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Mineralogical, Chemical and Morphological Studies of Fly Ashes from Thermal Power Stations of India

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Abstract: Mineralogical, chemical and morphological characteristics of fly ash collected from three thermal power stations viz. Bokaro Thermal Power Station (BTPS), Chandrapura Thermal Power Station (CTPS) and Durgapur Thermal Power Station (DTPS) of Damodar Valley Corporation (DVC), India have been well addressed in the present paper through analytical studies. The study reflects that all three samples are F type of fly ashes. According to mineralogical study quartz is the major component in all the three fly ash samples while the minor components are magnetite and hematite. Morphological study using scanning electron microscopy technique has revealed that the fly ash samples consist of spherical (solid or hollow spheres), oval or irregularly shaped particles of varying size. The study has also shown that the fly ashes from these thermal power stations can be used for various purposes such as backfilling in open cast mines, stowing in underground mines, cement manufacture, in paints as an extender, reclamation of subsided land etc.

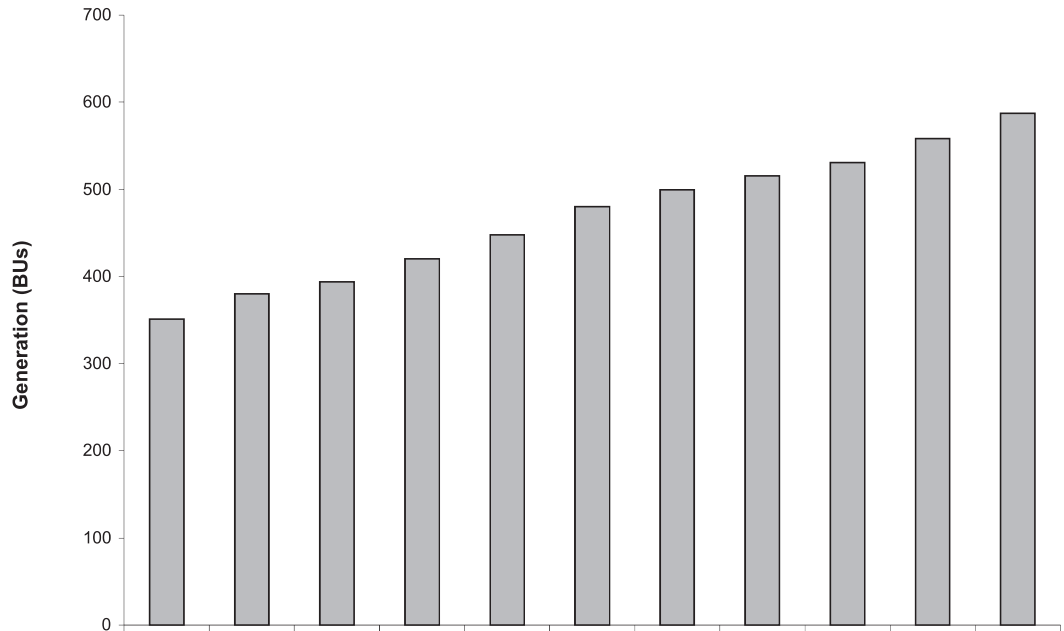
Key words: Fly ash, environment, morphology, thermal power stations, XRD, chemical composition.

Introduction

There has been a tremendous increase in the electricity demand the world over. In India alone the electricity generation has shown an impressive increase from what was 4.10 billion kWh in 1947-48 to 587.30 billion kWh in 2004-05 (TEDDY, 2003-04; MoP, 2005). Installed capacity as of Dec. 2006 was reported to be 110,773 MW (MoP, 2006). Figure 1 shows the year-wise power generation in India from 1994-95 to 2004-05 and Figure 2 shows the trend in the growth of total electricity generation in India (in GWh) during last fifty years.

