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Research Article

Assessment of Physicochemical Properties of Flash from TISCO Power Plant, Jamadoba, Jharia Coalfields, Jharkhand, India

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Abstract: This paper deals with some selected physicochemical properties of fly ash collected from a TISCO power plant at Jamadoba, Dhanbad, Jharkhand, India. The physical properties such as bulk density, moisture content, specific gravity, porosity water holding capacity and grain size distribution (sand, silt, clay) were measured, being 0.94gm/cc, 0.73%, 1.84%, 60.25% 76.55% and sand 63.3%, silt 32.6%, clay 2.6% respectively. The chemical properties included in this study were pH, electrical conductivity, organic carbon, cation exchange capacity and available nitrogen. The aim of the present study is to assess the suitability of fly ash of TISCO power plant at vegetation purposes in the low lying areas or degraded land. These physicochemical properties are of also great importance in the backfilling of opencast mines, plantation and reclamation of the abandoned opencast project.

Keywords: Coal, Fly ash, Bulk density, Organic carbon, Cation exchange capacity.

1. Introduction

Energy production has been increasing at a rapid rate due to rapid industrialization. There has been an impressive increase in the power generation in the country from a low capacity to high capacity. The power is generated from different sources like thermal power, nuclear power and power from fossil fuel and other nonconventional resources. Energy generation through thermal power plants is very normal nowadays. These power plants produce huge amount of fly ash all over the world and create problems for the several components of the environment (Srivastava *et al.*, 2007).

India generates more than 100 Mt of coal ash from it's existing 82 or more thermal power stations. This figure is likely to reach 175 Mt by 2012. More than 50% of the energy required in our country is met by coal based thermal power stations (Mishra, 2004). The power coals used in India have in general low grade high ash content coal of about 35% - 45% and are mostly mined by opencast mining methods. Most of the thermal power plant stations in our country are situated in and around coal mining areas. The use of coal for the power generation results in huge amounts of coal ash produced. These ashes are generally disposed of in the form of slurry to nearby ash ponds or bare lands. The emitted fly ash is spread in and around the different sites and affects the physicochemical parameters of soil and water. As reported in the United State Geological Survey (USGS), 2002, the utilization of coal ash was 13% in 2000 and the rest of the amount finds its way in the ash ponds. Kumar *et al.*, 2003 in their study reported utilization of coal ash was at 41%. Fly ash has a number of advantages for use in coal mining, such as favorable geomechanical properties, a capacity for placement in flowable paste or slurry form and availability in large quantities from power stations near many mine sites.

The physicochemical properties of fly ash including, mineralogical, morphological and radioactive properties are influenced by coal source and quality, combustion process, extent of weathering, particle size, and age of the ash (Adriano *et al.*, 1980). Indian fly ash is rich in available major and secondary nutrients, where weathered fly ash has more organic carbon (Khandakar *et al.*, 1993), concentrations of Zn, Cu, Ni, Cr and V are higher in lignite fly ash than coal fly ash

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(Sadasivan and Negi, 1991). Fly ash from thermal power station varies in chemical composition not only from plant to plant but also within the same plant (Carlson and Adriano, 1993). In India, fly ash is generally alkaline due to low sulphur content of coal and the presence of hydroxides and carbonates of calcium and magnesium (Aitken and Bess, 1985). The major chemical composition of fly ash is given in Table 1 (Rao, 1999).

The concept of fly ash applications in agriculture and forestry because of its favorable physicochemical properties and to its containing essential nutrients (Page *et al*., 1982). Many physical and chemical parameters of fly ash may benefit plant growth and can improve agronomic properties of the soil (Change *et al*., 1977). A large number of forestry species such as *Acacia, Eucalyptus, Dalbergia* and *Casuarina* have shown improvement in growth and biomass production in fly ash amended mine dumps (Paul, 2001). Fly ash application to acidic soils in coal mine areas increased the yields of different vegetation. Fly ash alone and in combination with press mud showed favorable conditions for growth of tree species. Plant growth on fly ash-amended soils is most often limited by nutrient deficiencies, excess soluble salts and phytotoxic B levels (Adriano *et al*., 1980). Natural vegetation in fly ash dumps sites is given in Table 2.

