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Review Article

FLY ASH OF THERMAL POWER PLANTS: REVIEW OF THE PROBLEMS AND MANAGEMENT OPTIONS WITH SPECIAL REFERENCE TO THE BAKRESHWAR THERMAL POWER PLANT, EASTERN INDIA

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ABSTRACT
There is an enormous stress on the coal-based thermal power plants (TPPs) to meet the energy requirements of our country. Currently 82 coal-fired TPPs exist in India and disposal of the increasing amounts of coal ash is becoming a serious concern to the environmentalists as the re-use/utilization rate is too low and inadequate or unscientific management results multi-furious geo-environmental degradation. Fly ash disposal and management of Bakreshwar Thermal Power Plant (BkTPP), the 3rd largest TPP in West Bengal has become a major issue of concern. This is because; the fly ash dumping ponds at Panuria and Raipur village has got filled-up about a year ago. The slurry from these ponds directly flow into the surrounding land and to the river Chandrabhaga and Bakreshwar leading to air, water and soil pollution. Overflow and blow-off the ash towards residential areas is causing unnecessary human exposure and has serious health risks. The villagers are even more affected as the ash is deposited in the fields and farmers use ash-laden water to irrigate. Due to huge siltation the river hydro-morphological serene have totally changed even upto 15 kilometer downstream. The river bed and banks resembles a cemented floor rising about 0.8 metre in some places. Recently (Nov, 27, 2014) the Eastern bench of the National Green Tribunal (NGT) directed the state-run Bakreshwar TPP to clean up the Chandrabhaga and Bakreshwar rivers within 15 days or face coercive measures. This article attempts to highlight the multifarious geo-environmental problems arising out of the overflow of fly-ash pond and management options for fruitful utilization of this solid waste.

***Keywords**: Thermal Power Plant (TPP), Fly Ash (FA), Ash Pond, Waste Management*

INTRODUCTION
For most of the developing countries, power being considered as an engine of growth and has always been a focus. Dependence on coal for power generation is inevitable (Taneja, 2004), although there have been continuous efforts for exploring its viable alternatives across the world. India is the 3rd largest producer of coal (annual production: about 250 mt, coal reserve: about 200 bt.) and coal based Thermal Power Plants (TPPs) in India contribute about 70% of the total power generation (Sahu *et al.*, 2009). At present, 120-150 million tons of coal Fly Ash (FA) is generated from 120 existing coal based TPP in India and ranks 4th in the world in the production of coal ash as by-product waste after USSR, USA and China (Lokeshappa and Dikshit, 2011). This annual generation of FA has increased from about 1 million tonne in 1947 to about 40 million tonne during 1994 and as per the Technology Information, Forecasting and Assessment Council (TIFAC), DST, Government of India the figures are expected to reach about 225 million tonne by 2017.

Environmental pollution by the coal based TPP all over the globe is cited to be one of the major sources of pollution affecting the general aesthetics of our environment in terms of air, soil and water pollution and land use, health hazards in particular (Carlson and Adriano, 1993; Mandal and Sengupta, 2005; Moon and Dermatas, 2007). Coal Combustion Residues (CCRs) namely fly ash, bottom ash and fluidized bed combustion ash (Keefer and Sajwan, 1993; Ashoka *et al.*, 2005) from coal based TPP contains significant amounts of fine powdered ferro-alumino-silicate material with Al, Ca, Mg, Fe, Na and Si as the predominant elements and toxic metals such as As, Ba, Hg, Cr, Ni, V, Pb, Zn and Se (Adriano *et al.*, 1980; Aitken and Bell 1985; Mattigod *et al.*, 1990). The coal fly ashes occupy more space in the premises of industrial plants (Flanders, 1999) and are mixed with water to discharge into fly ash settling ponds or landfills. Large quantities of coal fly ashes are stored in the form of waste heaps or deposits, whose contamination poses a serious threat to the environment in general (Fulekar and Dave, 1991) and can have deleterious effects on soils, surface water, and ground water (Hulett *et al.*, 1980; Baba and Kaya, 2004; Moon and Dermatas, 2007), human health (Yuan *et al.*, 2009), growth rate of major carps (Klose *et al.*, 2001) and even biotic organisms like fishes (Shrivastava and Dwivedi, 2011). With the present practice of fly-ash disposal in ash ponds (generally in the form of slurry), the total land required for ash disposal would be about 82,200 ha by the year 2020 at an estimated 0.6 ha per MW (CBRI ENVIS Centre on Fly Ash, 2011). So, some attempts are warranted to find the constituents of the fly ash coming out of for their proper disposal and treatment in view of safety aspects and it is rather necessary to treat FA as a byproduct rather than waste (Behera, 2010; Dwivedi and Jain, 2014).

Excess Disposal of ash from the Bakreshwar Thermal power plant (BkTPP) of Birbhum District, West Bengal, India to the nearby settling ponds and over flow during rainy season has become a serious threat not only to the nearby Bakreshwar and Chandrabhaga River and surrounding agricultural land but also causing unnecessary human exposure and has become serious health risk. In the light of the above ground in the present article the authors have been carrying out systematic geo-environmental study of local-problems associated with FA and spill over from the ash ponds of the BkTPP and attempt to highlight the potential beneficial applications of coal FA as a cause of concern for the future.

The Study Site

BkTPP is the 3rd largest TPP in West Bengal operated by West Bengal Power Development Corporation Limited (WBPDCL). It is located at the village of Mutaberia (23°50′N 87°27′E) under Chinpai and Bhurkuna GP of Dubrajpur Block, Birbhum District; in the North-Western part of West Bengal around 230 km. far from Kolkata (Pramanick, 2006) (vide figure 1). The Power Station is near the Panagarh–Morgram Highway, on the bank of Bakreshwar River, some distance downstream from the hot springs and temple at Bakreshwar and Chinpai railway station on the Andal-Sainthia Branch Line is nearby.