This increase in power generation has also resulted in huge amount of fly ash generation. India has low quality coal and is characterized by high ash content. Around 80% of coal has ash content of 30 to 50% (Coal Wing, Geological Survey of India, Calcutta, 2006; www.gsi.org). It has been reported that more than 100 MT of fly ash is generated in the country and with the present rate of growth (8-10%) of power generation it is expected that this figure would be 175 MT by 2012 (Kumar, 2003).

The quantum of fly ash generated in the country is a matter of great concern. Its disposal not only requires huge land and power, but also causes ecological problems. In order to solve the disposal problem to the maximum possible it is required to find out some end use of it in the form of bulk utilization. A study has reported that 41% of fly ash generated in India has been utilized for different applications (Kumar and Mathur, 2005). Still it is lower compared to utilization percentage of the countries like France, China, Germany, Belgium, Israel, Italy, Japan, Poland, Spain, Portugal, UK and USA where average utilization is more than 50%. The fly ash must be properly characterized and utilization must be recommended based on the study and other heavy metal components in the fly ash in order to maximize the utilization. Figure 3 shows the percentage ash utilized in the country during last ten years.



	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
Generation (BUs)	351.00	380.00	394.00	420.00	448.00	480.00	499.45	515.27	531.00	558.34	587.30

Years

Figure 1: Year-wise power generation (BUs) (1994-95 to 2004-05).

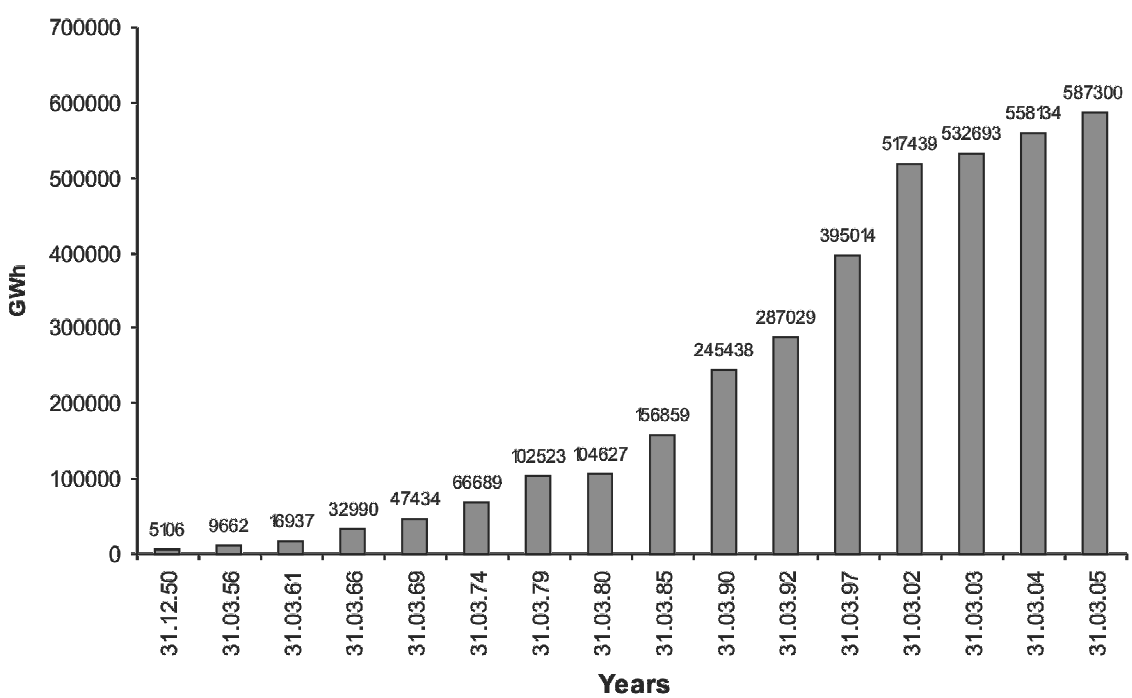


Figure 2: Growth of total electricity generation in India (GWh).