Table 1. Chemical composition of Indian fly ash.

S. No.	Constituents	Percentage
1	Silica	49-67
2	Alumina	16-29
3	Iron oxide	4-10
4	Calcium oxide	1-4
5	Magnesium oxide	0.2-2
6	Sulphur	0.1-2
7	Loss of ignition	0.4-0.6
8	Surface area (sq.m/N)	2300-5700

Table 2. Natural vegetation in the fly ash dump sites.

S. No.	Scientific name	Local name	Family	Nature of the species
1	***Ziziphus jujuba***	Ber	Rhamnaceae	Small shrubs
2	***Lantana camara***	Chotra	Verbenaceae	Perennial weeds
3	***Cyperus rotundus***	Mutha	Cyperaceae	Small herbs
4	***Cynodon dactylon***	Durba grass	Gramineae	Grazed by cattle
5	***Calotropis***	Madar	Asclepiadaceae	Shrub, never grazed by cattle
6	***Argemone mexicana***	Shialkanta	Papaveraceae	Small piny herb
7	***Amaranthus***	Amaranth	Amaranthaceae	Soft herbs
8	***Ageratum***	Dochunty	Compositae	Soft herbaceous weeds
9	***Blumea***	--	Compositae	Soft herbaceous weeds
10	***Croton***	Bantulsi	Euphorbiaceae	Weeds in waste places
11	***Ipomoea***	--	Convolvulaceae	Common in waste places
12	***Solanum***	Kantakari	Solanaceae	Spiny herbs

(Source: Maiti *et al*., 2005)

2. Materials and Methods

2.1 Study area

In the present study, Tata Iron & Steel Company Limited (TISCO) power plant (10 MW capacity), Jamadoba, Jharia Coalfields (JCF) has been selected for carrying out the research work. The Tata Iron & Steel Company Limited consists of six collieries in the Jharia division, located in the Dhanbad district of Jharkhand, which is about 180 km away from Jamshedpur city, and 12 km away from the Dhanbad district of Jharkhand. These collieries are split into two group Jamadoba group and Sijua group. Jamadoba group is chosen for study. Jamadoba group has a lease area of 5,508 acres and a production capacity of 1.5 million tonnes of prime coking coal (Paul, 2001). The map of the study area is given in Fig. 1 and a brief detail of TISCO power plant is shown in Table 3.

Beneficiation of coal during last 40 years in Tata Iron & Steel Company Limited (Jharia group of collieries) has resulted in accumulation of over 1.0 million tonnes of washery rejects above ground, disfiguring the landscape, land use patterns and polluting the soil, water and air. This washery rejects has been used in the generation of electricity. The washery rejects having about 64% ash and 26.67% carbon used as fuel in the plant (Pandey, 1998).

Table 3. Brief details of the fly ash production in TISCO power plant, Jamadoba, JCF (Paul, 2001).

S. No	Different aspects	Values
1	Ash production	400T/DAY
2	Fly ash: bottom ash ratio	80:20
3	Fly ash production	320T/DAY
4	Bottom ash production	80T/DAY
5	Fly ash used for stowing	120T/DAY
6	Unutilised fly ash	200T/DAY

2.2 Fly ash

Fly ash is a very fine powder and tends to travel far in the air. It is the residue of combustion of coal and comprises a wide range of inorganic particles, low to medium bulk density, high surface area and sandy silt to silt loam texture (Kumar, 2003). Fly ash occurs as very fine spherical particles, having a diameter in the range from a few microns to 100 microns. Fly ash is Ferro-aluminosilicate mineral with the major elements like Si, Al and Fe together with significant amounts of Ca, Mg, K, P and S (Aswar, 2001). Fly ash may often contain trace amounts of some heavy toxic metals like Molybdenum, Mercury, Selenium and Cadmium etc. Some metals enriched in fly ash such as Cd, Cr, Ni, Pb and Zn other have intermediately enriched like Al, Fe, Mn, Mg and Si (Adriano *et al*., 1980). A simple view of fly ash of TISCO power plants is shown in Fig. 2.