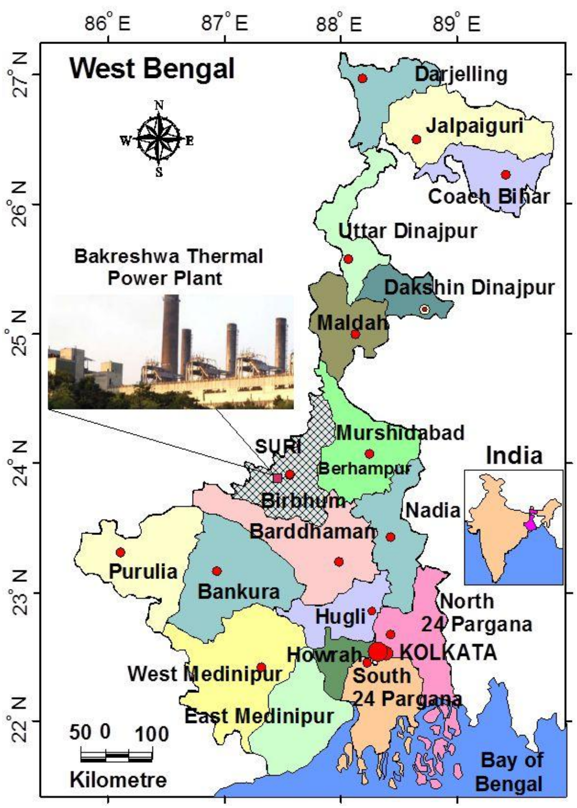


Figure 1: Study Site Location

The raw water required for power generation primarily comes from the Tilpara Reservoir located 15 km away and the NIL-Nirjon Dam (Bakreshwar Reservoir) (storage volume: 2.29 million m^3 and coverage area: 10 km^2) located at about 3 km northwest of the TPP. BkTPP has 5 power generating units of 210 MW each for a total capacity of 1050 MW.

The units were commissioned in four stages in 1999, 2001, 2008 and 2010. The power station is generating about 6250-6700 metric tons of FA every day by consuming a total of 14500 metric tons of coal.

The region is an integral part of north Rarh Bengal located at the pedimental plain of Chotonagpur plateau fringe. The area is overlain by a thin alluvial cover and forms a transition zone between hard rock and flat gently sloping alluvial terrain. The master slope is from West to East with the land having the average altitude 72 m. MSL. The climate of the area is sub-humid sub-tropical monsoonal type.

Origin of the Present Problems

The BkTPP was planned for the very purpose of alleviating states power shortage using coal mined in the North-Western part of West Bengal. Generating first 3 Units were constructed in the period from January, 1994 to April, 2004.

During initial plan proposal of BkTPP included the construction of a plant to utilize the FA. But the plant was cancelled, during the subsequent detailed study as, market for these products was found to be premature and acquired only about 150 hectares of land located at Panuria ($87^0$30′15.68″ E, $23^0$51′27.51″ N) and Raipur ($87^0$30′20.6″E, $23^0$51 44.15″ N) village under Chinpai-Varukana Gram Panchyet, situated about 8.4 km from the TPP, about 1km off the river Chandrabhaga and (about 16.1 km downstream) where the Panagarh–Morgram Highway meets the Mayurakshi-Bakreshwar Main canal to the to dump the FA.

These, damped FA has been supplied to several external companies since 2003 at a low price and the utilization rate of fly ash exceeded 60% in 2005.

Under 10^{th} Five Year Plan (2002–2007) Unit No. 4 and 5 (210 MW each) were established and started Commercial Operation by 2009. This has aggravated the problem of fly ash dumping and no such new attempt has taken by the authority.

The ash ponds has got filled-up about a year ago as a result, the initial decision to cancel the construction of a FA utilization plant has led to a risky option for this power plant.

Recently the National-Green *Tribunal* (NGT) on the hearing of a petition filed by environment activist *Datta* alleging pollution in the nearby river due to FA released by the BkTPP directed the plant to clean up the rivers within 15 days, asked the central and state pollution control boards to assess the situation and told the responsible authority to give a compliance report that must also mention that no further contamination would be done otherwise it will have to shut down operations.

Objectives

Primary objectives behind the present study are

- To have an overview of the problems arising out of the coal-fired BkTPP, especially from the FA and overflow of the ash ponds,
- To review the management options in order to overcome the problem.

Data-Base and Methodology

The present study is based mostly on secondary data bases. However, little field investigation has also done including field examination, sampling of water and soil, measurements and talking to the local villagers.

We have visited three sites on river Chandrabhaga namely Mallickpur (about 17.63 km downstream of source and 1.53 km downstream of the ash pond disposal location), Noapara (about 20.66 km downstream of source and 4.56 km downstream of the ash pond disposal location) and Gangte (about 24.45 km downstream of source and 8.35 km downstream of the ash pond disposal location). Further about 5.2 km downstream we have visited river Bakreshwar on Hatikra.

The authors are presently working in this ground and further field investigation will enrich the article in the subsequent stages.

Figure 2: Authors and their associates in the field (a) detecting ash layer in the river bank, (b) measuring ash deposition (c) taking cross section (d) collecting water sample (e) collecting soil sample (f) talking to local people

Fly-Ash from Coal-Fired Tpp: Composition, Production and Utilization

Fly-ash of coal-fired TPP is defined in Cement and Concrete Terminology as, the finely divided, fused residue of clay minerals residue resulting from the combustion coal having powdered ferro-aluminosilicate material with Al, Ca, Mg, Fe, Na and Si as the predominant elements.

A device called *Electro Static Precipitator* (ESP) is used to prevent ash from flying out the chimneys and the ash is collected in hoppers below the ESP and is disposed of by two methods- (i) *Dry System:* Ash is conveyed by compressed air to storage tanks called SILO. (ii) *Wet System:* Slurry (ash mixed with water) is disposed off in large ponds (ash ponds) where the ash is kept exposed in the sun to dry and is collected by many companies for their use.

Physico-Chemical Composition of the Indian Fly Ashes: A General Overview

In a thermal power plant, the clay minerals in coal converts into a range of fused ultra-fine particles (<100 nm) with diverse minerals (Chen *et al.*, 2004; Hower *et al.*, 2008). Primary ingredients of fly ashes are SiO_2, Al_2O_3, Fe_2O_3, Fe_3O_4, TiO_2 and CaO. Besides, it contains a petite quantity of unburnt carbon with minute percentage of the oxides of Mg, Cr, Na, and K (Chaddha and Seehra, 1983; Flanders, 1999; Lu *et al.*, 2009) and several potential toxic heavy metal elements like Pb, Zn, Cd, Ni, As, and Co, which would pollute soils, surface water, and ground water (Hulett *et al.*, 1980; Moon and Dermatas, 2007). Moreover, Fly ash restrain considerable amount of magnetic minerals of which iron oxides are in common (Matzka and Maher, 1999; Yang *et al.*, 2007).