Source: Annual Report 2004-2005, Ministry of Power, Govt. of India (www.powermin.nic.in)

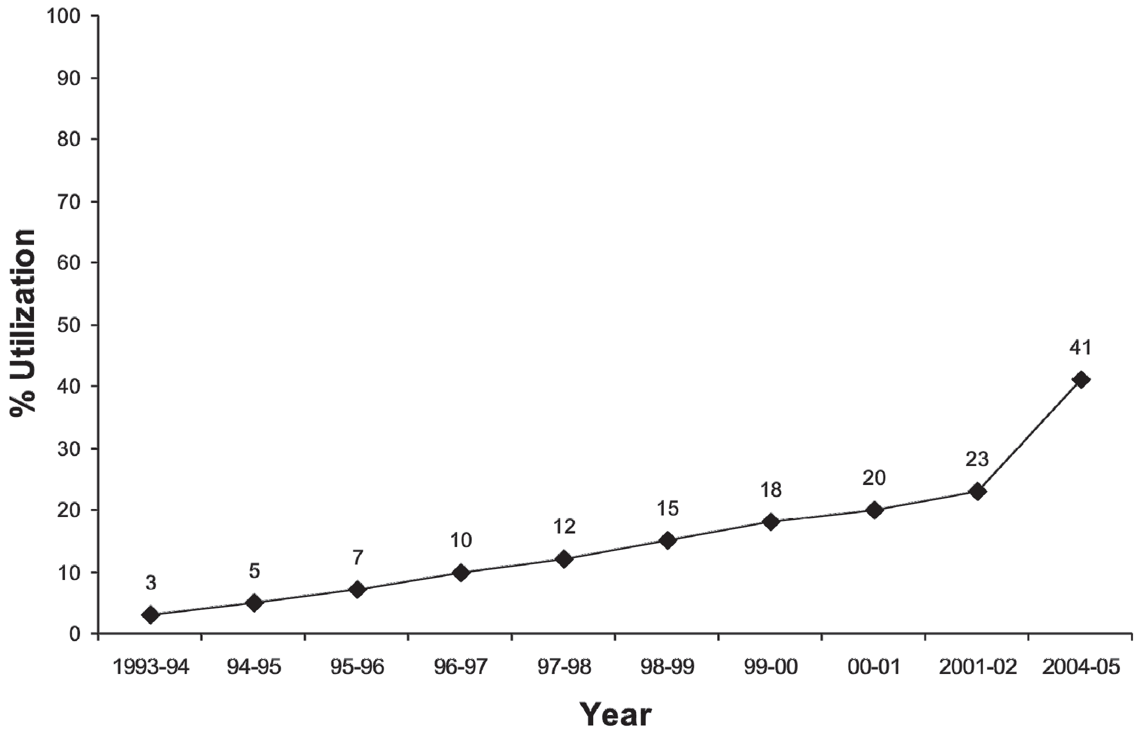


Figure 3: Percentage ash utilised.

The aim of the study, therefore, was to investigate the fly ash samples from the three thermal power stations of Damodar Valley Corporation, India, with respect to its mineralogical, chemical and morphological characteristics and thereby ascertain its bulk utilization potential.

Study Area

Fly ash samples were collected from three thermal power stations viz. Bokaro Thermal Power Station (BTPS), Chandrapura Thermal Power Station (CTPS) and Durgapur Thermal Power Station (DTPS) of Damodar Valley Corporation, India. Figure 4 shows the location of the power stations under study along the river Damodar.

Methodology

Sampling

Fly ash samples from the three thermal power stations of Damodar Valley Corporation were collected on five different days over a week and final homogenised sample was prepared by mixing the appropriate portions.

Experiments

X-ray Diffraction

The fly ash samples were examined by X-ray diffraction (XRD) using Phillips diffraction unit Model PW-1011 and copper Kα radiation. The diffractograms corresponding to the three samples were recorded.

X-ray Fluorescence

The three fly ash samples were analysed for chemical composition by x-ray fluorescence (XRF) technique using Phillips XRF unit, Model PW 2400.

