}K	^{226}Ra	^{228}Ac
Case –I				
Rice grain	320	28.8	0.19	0.24
Wheat grain	80	5.8	0.03	0.07
Vegetables	200	22.2	0.15	0.22
Total intake		56.8	0.37	0.53
Case-II				
Wheat grain	320	23.2	0.12	0.28
Rice grain	80	7.2	0.05	0.06
Vegetables	200	22.2	0.15	0.22
Total intake		52.6	0.32	0.56
Daily intake Limit (Bq/day)		104.0	0.61	2.2

Note : Even though, in the above specific cases, total intake would be within the permissible limit if a man consumes about 1.5 times the specified daily consumption

5.0 Potential of Vermicomposted fly ash in agriculture

Vermicomposed fly ash developed2 at Soil Testing Laboratory, Institute of Agriculture, Visva Bharti University, (W.B) is an improvised product of degraded fly ash and humified organic wastes, facilitated with the help of the intestinal microflora of epigeic earthworms. This material exhibits considerably higher availability of different plant nutrients which leads to production of good crop and reduced use of mineral fertilizers. A good share of this increased availability of different nutrients in vermicomposted fly ash comes from fly ash alone thus improving upon its original quality with regard to supply of plant nutrients. Application of this vermicomposted fly ash in agricultural fields has shown considerable potential in reducing the quantum of application of mineral fertilizers. Since vermicomposted fly ash is a good source of phosphorus and potassium, which fertilizers are largely imported from abroad, large scale adoption of this practice is likely to have a positive effect on the economy of the country also.

6.0 Multiplier effects on the use of fly ash: Large Scale Field Demonstration in farmers' field for confidence building

Large number of field demonstration experiments1 in the farmers' field in the vicinity of different thermal power plants in the country for popularization of beneficial uses of fly ash in agriculture / wasteland development have been /are being conducted as a result of technology demonstration projects of FAM/FAUP, TIFAC, DST. Location of some of the demonstration sites is given below:

Title of the project	Place
Long term studies / field trials and demonstration of utilization of lignite fly ash in agricultural lands of Neyveli and for reclamation of mine spoil	CARD, Neyveli
Utilisation of fly ash from RSTPS in agriculture and the vicinity of Ramagundam STPP (AP)	Villages in the vicinity of TPP
Extended study on utilization of fly ash from BKTPP in agriculture / waste land management vis-a-vis associated environmental issues	Villages in the vicinity of TPP
Demonstration trials in farmers field for popularization of bulk use of fly ash from different TPPs (Anpara, Obra, Harduaganj) of UPRVUNL in agriculture and for reclamation of degraded / waste land	Villages in the vicinity of TPP
Mitigation of GHG via in-situ infusion of fly ash in TPPs	CFRI
Mitigation of GHG through afforestation in fly ash	Talcher
Bioreclamation of wasteland through fly ash amendment for cultivation of medicinal plants	Boriadih & Rungadagada, Mohanpur (Bokaro)
Bio-reclamation of OB dumps of Talcher / Ib coal-fields (MCL) through fly ash amendment for cultivation of multipurpose medicinal plants	Talcher & Lb Valley Coal Field
Bio-conversion of lignite to humic acid as other amendment with fly ash	CFRI & NLC
Bio-restoration of OB dumps through the plantation of efficient photosynthetic / soil conserver species in Eastern Jharia Coalfields, BCCL	Eastern Jharia (BCCL)
Study of leaching characteristics of lignite fly ash from environmental point of view for its dumping above ground level	CFRI
Bio-reclamation of low lying area filled with fly ash from Tata Steel's FBC power plants at Jamadoba and associated environmental studies	Tata Steel, Jamadoba
Evaluation of impact of Ammonia dosing on properties of fly ash vis-a-vis agriculture related applications	HWP, Manuguru (A.P.)
Popularisation of beneficial use of fly ash from HWP, Manuguru for cultivation of different crops amongst local farmers	HWP, Manuguru (A.P.)
Demonstration of bulk use of pond ash in Koradi, Khaperkheda, Chandrapur, Nashik, Paras, Bhusawal & Parli,V. TPSs of MAHAGENCO in the nearby farmers' fields	Villages in the vicinity of TPPs of MAHAGENCO
Demonstration of bulk use of fly ash in farmers field in the vicinity of MPPGCL, Sarni TPP	Villages in the vicinity of sarni TPP