Among several iron oxides, Fe_3O_4 might be the most vital root of anthropogenic magnetic particles in soils, sediments, and tree leaves in the fly ash affected areas (Lu *et al.*, 2009). Furthermore, there are some reports that coals as available in India contains 1.8– 6.0 ppm 238U and 6.0–15.0 ppm of 232Th (Mishra and Ramachandran, 1991) which is a serious threat to the environment due to the radioactivity (Mandal and Sengupta, 2005).

So, some attempts are warranted to find the constituents of the fly ash (vide table 1 and 2) coming out of thermal power plants after coal combustion, for their proper disposal and treatment in view of safety aspects.

Table 1: Chemical Composition of Fly Ash

Name	Formula	Percentage (%)
Silica	SiO_2	62
Iron oxide	Fe_2O_3	63
Aluminum	Al_2O_3	26
Titanium oxide	TiO_2	1.8
Potassium oxide	K_2O	1.28
Calcium oxide	CaO	1.13
Magnesium oxide	MgO	0.49
Phosphorus pentaoxide	P_2O_5	0.40
Sulfate	SO_4	0.36
Disodium oxide	Na_2O	0.28

Source: Critical Review in Environmental Control CRC Press, 3, (1989)

Coal-Based Electricity Generation in India

At present India's energy generation is predominantly dependent on coal and accounts for about 41% of the total primary energy used. Table 2 shows the present and projected coal requirement for power generation in India. Figure 3 shows the share of electricity generation in India by different fuel sources in 2011. Figure 4 shows the share of thermal-based power, renewable and nuclear in India's electricity generation. Coal accounted for nearly 69% of the total electricity generation in 2011 and 59% of the installed capacity in 2013.

Table 2: Present and projected coal requirement for power generation in India

Plan	Terminal year of plan	Capacity (MW)	Requirement of coal (MT)
VIII plan	1996-97	50000	210
IX plan	2001-02	87100	285
X plan	2006-07	116400	400
XI plan	2011-12	138000	500

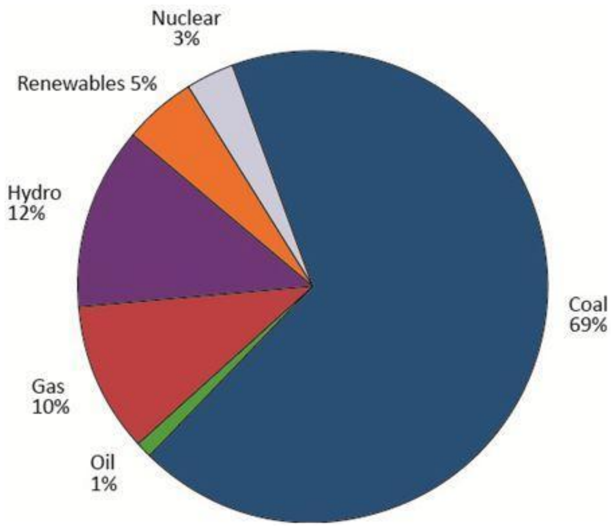


Figure 3: Electricity generation in India in 2011

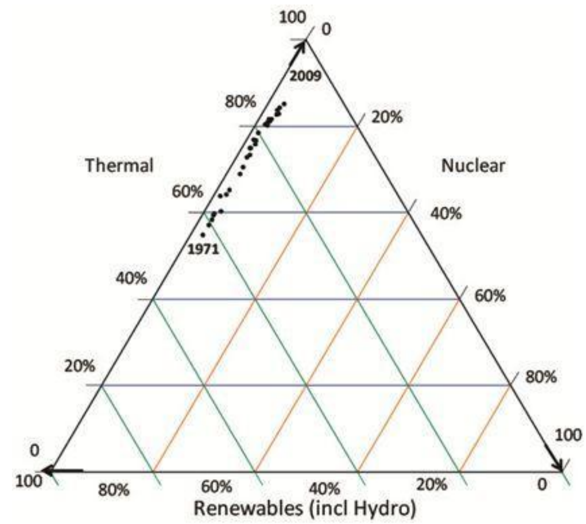


Figure 4: Electricity variation trends 1970–2009

Source: Report under preparation for TIFAC; http://www.tifac.org.in

Fly Ash Generation and Utilization in the Global to the Regional Level

The large production of electricity is depending on the coal based TPP in whole world, so the amounts of FA generated by these TPP are also increased regularly. According to Singh and Siddiqui (2003) in India there is about 79% of the whole electricity generated by coal based TPP. Jamwal (2003) have reported that about 110 MT fly ash produced from these plants every year. In present time, India consume 43000 T of coal per day in the process generate ash (fly ash and bottom ash) of about 18500T. Kalra *et al.*, (2003) has been documented that it will cross the 140 MT by the year 2020. China, India, United States, South Africa, Australia, Greece, and Japan are the countries having higher rate of FA production (Ram and Masto, 2010).

Table 3: Fly ash production and its utilization in all over world

Name of the Country	Annual fly ash production (MT)	Ash utilization %
India	112	38
China	100.0	45
USA (1991)	75	65
Germany (1989)	40.0	85
U K (1989)	15.0	50
Australia (1990)	10.0	8
Canada	6.0	75
France (1989)	3.00	85
Denmark	2.00	100
Italy	2.00	100
Netherland	2.00	100

Source: http://www.tifac.org.in

Table 4: Thermal power generation, coal consumption and ash generation in India

Year	Thermal power generation (mW)	Coal consumption (mt)	Ash generation (mt)
1995	54,000	200	75
2000	70,000	250	90
2010	98,000	300	110
2020	137,000	350	140

Source: Senapati (2011)

Table 5: Fly ash Generation and utilization by major TPP of West Bengal 2009-10

Name of the TPP	Capacity (MW)	Coal Cons. (mta)	Ash Gen. (mta)	Ash Uti. (mta)	% utilisation
Meizia, DVC	630	3.32	1.32	0.0013	0.1
Durgapur , DVC	350	0.872	0.349	0.495	141.8
Durgapur Projects Ltd.	401	1.686	0.573	0.737	128.6
Santaldih, WBPDCL	480	0.843	0.253	0.875	345.85
Budge Budge, CESC	500	2.52	0.908	0.908	100
Titagarh , CESC	240	1.17	0.33	0.33	100
Sounthern , CESC,	135	0.68	0.24	0.24	100
Kolaghat. WBPDCL	1260	5.086	1.618	1.988	122.9
Farrakka, NTPC	1600	9.26	3.426	2.06	60.1
Bakreswar, WBPDCL	1050	4.145	1.148	0.403	35.1
Bandel, WBPDCL	530	1.285	0.413	0.18	43.6
Total	7176	30.867	10.578	8.2173	77.68

Source: Central Pollution Control Board, Pollution Control Implementation Division – II, 2011

Sinha and Basu (1998) have reported that in other countries like USA, Germany, France and Netherland the use of FA about 70%, but in our country it is only about up to 15%. The Eastern Indian coals are typically high ash coals and the ash content of coal supplied to majority of power stations is of the order of 36 to 44 %. So, it is necessary to invent some new field of the utilization of this solid waste in a proper and suitable way.