Morphology

The morphology of the three fly ash samples was studied by the scanning electron microscope Model 415A.

Results and Discussion

X-ray Diffraction Analysis

Results of the X-ray diffraction analysis are presented in Table 1 and the X-ray diffractograms are shown in Figures 5a to 5c. From the diffractograms one can see that in all the three samples the major component consists of quartz (Q). The prominent peak in the diffractograms is that of quartz. The minor components included magnetite and hematite in case of BTPS and CTPS and magnetite in case of DTPS.

Similar studies carried out on Indian fly ashes also reports that the major component is quartz and minor components are magnetite, hematite and mullite (Ojha et al., 2004; Pandian, 2004; Sarkar, 2006; Das, 2005, 2003).

Table 1: Summary of X-ray diffraction analysis of fly ash samples from different thermal power stations of DVC

Thermal power stations	*Major component*	*Minor component*
BTPS	Quartz	Magnetite, hematite
CTPS	Quartz	Magnetite, hematite
DTPS	Quartz	Magnetite

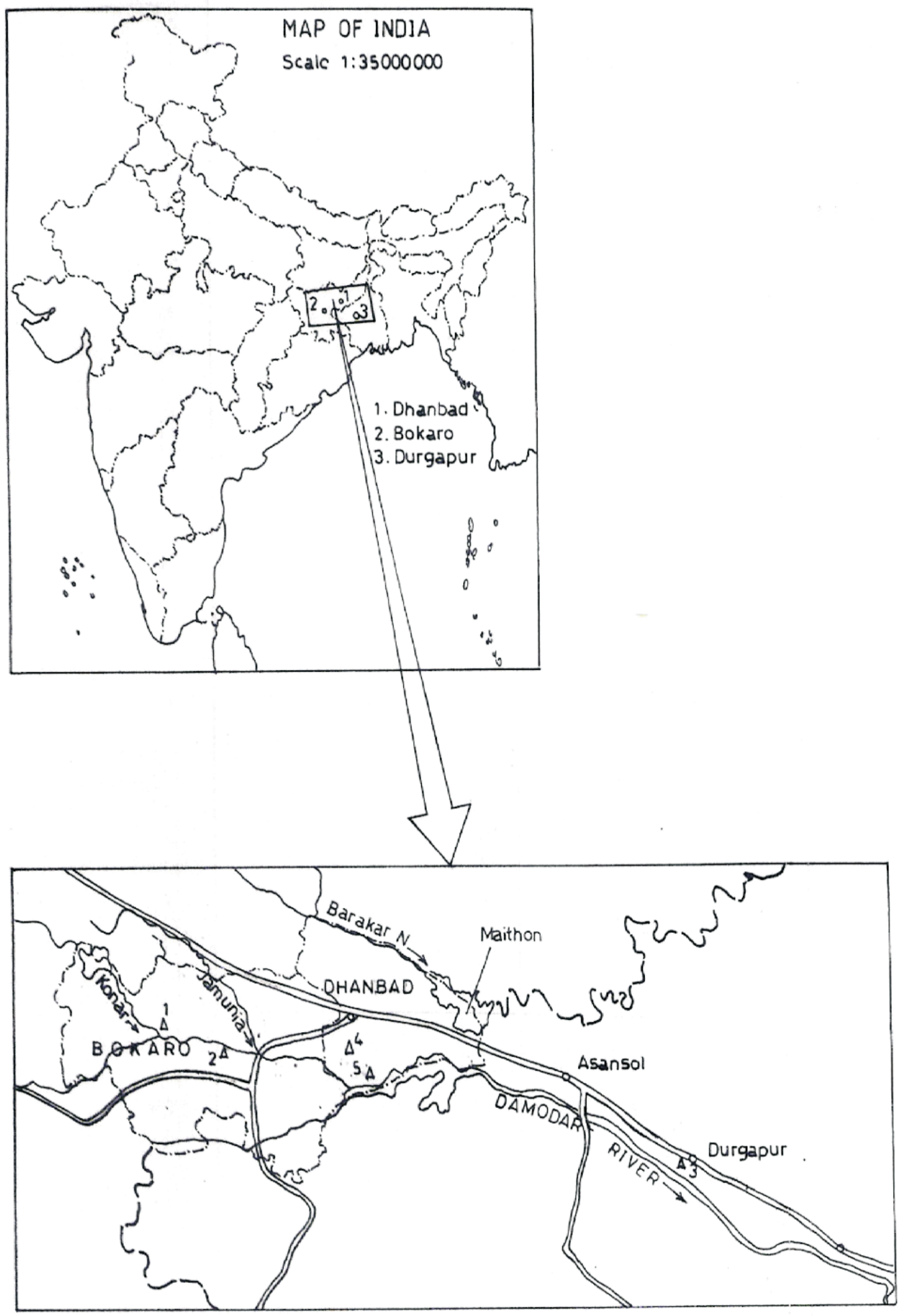


Figure 4: Location map of thermal power stations along the river Damodar.

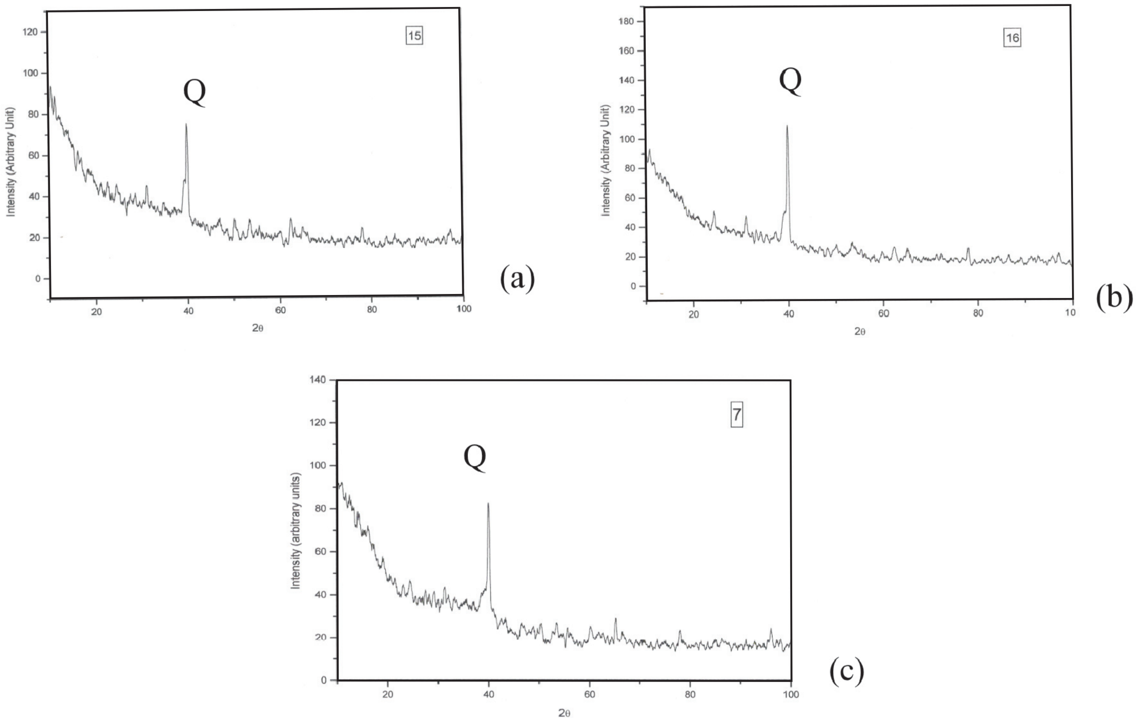


Figure 5: X-ray diffractograms: (a) BTPS fly ash, (b) CTPS fly ash, and (c) DTPS fly ash; Q: Quartz.