2.3 Types of fly ash

The ash generated in thermal power plants is of two types: Fly ash & Bottom ash. Fly ash is the chemically reactive and finer in texture (0-100 microns). Bottom ash is the heavy and coarse fraction (>100 microns). Generally fly ash mostly consists of aluminum oxide, iron oxide and silicon oxide which is present in two forms: amorphous which is rounded and smooth, and crystalline, which is sharp, pointed. Fly ash is generally heterogeneous, consisting of a mixture of glassy particles with various crystalline identifiable crystalline phases such as quartz, mullite and various oxides.

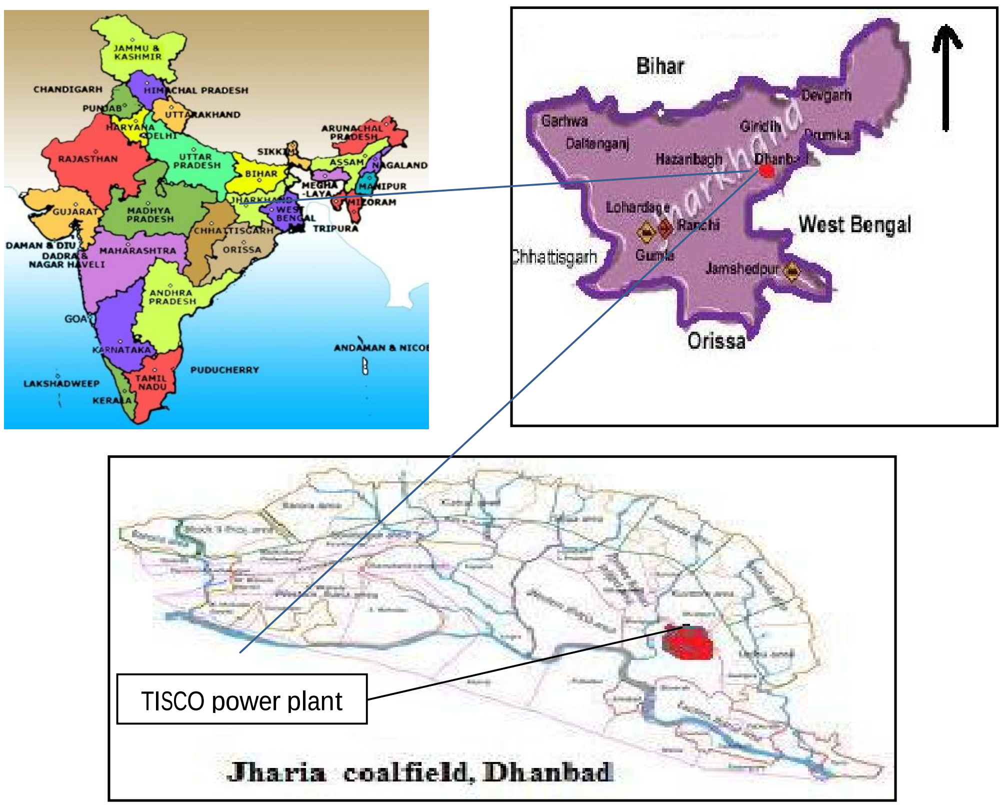

Fig. 1. Location of study area, Jamadoba, JCF (not to scale).

Fig. 2. Simple view of fly ash, TISCO power plant, Jamadoba.

2.4 Classification of fly ash

According to ASTM C 618, two major classes of fly ash are classified on the basis of their chemical composition resulting from the type of coal burned in thermal power plants. It can be classified as Class F produced from burning of bituminous and anthracite coal. It has CaO less than 10%. Class C is generally produced from burning of sub-bituminous or lignite coal. It has CaO greater than 10%.

2.5 Collection of samples

Fly ash samples from the TISCO power plant, Jamadoba, were collected from the waste disposal site divided into 25 by 50 m grid, then about 0.5 kg samples was taken at the corner and middle of the grid at a depth of 10cm, all of the samples are mixed properly to represent one single sample and subsequently used for physical and chemical characterization by standard method. The fly ash samples were air dried and sieved through a 2mm mesh size. The samples were analyzed for bulk density, moisture content, specific gravity, porosity, water holding capacity, grain size distribution, ph, electrical conductivity, organic carbon, cation exchange capacity and available nitrogen. Samples were subjected to analysis within 12 hours of collection in the month of summer 2009. These analyzed fly ash data were not compared with any local soil data.