Recent Attempt for Fly Ash Utilization in India

In India, FA generation is expected to grow further as coal would continue to remain as major source of energy at least for next 25 years. The FA, which is a resource material, if not managed well, may cause environmental challenges. FA Utilisation Programme (FAUP), a Technology Project in Mission Mode of Government of India commissioned during 1994, is a joint activity of Department of Science & Technology (DST), Ministry of Power (MOP) and Ministry of Environment & Forests (MOEF), wherein Department of Science & Technology is the nodal agency and Technology Information, Forecasting and Assessment Council (TIFAC) is the implementing agency. FAUP has been undertaking various attempts for the technology development, creating awareness, facilitating multiplier effects, policy interventions etc. in the area of safe management & gainful utilization of FA. The Central Institute of Mining and Fuel Research (CIMFR), Dhanbad is also being associated with the research and development work on FA conversion processes and associated environmental concerns. Figure 5 shows some fly ash mission project site undertaken by FAUP. At present FA utilization in India has reached to the level of about 46%. The policy guidelines in India encourage the use of at least 25% ash in clay bricks manufactured within a radius of 100 km from coal and lignite based TPPs (Ram and Masto, 2010). There is a directive to use 100% FA in the near future.

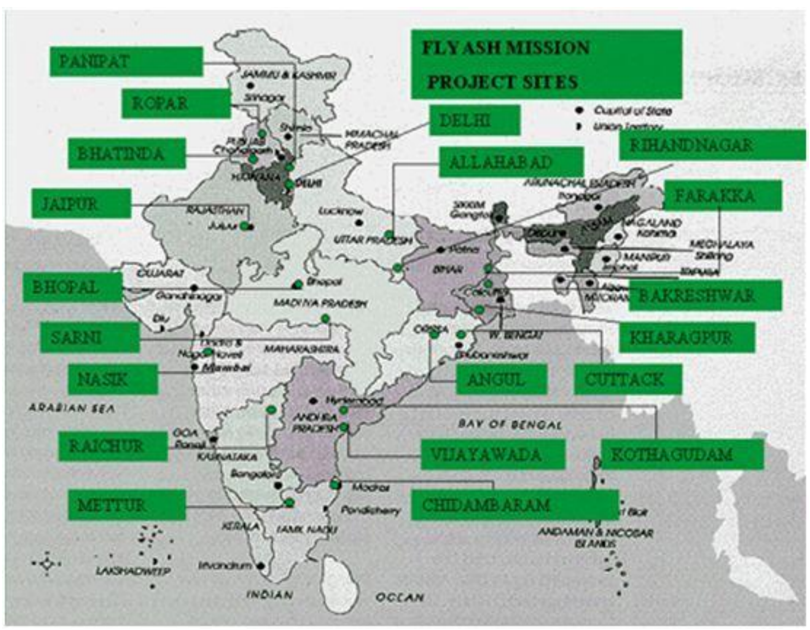


Figure 5: Fly ash mission project site (Source: *http://www.tifac.org.in*)

Appraisal of the Problems Associated with Fly Ash, Bottom Ash and Ash Pond of the Bktpp

Present coal consumption in thermal power plant in India results in adding of estimated 12.21 million tons fly ash in to ash collection system. Commonly both fly ash and bottom ash together are discharged as slurry to the ash pond/lagoon. Environmental pollution caused due to Fly ash water and overflow from the abandoned ash ponds by the coal based BkTPP has become the major sources of pollution affecting the general aesthetics of local environment in terms of air, water and soil pollution, land use, health hazards in particular and thus leads to geo-environmental degradation in general. This section assesses the nature and kind of problems arising out of FA generation, dumping and overflow of the BkTPP.

Air Pollution

As stated earlier FA emissions from a TPP unit have showed a wide range of composition and considered as a major source of air pollution. A 500 MW TPP releases 200 mt SO_2, 70 t NO_2. Concentration of most trace elements in coal ash is approximately 10 times of the concentration in the original coal. Emission of green house gases (CO_2, SO_2 etc.) is another cause of air pollution.

Like each power generating unit BkTPP has individual ESP as Air Pollution Control Device (APCD) and ETP (Effluent Treatment Plant). But, most of the cases these are not just sufficient for completely control the air pollution.

The West Bengal Pollution Control Board (WBPCB) has been accused BkTPP for causing an environmental pollution in August, 2012. PCB officials gave the responsibilities to BkTPP authorities to task for failing to curb the problem. The industry also failed miserably to meet the PM emission standard during sampling on 24.01.12 and 16.4.12 (table 6). The authority opined that they are trying to maintain the PM emission standard but it is difficult within a short period of time. Planning is formulated to enhance the efficiency of ESPs to meet the PM emission standard.

Table 6: PM Emission from the BkTPP

Sample Collected from	**Parameter**	**Results Obtained On (mg/Nm3)**		**Permissible Limit (mg/Nm3)**
		24.1.2012	**16.4.2012**	
Boiler Unit no. 1	Particulate Matter	589.4077	436.176	150
Boiler Unit no. 2		873.2993	606.2527	
Boiler Unit no. 3		512.715	207.9859	
Boiler 5 (Pass A)		634.5365	324.4142	
Boiler 5 (Pass B)		532.7801	338.9261	
Boiler 6 (Pass A)		154.9112	145.7088	
Boiler 6 (Pass B)		198.6935	198.2935	

Source: West Bengal Pollution Control Board, August, 2011

Hydro-Morphological Nuisances of the Chandrabhaga and Bakreshwar River

As stated earlier the treated effluent from ETP (physico-chemical type) is recycled to make ash slurry and the rest is discharged to the ash ponds.