X-ray Flourescence Analysis

The observations of the composition of fly ash samples using XRF technique are given in Table 2. The study shows that the fly ash samples belong to SiO_2-Al_2O_3-Fe_2O_3 system. The main components in all the three fly ash samples were quartz (SiO_2) and alumina (Al_2O_3), which accounted for more than 70% of the total and hence they belong to class F ash. Other component Fe_2O_3 was less than 10% in all the three fly ash samples. Minor amounts of CaO, K_2O, MgO, TiO_2 and SO_3 were also observed in the samples. There are fluctuations in the chemical composition of the samples much due to the different mineral component in the parent coals. These fluctuations are also much related to the compositions of the parent rocks in the formation of peat and coal and also the plant species involved in the coal formation.

Some of the researchers (Ojha et al., 2004; Pandian, 2004; Sarkar, 2006) have carried out similar studies on Indian fly ashes and fly ashes from other parts of the world and it has been observed that the major constituents in fly ash were SiO_3, Al_2O_3 and Fe_2O_3 and the lesser constituents included oxides such as CaO, MgO, Na_2O, K_2O and SO_3.

Table 2: Summary of compositional analysis of fly ash samples (%) from three thermal power stations of DVC

Components	*Thermal power stations*		
	BTPS	*CTPS*	*DTPS*
SiO_2	55.56	58.51	55.04
Al_2O_3	28.06	27.47	25.23
Fe_2O_3	4.78	7.28	4.44
Na_2O	3.40	1.52	3.75
K_2O	1.96	0.61	1.95
CaO	0.86	0.08	0.99
MgO	0.20	0.02	1.43
SO_3	0.05	1.34	-
TiO_2	1.61	1.79	2.73

Scanning Electron Microscopy Study

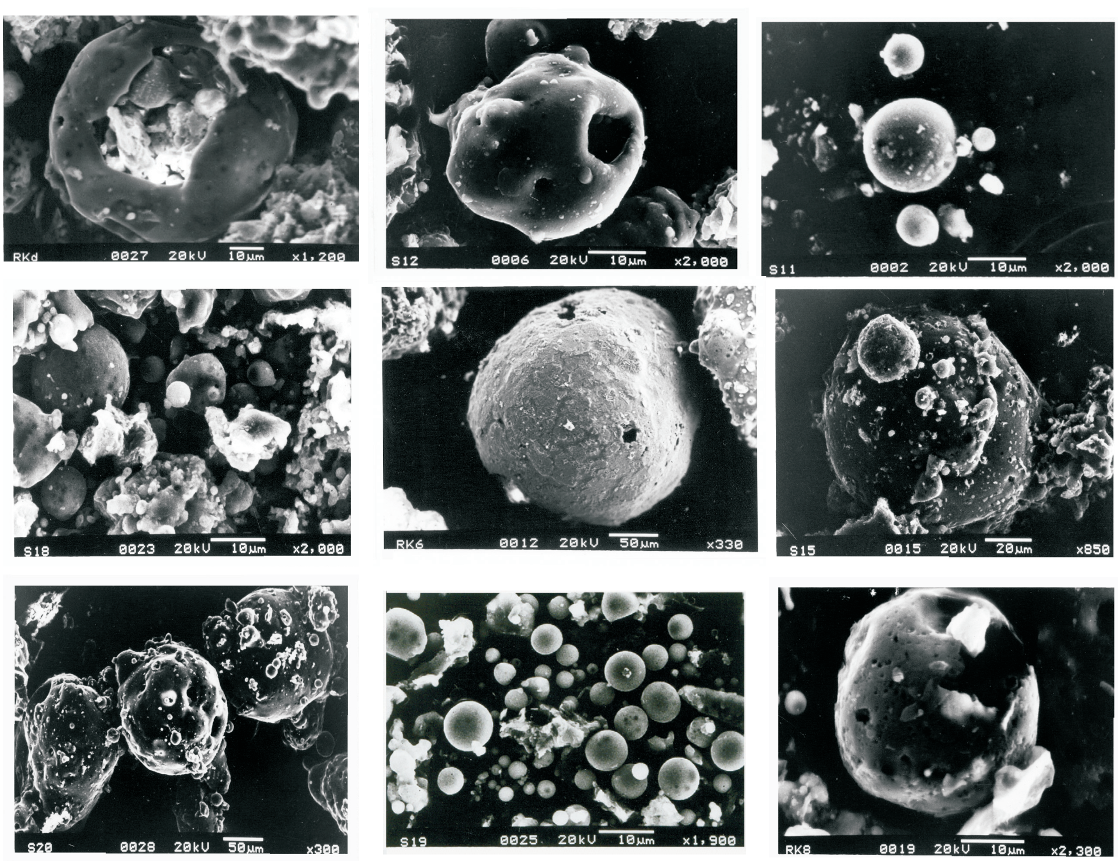
Examination under the scanning electron microscope (Figures 6a to 6c) has shown that the three fly ash samples in general consisted of spherical particles with nodules present on it. The particles are of different sizes and ranged from 1 μ to 100 μ. The fly ash particles in all the three samples were found agglomerated. Beside this, particles were observed to be of porous nature. Some cenospheres and a few plerospheres could also be seen from the micrographs. The cenospheric particles showed frequent bursts, which is inductive of chemical activity having occurred within them. Further small size particles were seen sticking to the larger spherical particles possibly on account of the convexity of the surfaces. Some spongy morphology also could be noticed from the micrographs. A point of special importance is the fact that most of the particles are found to be of spherical nature. Due to being spherical mixed with cement it can add workability to cement concrete mix. Being spherical and hollow can also be used as filler in paints.