3. Methodology

Bulk density was determined by oven dried weight of a known volume of the fly ash sample was taken and mass per unit volume was calculated. Moisture content also called the Water content is defined as the ratio of the weight of water to the weight of solids in a given mass of the sample. The moisture content was determined by gravimetric method and expressed as a percentage. Specific gravity is defined as the ratio of the weight of a given volume of fly ash solids at a given temperature to the weight of an equal volume of distilled water at that temperature. The specific gravity of the ash sample was determined using a specific gravity bottle, having a 25ml as per the guidelines provided by the ASTM D 284. Porosity (n) is the ratio of the volume of voids to the total volume of the given fly ash mass. Porosity was calculated by using the following relationship:

$$\text{Porosity} = \frac{1 - \text{Bulk density}}{\text{Specific gravity G}} \text{ X } 100$$

Water holding capacity of the ash sample was determined using a keen box having perforated bottom as (Fig. 3). Grain size distribution was determined by shaker using different sizes of sieves. pH was determined in fly ash /water (1:2.5) suspension with a pH meter. Cyber scans 200 conductivity meter was used for the measurement of conductivity. Organic carbon was estimated by the rapid dichromate oxidation method (Walkley and Black, 1934). Cation exchange capacity was determined by extraction with 1N sodium acetate, followed by washing with 95% ethanol and leached with 1N ammonium acetate solution and measured by a flame photometer (Jackson, 1973). Available nitrogen was determined by the alkaline potassium permanganate method (Subbaih and Asija, 1956).

Fig. 3. Circular keen box for water holding capacity of fly ash.

4. Results and Discussions

A result of physical, and chemical parameters conducted in the laboratory on the fly ash sample is given in Table 4 and Table 5 respectively. A very brief description of discussions is presented in the following paragraphs.

Table 4. Physical properties of fly ash, TISCO, Jamadoba.

S. No	Physical Parameters	Unit	Values
1	Bulk density	gm/cc	0.94
2	Moisture content	%	0.73
3	Specific gravity	--	1.84
4	Porosity	%	60.25
5	Water holding capacity	%	76.55
6	Grain size distribution	%	
	Sand		63.3
	Silt		32.6
	Clay		2.6

Table 5. Chemical properties of fly ash, TISCO, Jamadoba.

S. No	Chemical Parameters	Units	Values
1	pH	-	9.63
2	Electrical conductivity	mmhos /cm	0.24
3	Organic carbon	%	0.16
4	Cation exchange capacity	meq/100gm	2.65
5	Available nitrogen	kg/ha	1.4

Bulk density is a measure of the weight of the soil per unit volume as expressed in gm/cc, usually given an oven dry basis. Variation in bulk density is attributable to the relative proportion and specific gravity of solid organic, inorganic particles and the porosity of the fly ash. Increase in bulk density of the fly ash sample usually indicates a poorer environment for root growth, reduced aeration and reduced water infiltration (Kumar *et al*., 1998). During this study, bulk density of the TISCO power plant was found as low as 0.94gm/cc. It has been found that fly ash with low bulk density is generally more suitable for agriculture. Rai *et al*., 2010 have pointed out that low bulk density can have a potential as a fill material or stowing purposes in open-cast as well as underground mines respectively. It has been observed that the optimum bulk density in improving the soil porosity, the nature, workability of the soil, the root penetration and the moisture retention capacity of the soil.