As it has abandoned about a year ago, huge amount ash flown into the River Chandrabhaga and Bakreshwar River particularly during rainy season. Some amount has also discharged into the canals (Mayurakshi-Bakreshwar and Kopai-Bakreshwar Canal). The inhabitants of the surrounding area are facing severe water pollution problems due to this. They also alleged that the rivers are filled up with thick layer of ash. During our field survey in subsequent two phases in 2014-15 we have taken sample and investigated the status of the river Chandrabhaga in three sites namely Mallickpur, Noapara and Kanspai and one site namely Hatikra on river Bakreshwar.

The water sample taken at Mallikpur and Gangte on Chandrabhaga River and its laboratory analysis revealed that, there have the presence of heavy metals (As, Cd, Cu, Cr, Hg, Pb, Zn etc.) and organic matter (benzol, phenol etc.) as well (table 7). Discharges of these waste materials with variable chemical and mineralogical composition have harmful effects the nearby residents. We have talked to people of Mallikpur and Noapara villages residing near the Chandrabhaga River and most of them have said that during the last few months they have seen that, bathing on the river have caused skin diseases on several and the domestic animals have faced the problem of dihoria and death due to drinking of water from the river.

Few local people associated with fishing from the nearby river opined that, Pollution of their river have resulted decreasing of fish population and other aquatic organisms as well. During our last field survey we have also seen that, the FA dumping continued to cause surface water contamination even during recent heavy rainfall in June 2015.

Table 7: Physico-Chemical Characteristics of Water of Chandrabhaga River (Average of Site Mallikpur and Gangte)

Parameters	Results Obtained	Ideal /Permissible Limit
Transparency (cm)	12.1	60
pH	8.1	6.5-8.5
Salinity (‰)	0.6	0-30
Alkalinity (mg/litre as CaCO3)	92.7	20-100
Conductivity (micromho/cm)	1156.5	100-2000
Total Hardness	121.8	15-120
Ca-Hardness (mg/litre as $CaCO_3$)	76.6	10-80
Mg-Hardness(mg/litre as $CaCO_3$)	38.3	5-40
Grain Size (diameter in mm)	0.3-0.7	.001-2
Total Dissolved Solid (mg/litre)	655.5	500
Total Suspended Solid (mg/litre)	611.5	350
Free CO_2 (mg/litre)	2.7	< 2
D.O. (mg/litre)	7.6	5-10
C.O.D. (mg/litre)	86.4	<10
B.O.D. (mg/litre)	3.8	0.8-5.0
Total phosphate P (mg/litre)	2.5	<10
Chloride (mg/litre)	175	<250
Total kjeldahl N (mg/litre)	1.7	<0.5

Source: Data collected by the authors in October, 2014

Figure 6: Ash layer formation in the river bank (a & b) and river bed (c & d)

Continuous deposition of fly ash in the Chandrabhaga and Bakreshwar River results in excessive siltation of river bed. In the survey site Malikpur, Noapara, Gangte and Hatikra we have measured that the river bed have been elevated from 10 cm to as much as 0.8 metre. This type of continuous deposition of ash has changed the morphological character of the river and may encourage the potentiality of flooding. Recently after the National Green Tribunal Order on 27th of November 2014 (Vide: Ananda Bazar Patrika, 22 december 2014) the authority has taken attempt to remove the ash from the river bed. This attempt has made substantial change to the morphological character of the river and the problem continued as the removed as has dumped astride the river bank.

Soil and Water Pollution

Several studies on the present ground showed that wet disposal of this waste causes migration of metal into the soil (Jean, 1973). Since coal contains trace elements like arsenic, barium, beryllium, boron, cadmium, chromium, thallium, selenium, molybdenum and mercury, hence if ash overflow and disposal continues then rainwater can leach the metals and move them to aquifers as well. Leaching and movement of water through materials containing soluble components from the abandoned ash ponds at Raipur village significantly influenced the surrounding soil character (table 8). Usually where fly ash is dumped in bulk, it is usually stored wet rather than dry so that fugitive dust is minimized but in the present case most of the times this norms have not followed. As a result during dry period storms associated with Norwester (Kal-baisakhi) blowoff the ash upto about 5 kilometre diameter. As per the local people Muromath, Raipur, Metegram, Panuria village is affected much by this 'ash-storm'. Many shops have been shuted down at the Panuria-more due to this event. We have also taken sample from the nearby tube wells and it has found that the pH of the water samples range from 7.02 to 8.78 indicates alkaline nature of water. The amount of some elements like aluminum, iron, arsenic and manganese is also above than WHO guideline of safe drinking water.

Table 7: Physico-Chemical character of Soil samples taken near the ash pond of Raipur village

Parameters	Results Obtained	Permissible Limit
pH	8.1	6.5-8.5
Salinity (‰)	0.1	<0.5
Organic Carbon (%)	5.2	6-8
Soil Texture (%): Sand	23.2	23-52
Silt	42.7	28-50
Clay	34.1	7-27

Source: Laboratory analysis of the soil sample taken by the authors in October, 2014

We have also taken water sample just at the outlet of the ash pond of Raipur village to assess the quality of toxic elements that can contaminate the soil and ground water system. It has found that, the levels of Total Soluble Salt (mg/litre), pH and elements like Chromium, Copper, Zinc, Iron and Phosphate in greater than the Permissible Limit. These elements are infiltrates in to the soil and ground water through leaching from the ash pond. This can lead to increase of the incidence of skin and bone diseases.

Table 8: Physico-Chemical character of water samples taken near the ash pond of Raipur village

Parameters	Results Obtained	Permissible Limit
pH	8.6	6.5 to 8.5
Total Soluble Salt (mg/litre)	79	100
BOD (mg/litre)	24	20
COD (mg/litre)	29	80
Iron (mg/litre)	0.42	1
Copper (mg/litre)	0.14	1
Zinc (mg/litre)	0.7	1
Phosphate (mg/litre)	1.8	5
Chromium (mg/litre)	0.23	0.2

Source: Laboratory analysis of the soil sample taken by the authors in October, 2014

Problems of Human Health

Bhattacharjee *et al.*, (2013a, 2013b) have made substantial study on the elemental analysis, physical nature, and magnetization etc. present in the samples of Fly Ashes of BkTPP. They have found that, the samples are crystalline, and the major components are mullite and quartz. Quantitative magnetic characterizations of these fly ash samples of BkTPP are consisting of course, fine and ultrafine magnetic particulate materials. The presence of spherical particles has found and particle sizes lie within 0.29-4.14 μm. The elements found are O, Al, Si, C, Fe, K and Ti but S has not found hence there is no chance of sulfur-contamination of the environment due to air- borne/dumping of fly ash. Notably, no radioactive element in these samples has found. But different extent of magnetic eminence observed in these samples. This ultrafine particulate matter of the fly ashes is one of the potential air pollutants inhalation of which would cause several physiological disorders and other related health problems. All others heavy metals (Ni, Cd, Sb, As, Cr, Pb, etc.) usually found in fly ash are toxic in nature (Figure 7). Table 9 provides a list of diseases caused due to the presence of these toxic metals. As per the local people more than 200 people were affected due to fly ash exposure and 50-55% is affected with asthmatic disorder due to fly ash exposure in recent past.