The large-scale laboratory and field demonstration activities undertaken by FAM/ FAUP over the last decade have developed good amount of confidence building amongst various agencies as well as decision makers. The ice of apprehension has started melting and phase of LET'S-TRY-AND-SEE has begun. MAHAGENCO (earlier MSEB, Mumbai) and other thermal power stations have commissioned activities under 5 years programme with FAUP, TIFAC for large scale field demonstration on use of fly ash in agriculture. This thrust programme is to continue with involvement of farmers, village panchayat, district agriculture agencies, NABARD, local NGOs, colleges/ Universities and other agencies by organizing kisan goshties / melas / national Seminars / trainings/ wide media coverage / audio visual aids / pamphlets etc. The objective is to take the information and knowledge to mass farmers and help them to realize the gain from fly ash that it holds the potential. The scheme has received overwhelming response from the farmers and thousands of farmers are getting

benefit through technical advise and guidance provided free of charge. Enthusiastic farmers are applying flyash in their fields by transporting the ash at their own cost. However, on request from FAUP, TIFAC, NABARD has also come forward, to extend financial support for transport of fly ash from ash pond to their fields.

7.0 CONCLUDING OBSERVATIONS

It has been proved, beyond doubt, that use of fly ash in agriculture has no significant ill effects. Mineralogically, fly Ash is broadly similar to soil but rich in macro and micro nutrients. Particle size distribution of fly ash improves physical conditions of soil, specifically black cotton and lateritic soil, significantly.

Application of fly ash increases yields of all crops namely; cereals, oil seeds, sugarcane, cotton, vegetables, pulses, etc. and its residual effects last for 6 to 8 years.

The impact of use of fly ash in 75% of agricultural land falling within economic lead zone of 100 KM of Thermal Power station would be enormous. On an average, 12½ % yield increase for cereals, oilseeds, pulses, sugarcane, cotton & 30% for vegetable could be achieved.

The quantity of fly ash required for the projected level of activities would be manifold than the current generation and the accumulated stocks. The use of fly ash in agriculture with a required policy support and facilitation can progressively increase from the current nascent level and large scale demonstration/ confidence building stage to at least 2 million hectare land which is about 1½ % of total 143 million hectare agriculture land.

This means that the fly ash holds potential to increase the production of cereals and pulses by 10% taking it from the present level of 213 million tonne food grains to 234 million tonne.

The above impact that fly ash holds the potential is nothing but another green revolution.

REFERENCES:

1. Use of Fly Ash in Agriculture and Related Studies, Report of FAUP, TIFAC, DST, 2005
2. Bhattacharya S.S., Chattopadhaya G.N (2002); Increasing bio-availability of phosphorous from fly ash through vermicomposting. Journal of Environmental Quality, 31: 2116-2119.

BRIEF BIOGRAPHY OF THE PRIMARY AUTHOR (Dr. Vimal Kumar)

Dr. Vimal Kumar, Adviser, Department of Science & Technology is the founder Mission Director of Fly Ash Mission, TIFAC, DST, Government of India. Fly Ash Mission conceived and implemented under his guidance has made a significant impact. Fly ash has now started to be accepted as a useful material in the country. It provides durable, economical and environment friendly building materials. The thrust provided by Fly Ash Mission has increased utilisation of fly ash in the country from 3% per annum to 45% and is targeted to reach much higher levels in years to come.

Dr. Vimal Kumar holds Bachelors Degree in Mechanical Engineering, MBA from Indian Institute of Management-Ahemadabad & Ph.D in Development and Commercialisation of New Technologies from Indian Institute of Technology-Delhi. He is also Adviser in Technology Development Board (TDB) of DST, Govt. of India. Dr. Vimal Kumar has been instrumental for development and large scale utilisation of a number of technologies for use of fly ash in building / construction industry as well as many other technologies in other industrial sectors. He has published / presented more than 150 Technical Papers, Contributed / Co-Authored 6 books, widely traveled, Chairman & Member of Advisory Bodies / Research Council of a number of institutes / research bodies, visiting faculty to technology and management institutes and on the Editorial Board of International Journal of Technology Management, U.K.