Moisture content is a measure of the water content in the fly ash sample. The moisture content of the TISCO power plant was recorded very low 0.73% indicating the chances of dust emission problems in the summer season and not suitable for vegetation purposes. It can be mixed with local soil then used in vegetation purposes. Specific gravity generally depends on the mineral and inorganic materials that are present in the fly ash sample. Mineral with a specific gravity below 2 is considered light, between 2 and 4.5 averages, greater than 4.5 heavy. During the present study, specific gravity of the fly ash sample was measured at 1.84 and it is too low for backfilled purposes. This may be due to the presence of unburnt carbon and cenospheres in the ash sample (Mishra and Singh, 2007). It can be used in amending paints and as a soil amendment. It can be also used in the agriculture and backfilling purposes. Porosity (%) generally influences physical properties such as water holding capacity and aggregation of the ash sample. It has been suggested by many researchers that higher porosity indicates a lesser density which means a lesser compressive strength in the landfill areas. In the present study, porosity of the fly ash sample was found to 60.25%. Such fly ash can be used for wasteland reclamation backfilling of open-cast mines or making desired amendments in soil type materials. The water holding capacity is an index of a number of physical properties of soil or fly ash. Good water holding capacity shows the good physical condition of fly ash.

The application of fly ash has been found to increase the available water content of loamy sand soil by 120% and of a sandy soil by 67% (PAU, 1993). RRL Bhopal reported that application of fly ash increases the porosity of black cotton soil and decreases the porosity of sandy soils and thereby saves irrigation water, around by 26% and 30% respectively.

Chang *et al*., (1977) reported that as an addition of 8% by weight fly ash increased the water holding capacity of soil. They also reported that soil hydraulic conductivity improved at lower rates of fly ash application but deteriorated when the rate of fly ash amendment exceeded 20% in calcareous soils and 10% in acidic soils. This improvement in water holding capacity is beneficial to the plants, especially under rain fed agriculture. During this study, water holding capacity of the fly ash sample was measured at 76.55% indicating more pores present in the sample and beneficial for plantation and vegetation purposes. It means ash can improve the soil property of holding water. Mishra and Singh, 2007 reported that the high value of porosity is one of the reasons for higher values of water holding capacity In general; soils are comprised primarily of coarse sand-sized particles, whereas most of the fly ashes are primarily fine sand and silt-sized particles. The data obtained from the grain size distribution is used in the design of filters for earth dams to determine suitability of ash or soil for road construction, railway embankment, backfilling of open-cast areas and airfield (Dewangan *et al.*, 2010). During this study, the values obtained from Table 3, sand was found at 63.3%, silt was found at 32.6%, and clay was found as 2.6% in the sample. It has been observed that the ash sample belongs to a sandy textural class.

pH of the fly ash is directly related to the availability of macro and micronutrients. pH indicates that whether fly ash is acidic or alkaline in nature. Based on the pH, fly ash has been classified into 3 categories, namely;

a) Slightly alkaline 6.5 – 7.5.
b) Moderately alkaline 7.5-8.5.
c) Highly alkaline >8.5.

The neutral pH may be generally used in amending both acidic and alkali soils (Kumar *et al*., 1998). In India, fly ash is generally highly alkaline due to low sulfur content of coal and the presence of hydroxides and carbonates of calcium and magnesium (Maiti *et al*., 2005). This property of fly ash can be exploited to neutralize acidic soils (Elseewi *et al.*, 1978; Phung *et al.*, 1978). Jastrow *et al.*, (1979) reported that while the addition of fly ash improves soil pH, on one hand, it simultaneously adds essential plant nutrients to the soil on the other hand. Page *et al.*, (1979) observed that experiments with calcareous and acidic soils revealed that the fly ash addition increased the pH of the former from 8.0 to 10.8 and that of the latter from 5.4 to 9.9. It has also been reported that the use of excessive quantities of fly ash to alter pH can cause an increase in soil salinity especially with un-weathered fly ash (Sharma *et al.*, 1989). In the present study, pH of the fly ash sample was measured as 9.63; it indicates that fly ash was alkaline in nature and can be used for reclamation of acidic soil in the nearby coal mining area of Jharia coalfields. The soluble salt content of fly ash is measured by an assessment of electrical conductivity (EC) of water extract. Electrical conductivity indicates the availability of different ions in the fly ash sample. In the present study, electrical conductivity was measured at 0.24mmhos/cm in the sample. Thus it was found that this fly ash could be used as an additive/amendment material in agriculture applications. Organic carbon is the generic name for carbon held within the fly ash, primarily in association with its organic content. Soil carbon is the largest terrestrial pool of carbon. Organic carbon was measured at 0.16% which is lower than required 0.5% to 0.7% for plant growth. Cation exchange capacity (CEC) is the capacity of a soil for ion exchange of cations between the soil and the soil solution. CEC is used as a measure of fertility, nutrient retention capacity and the capacity to protect groundwater from cation contamination. The quantity of positively charged ions (cations) that a clay mineral or similar material can accommodate on its negatively charged surface is expressed as Milli-ion equivalent per 100 g, or more commonly as milliequivalent (meq) per 100 g or cmol/kg. In the present study, cation exchange capacity of the fly ash sample was observed as 2.65 meq/100gm. In the fly ash sample values of CEC were favorable for normal plant growth. Available nitrogen is easily mineralizable nitrogen in soils.