Table 9: Diseases due to the presence of heavy metals in FA

Metal	Content (ppm)	Diseases
Nickel (Ni)	77.6	Respiratory problem, lung cancer
Cadmium (Cd)	3.4	Anaemia, hepatic disorder
Antimony (Sb)	4.5	Gastroenteritis
Arsenic (As)	43.4	Skin cancer, dermatitis
Chromium (Cr)	136	Cancer
Lead (Pb)	56	Anaemia

Source: Current Sc 1792 IENCE Vol. 100,No. 12, 25 June 2011, pp. 1793

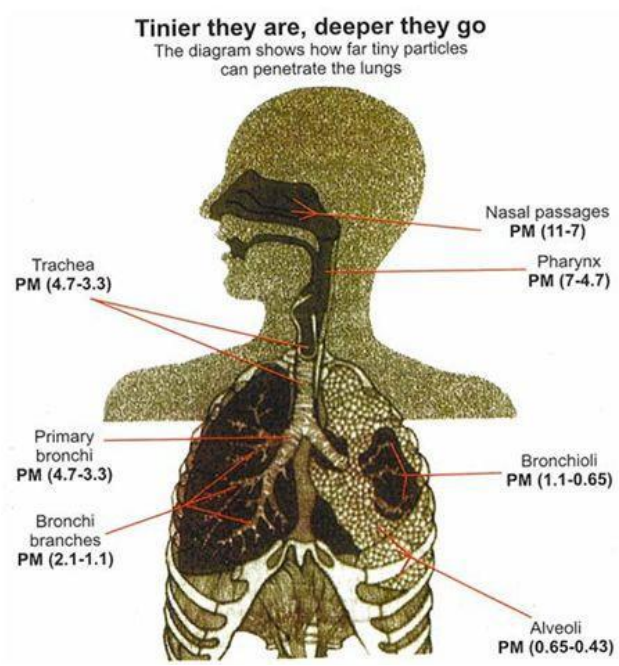


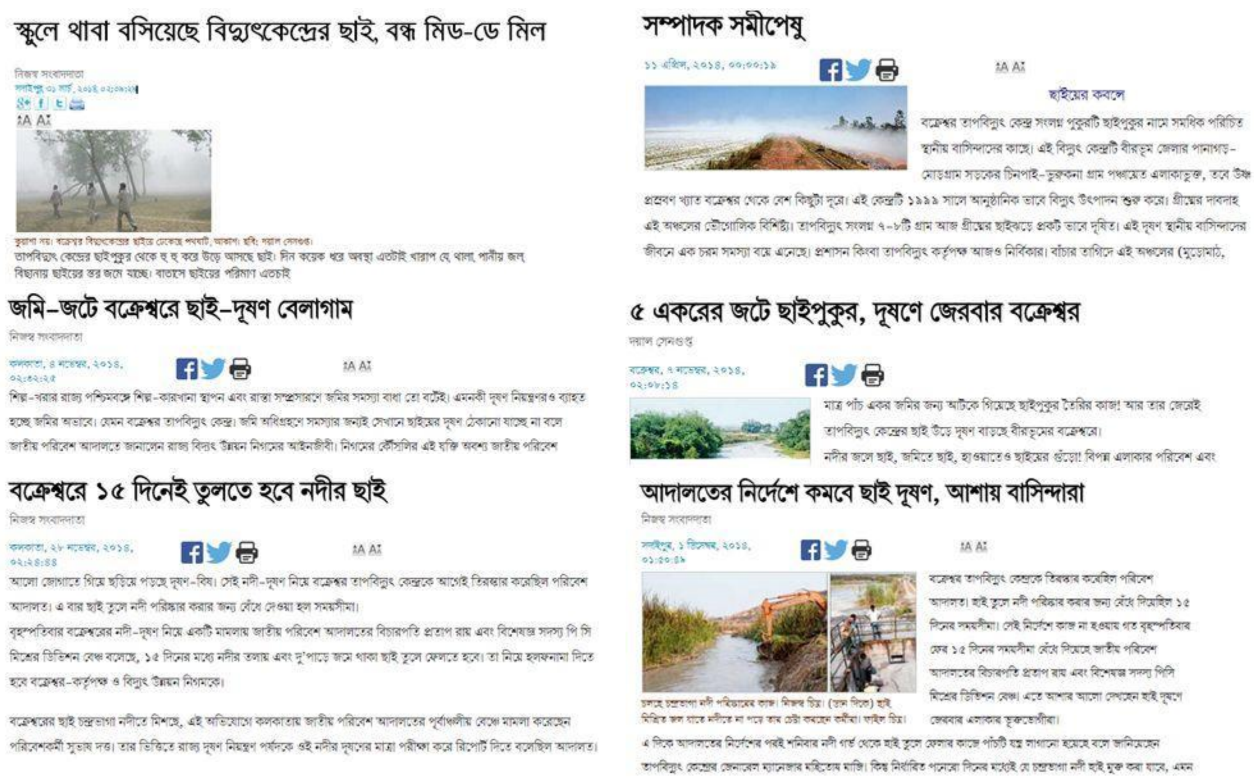
Figure 7: Penetration of tiny particles into the lungs
Source: Current Sc 1792 IENCE Vol. 100, No. 12, 25 June 2011, pp. 1792

Apart from the above we have talked to the local people and they have opined that ash disposal have caused decline of their agricultural productivity. Actually, the layer of the fly ash sometimes blocks the air circulation in the soil and saplings cannot have sufficient amount of nutrients and food and as a result the growth is thwarted.

Problems as Reported by Daily Popular News Papers

Some well known Daily news papers like Anandobazar, The Telegraph, The Times of India etc. have continuously reported voice of the local people regarding the problems. But no such attempts have taken by the authority. Seeing the problem environmental activist Subash Dutta has filed a petition in National Green Tribunal (NGT) and the court have directed the plant to clean up the rivers within 15 days, asked the central and state pollution control boards to assess the situation and told the PP to give a compliance report that must also mention that no further contamination would be done otherwise it will have to shut down operations. After that some attempts have taken by the authority but the problems have not aliviated and continue to cause problems to the local settlers. Here are few glimpses from the e-news papers.

Few Glimpses from Bengali Daily News Paper *Anandabazar Patrika*


স্কুলে থাবা বসিয়েছে বিদ্যুৎকেন্দ্রের ছাই, বন্ধ মিড-ডে মিল

সম্পাদক সমীপেষু

জমি-জটে বক্রেশ্বরে ছাই-দূষণ বেলাগাম

নিজস্ব সংবাদদাতা

শিল্প-খরার রাজ্য পশ্চিমবঙ্গে শিল্প-কারখানা স্থাপন এবং রাস্তা সম্প্রসারণে জমির সমস্যা বাধা তো বটেই। এমনকী দূষণ নিয়ন্ত্রণও ব্যাহত হচ্ছে জমির অভাবে। যেমন বক্রেশ্বর তাপবিদ্যুৎ কেন্দ্র। জমি অধিগ্রহণে সমস্যার জন্যই সেখানে ছাইয়ের দূষণ ঠেকানো যাচ্ছে না বলে জাতীয় পরিবেশ আদালতে জানালেন রাজ্য বিদ্যুৎ উন্নয়ন নিগমের আইনজীবী। নিগমের কৌঁসুলির এই যুক্তি অবশ্য জাতীয় পরিবেশ

৫ একরের জটে ছাইপুকুর, দূষণে জেরবার বক্রেশ্বর

মাত্র পাঁচ একর জমির জন্য আটকে গিয়েছে ছাইপুকুর তৈরির কাজ! আর তার জেরেই তাপবিদ্যুৎ কেন্দ্রের ছাই উড়ে দূষণ বাড়ছে বীরভূমের বক্রেশ্বরে।

নদীর জলে ছাই, জমিতে ছাই, হাওয়াতেও ছাইয়ের গুঁড়ো! বিপন্ন এলাকার পরিবেশ এবং

বক্রেশ্বরে ১৫ দিনেই তুলতে হবে নদীর ছাই

নিজস্ব সংবাদদাতা

কলকাতা, ২৮ নভেম্বর, ২০১৪, ০২:২৪:৪৪

আলো জোগাতে গিয়ে ছড়িয়ে পড়ছে দূষণ-বিষ। সেই নদী-দূষণ নিয়ে বক্রেশ্বর তাপবিদ্যুৎ কেন্দ্রকে আগেই তিরস্কার করেছিল পরিবেশ আদালত। এ বার ছাই তুলে নদী পরিষ্কার করার জন্য বেঁধে দেওয়া হল সময়সীমা।

বৃহস্পতিবার বক্রেশ্বরের নদী-দূষণ নিয়ে একটি মামলায় জাতীয় পরিবেশ আদালতের বিচারপতি প্রতাপ রায় এবং বিশেষজ্ঞ সদস্য পি সি মিশ্রের ডিভিশন বেঞ্চ বলেছে, ১৫ দিনের মধ্যে নদীর তলায় এবং দু'পাড়ে জমে থাকা ছাই তুলে ফেলতে হবে। তা নিয়ে হলফনামা দিতে হবে বক্রেশ্বর-কর্তৃপক্ষ ও বিদ্যুৎ উন্নয়ন নিগমকে।

বক্রেশ্বরের ছাই চন্দ্রভাগা নদীতে মিশছে, এই অভিযোগে কলকাতায় জাতীয় পরিবেশ আদালতের পূর্বাঞ্চলীয় বেঞ্চে মামলা করেছেন পরিবেশকর্মী সুভাষ দত্ত। তার ভিত্তিতে রাজ্য দূষণ নিয়ন্ত্রণ পর্ষদকে ওই নদীর দূষণের মাত্রা পরীক্ষা করে রিপোর্ট দিতে বলেছিল আদালত।

আদালতের নির্দেশে কমবে ছাই দূষণ, আশায় বাসিন্দারা

নিজস্ব সংবাদদাতা

(Source: http://www.anandabazar.com/)

Few glimpses from some English daily news paper *The Telegraph* and *The Times of India*


The Telegraph
calcutta, india

Edition | Friday, November 28, 2014 |

Front Page > Bengal > Story

Power plant told to clean rivers

JAYANTA BASU

Calcutta, Nov. 27: The eastern bench of the National Green Tribunal today directed the state-run Bakreswar thermal power plant to clean up the Chandrabhaga and Bakreswar rivers within 15 days or face "coercive measures".

The order was issued by the tribunal of Justice Pratap Chandra Roy, a former Calcutta High Court judge, and P.C. Gupta, a member, at its Rajarhat-New Town office in response to a petition by environmentalist Subhas Datta.


THE TIMES OF INDIA — Kolkata

RELATED KEYWORDS: National-Green-Tribunal | Bakreswar-Thermal-Power-Project

NGT warns Bakreswar Thermal Power Project may have to shut down

Jayanta Gupta

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KOLKATA: The Bakreswar Thermal Power Project (BkTPP), under the West Bengal Power Development Corporation Ltd (WBPDCL) has run into trouble with the National Green Tribunal (NGT) warning that it will have to shut down operations unless it stops dumping fly-ash into the Chandrabhaga River in Birbhum within 15 days. The bench of the NGT's Eastern Zone Bench comprising Justice Pratap Kumar Ray and Prof (Dr) P C Mishra also sought a status report from the chief secretary within the next 15 days on whether land is available for an additional fly ash pond.

(Source: http://www.telegraphindia.com/ & http://timesofindia.indiatimes.com/)

Fly-Ash Management/Utilization Options

Ash generated from volcanoes was used extensively in the construction of Roman structures. The colosseum (constructed in AD 100) is a classic example constructed using volcanic ash (Senapati, 2011). During the last 30 years, extensive research has been carried out to utilize the FA in various sectors and many have considered FA as a by-product rather than waste (Matani, 1998) Currently FA, an industrial by-product from TPPs has proven suitability for variety of applications as admixture in cement/concrete/mortar, lime pozzolana mixture (bricks/blocks) etc. Cement and Concrete Industry accounts for 50% FA utilization and other areas of application are Low lying area fill (17%), Roads & Embankments (15%), Dyke Raising (4%), Brick manufacturing (2%), agriculture etc. (Alami and Akhtar, 2011). Broadly, FA utilization programmes can be viewed from two angles, i.e. mitigating environmental effects and addressing disposal problems (low value–high volume utilization) (Senapati, 2011). Following are some of the potential areas of use of fly ash-

Fly Ash Bricks

Fly Ash bricks are made of fly ash, lime, gypsum cement and sand. These can be extensively used in all building constructional activities similar to that of common burnt clay bricks (Parul, 2004). The fly ash bricks are comparatively lighter in weight and stronger than common clay bricks (Kumar *et al.*, 2014).