In soil, nitrogen presents as organic nitrogen, ammoniacal nitrogen, nitrate and nitrite nitrogen. Major portions of soil nitrogen exist in combination with the organic matter. Only a negligible fraction of soil – N, which is inorganic in form is available to plants. Therefore, organic – N mineralized to inorganic form is then available to plants (Maiti, 2003). In the present study, available nitrogen was found as 1.4 kg/ha in the fly ash samples. It is sufficient for vegetation purposes or plantation purposes. An almost similar observation was made by Paul, 2001 in the fly ash of TISCO power plant at Jamadoba, Jharia coalfields.

5. Conclusion

On the basis of the above results and discussions of the various properties of fly ash the following conclusion is drawn in brief:

Fly ash of TISCO power plant has been found to be suitable for bulk utilization for mine backfilling and soil amendment for plantation, vegetation and in bioreclamation applications. Some studies conducted by many scientists (CIMFR, Dhanbad) in most part of the Jharia Coalfields has shown that fly ash of TISCO power plant has the potential of improving soil quality parameters and lead to higher fertility in nearby areas. This waste material (fly ash) could be used as an amendment material in agricultural applications and backfilled material in abandoned open-cast mines. The above result indicates that fly ash of TISCO power plant has the potential to support moderate greenery around the mining area and behaves as a good backfilled material.

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References

[1]. Srivastava, R., Sharma, S.K. and Sethi, R. (**2007**). The utilization of fly ash: Its scope in India. *MINETECH*, Volume 28, No 4, 9 – 14.

[2]. Mishra, U.C. (**2004**). Environmental impact of coal industry and thermal power plants in India. *Journal of Environmental Radioactivity*, 72: (1-2) 35-40.

[3]. USGS (**2002).** Mineral Industry Surveys: Coal Combustion Products.

[4]. Kumar, V., Kumar, A. & Mathur, M. (**2003).** Management of fly ash in India: A Perspective. Proceedings of Third International Conference on Fly Ash Utilization & Disposal, New Delhi.1:1-18.

[5]. Adriano, D.C., Page, A.L., Eleewi, A.A., Chang, A.C. and Straugham, I. (**1980**). Utilization and disposal of fly ash and coal residues on soil, turf grass and groundwater quality. *Water, Air, Soil Pollution*, 139: 365-385.

[6]. Khandkar, U.R., Gangwar, M.S., Srivastava, P.C. & Singh, M. (**1993).** Edaphological characteristics of unweathered and weathered fly ashes from Gondwana and Lignite coal. *Environment Pollution*, 79(3):297-302.

[7]. Sadasivan, S. and Negi, B.S. (**1991**). Chemical characteristics of fly ash from coal fired thermal power plants in India. *Science of the Total Environment*, 103(2-3): 151-158.

[8]. Carlson, C.L. and Adraino, D.C. (**1993**). Environmental impacts of coal combustion residues. *J. of Env. Quality*, 22: 227 -247.

[9]. Aitken, R.L. and Bell, L.C. (**1985**). Plant uptake and Phytotoxicity of boron in Australian fly ash. *Plant and Soil*, 84: 245 -257.

[10]. Rao, A.V. (**1999**). Characteristics of fly ash & its application **-** A Brief Review, Proceedings of the National Seminar on Fly ash Characteristics & its Geotechnical Applications. IISC, Bangalore, India.