Fly Ash in Manufacture of Cement

Fly ash has a high amount of silica and alumina in reactive form. These reactive elements complement the hydration chemistry of cement (Murahari and Rao, 2013). As per the specifications of Bureau of Indian Standards fly ash upto 35% can be used in manufacture of cement, while worldwide there are examples of countries that permit upto 55% utilisation of fly ash in cement production. (Kumar *et al.*, 1999).

Fly Ash as Fertilizer

FA serves as a good fertilizer. It provides the uptake of vital nutrients/minerals (Ca, Mg, Fe, Zn, Mo, S and Se) to crops and vegetation, and can be considered as a potential growth improver (Scott and Mackiewicz, 2005). Elseewi *et al.*, (1981); Elseewi and Page (1984); Chang *et al.*, (1977) and Page *et al.*, (2005) reported that addition of fly ash improves soil pH and simultaneously adds essential plant nutrients to the soil. The improvement in yield has been recorded with fly ash doses varying from 20 tone/hectare to 100 tone/hectare. On an average 20-30% yield increase has been observed (Ling, 2008).

Role of Bio-Amelioration of FA on Soil

Recent investigations suggest that FA can find better application if combined with organic amendments such as cow manure, press mud, paper factory sludge, farmyard manure, sewage sludge, crop residues and organic compost for improvement of degraded/marginal soil (Tripathi *et al.*, 2000). Few beneficial combined effects of FA and organic matter on soil have been found such as reduced heavy- metal availability and killing pathogens in the sludge (Wong, 1995), improved soils through higher nutrient concentrations, better texture, lower bulk density, higher porosity and mass moisture content and higher content of fine-grained minerals (Shen *et al.*, 2008); enhanced the biological activity in the soil (Kumpiene *et al.*, 2007); reduced the leaching of major nutrients (Sajwan *et al.*, 2003) and also helpfull for vegetation (Rautaray *et al.*, 2003). So amendment with FA will enhance agricultural sector for crop production. Further, organic amendment application will provided anchorage and growth of the plant on a FA dumping site (Pandey and Singh, 2010).

Fly Ash-Based Ceramics

FA, when mixed with traditional raw materials, has the necessary requirements to be used as a raw material for production of ceramic tiles (Zimmer and Bergmann, 2007). The studies of Barbieri *et al.*, (1999) and Leroy *et al.*, (2001) are examples of the glass–ceramics obtained using FA. Moreover ceramics produced from FA are thermally and mechanically stable and exhibit good chemical durability (Palomo *et al.*, 1999).

Fly Ash as a Raw Material to Construct Fills, Roads, Embankments and Dams

Fly ash can be used as a raw material to construct fills, roads and embankments (DiGioia *et al.*, 1972 Jenny *et al.*, 2012; Martin *et al.*, 1989). Use of FA in the construction of structural fills/embankments range from small fills for road shoulders to large fills for interstate highway embankments (Pekrioglu *et* *al.*, 2003). National Highway Authority of India (NHAI) is currently using 60 lakh m^3 of Fly Ash and proposed to use another 67 lakh m^3 in future projects. (Mukherjee and Vesmawala, 2013). Another application of FA is in Roller Compacted Concrete (RCC) dams. RCC have been used in the Ghatghar Dam Project in India (Kumar *et al.*, 1999).

Other areas of Fly ash application

The un-burnt carbon of the fly ash serves as *fuel* for burning. Approximately 20-30% energy can be reduced by adding25-40% fly ash (www.wealthywaste.com/fly-ash-utilization-in-india). BMTPC in collaboration with regional research laboratory, Bhopal have developed a technology to use FA based *polymer composite* (Alam and Akhtar, 2011) as wood substitute. *Distemper* manufactured with fly ash as a replacement for white cement has been used in several buildings in Neyveli, Tamil Nadu and the cost of production will only be 50% that of commercial distemper (Senapati, 2011).

Economic Benefits from Fly Ash Management

With the recent advancements in technology FA is now recognized as a valuable substance which is useful for different applications and is categorized as resource material instead of waste material. Even though numerous steps have taken by the Govt. of India like, updating existing standards, enhance policies for effective utilization of fly ash. Ministry of Environment and forest (MOEF) issued a regulation taking it mandatory for both existing and new coal based TPPs to utilize 100% of FA produced within a stipulated time frame (Lokshappa and Dikshit, 2011). However, the FA utilization rate is only 38% (30). There is a great need to implement the order for utilization of FA by developing different above mentioned by-products in a massive scale. Several authors like Dwivedi and Jain (2014) (vide table 10), David (2009) have enlighten that, is great potentiality to get economic benefits from FA utilization.

Table 10: Economic Benefits of Fly Ash Management

Sl No	Utilization	Fly Ash Consumption (Million tonnes/year)	Savings per year (rupees in crore)
1	Cements	25	2500
2	Roads and Embankments	15-20	100
3	Minefills	15-20	150
4	Bricks	5	20
5	Agriculture	200	3000
Total			5770 around 1.2billion US$

Source: Dwivedi and Jain (2014)

CONCLUSION

It has been recognized worldwide that the utilization of an enormous amount of fossil fuels has created various adverse effects on the environment, including acid rain and global warming. An increase in the average global temperature of approximately 0.56 K has been measured over the past century (global warming). Gases with three or more atoms that have higher heat capacities than those of O_2 and N_2 cause the greenhouse effect.

Carbon dioxide (CO_2) is a main greenhouse gas associated with global climate change. The disposal, management and proper utilization of waste products has become a concern for the scientists and environmentalists. Proper management of solid-waste fly ash from thermal power plants is necessary to safeguard our environment.

Because of high cost involved in road transportation for the dumping of fly ash, it is advisable to explore all its possible applications. The Pradhan Mantri Gram Sarak Yojana would be a successful and economically viable project with the utilization of fly ash in road construction in remote and rural areas. Every village in India will have concrete roads and large amounts of fly ash can be consumed in this process. Concentrated efforts are needed to utilize fly ash in the manufacture of building bricks, cement and ceramics, and mitigate the unemployment problem as well.

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