[11]. Page, A.L., Miller, R.H. & Kewy, D.R. (**1982**). American Soc. of Agronomy, Monogram, Vol. 2, 9.

[12]. Chang, A.C., Lund, L.J., Page, A.L. & Warneke, J.E. (**1977**). Physical properties of fly ash amended soils. *Journal of Env. Quality*, 6: 267-270.

[13]. Pandey, M. (**1998).** Environmental management in a fluidized bed thermal power station in JCF, Proc. of the Seventh National Symposium on Environment, ISM, Dhanbad, Jharkhand. 234 - 236.

[14]. Paul, B. (**2001**). Investigation into the utilization of fly ash in the economic management of mining

degraded land with special reference to the TISCO leasehold area in Jharia Coalfield, Ph.D. Thesis, Indian School of Mines, Dhanbad, India.

[15]. Maiti, S.K., Singh, G. and Srivastava, S.B. (**2005**). Study of the possibility of utilizing fly ash for backfilling and reclamation of opencast mines: Plot and field scale study with Chandrapura fly ash. FAUP, TIFAC, DST, New Delhi, India.

[16]. Aswar, W.R. (**2001**). Fly ash disposal and utilization: National scenario, International Conference on Fly ash Disposal and Utilization, New Delhi, India. 80 -86.

[17]. Walkley, A. & Black, C.A. (**1934).** An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci*., 37:29-38.

[18]. Jackson, M.L. (**1973**). Soil chemical analysis, Prentice Hall of India Pvt. Ltd. New Delhi, India.

[19]. Subbiah, B.V. & Asija G.L. (**1956).** A rapid procedure for estimation of available nitrogen in soils. *Current Science*, 25: 259 -260.

[20]. Kumar, N., Loveson, V.J. & Singh, T.N. (**1998).** Effect of the bulk density on the growth and biomass of the selected grasses over mine dumps around coal mining areas, Proc. of the Seventh National Symposium on Environment, ISM, Dhanbad, Jharkhand. 182-185

[21]. Rai, A.K., Paul, B. and Singh, G. (**2010**). Physicochemical properties of fly ash and soil from TISCO power plant, Jharia coalfield, Jharkhand, India. *Journal of Report and Opinion*, 2(10): 50-57.

[22]. Mishra, S. & Singh, G**. (2007)**. Comprehensive characterization of and leaching studies of CCRs from Chandrapura Thermal Power Station, Jharkhand. First International Conference on MSECCMI, New Delhi, India. 823 - 827.

[23]. Punjab Agriculture University (**1993)**. Utilization of fly ash in agriculture and re-vegetation of dumping sites. Annual Progress Report.

[24]. Dewangan, P., Pradhan, M., Kishore, N. (**2010)**. Utilization of fly ash as a structural fill material for safe and sustainable development: Need of the Hour. *Indian Min. Eng. J. Mine Tech*, 10: 134 - 139.

[25]. Elseewi, A.A., Binghman, F.T. and Page, A.L. (**1978)**. Growth and mineral composition of lettuce and swiss chard grown on fly ash amended soils, in Environmental Chemistry and Cycling processes, Conf. 760429, Adriano, D.C. and Brisbin, I.L., Eds., U.S. Department of Commerce.

[26]. Jastrow, J.D., Zimmerman, C.A., Dvorak, A.J. and Hinchman, R.R. (**1979).** Comparison of lime and fly ash as amendments to acidic coal mine refuse: Growth Responses and Trace Element Uptake of Two Grasses. Argonne National Laboratory, Argonne, IL, 43.

[27]. Page, A.L., Elseewi, A.A. and Straughan, I.R. (**1979)**. Physical and chemical properties of fly ash from coal-fired plants with reference to environmental impacts. *Residue Rev*., 71, 83-120.

[28]. Sharma, S. (**1989)**. Fly ash dynamics in soil-water systems. *Critical Reviews in Environmental Control*, 19(3), 251-275.

[29]. Maiti, S.K. (**2003)**. Handbook of Methods in Environmental Studies, Volume 1: Air, Noise and Overburden analysis, ABD Publishers, Jaipur, India.