Researchers such as Georgakopoulos (2003), Ojha et al. (2004), Pandian (2004) and Sarkar (2006) studied morphology of Indian fly ashes and fly ashes from other parts of the world and found that particles are mostly spherical in shape with small percentage consisting of cenospheres and plerospheres.

Utilization

Based on the study some utilization is being suggested here. The utilisation of fly ash as an engineering material primarily stems from its pozzolanic nature, spherical shape and relative uniformity. Literature survey has shown that fly ash can be used in areas such as manufacture of Portland Cement (Bakharev, 2005; Blanco et al., 2005; Ilic et al., 2003; Bhattacharjee, Vassilev and Vassileva, 2007; Moreno et al., 2005; Kandpal, 2002), mine reclamation (Ashokan et al., 2005; Saxena, 2003), waste stabilisation and solidification (Saxena et al., 2003), stabilisation of soft soils and as filler and extender in paints, and wood and plastic products (Iyer and Scott, 2001). It can also be used as a component in geopolymer mixtures (Phair et al., 2000; Xu and Deventer, 2000).

The study of the fly ash samples from the three thermal power stations of DVC in this paper has shown that these



(a)

(b)

(c)

Figure 6: SEM micrographs of fly ash from thermal power stations of DVC: (a) BTPS, (b) CTPS and (c) DTPS.

fly ashes consist of SiO_2, Al_2O_3 and Fe_2O_3 and hence, it is a suitable source of Al and Si for geopolymers. It can be used as a replacement of Portland Cement in concrete owing to its pozzolanic properties and spherical shape. It can be used for stabilization of soft soils owing to its pozzolanic properties and using additives such as lime or cement. It can be used as a component in the production of flowable fill. Fly ash can also replace fine aggregate, in most cases river sand, as a filler material.

Fly ash, like soil, contains trace concentrations of many heavy metals that are known to be detrimental to health in sufficient quantities. These include nickel, vanadium, arsenic, beryllium, cadmium, barium, chromium, copper, molybdenum, zinc, lead and selenium. These heavy metals have always stood in the way of bulk utilization of fly ashes. The study as carried out on fly ash samples from these thermal power stations have shown that the leachates do not contain these elements in alarming limits and as such do not pose any adverse environmental impact in its disposal system (Singh et al., 2007).

Conclusion

Ever increasing fly ash generation has thrown open challenge before scientists, technologists and engineers for its proper management in the form of safe disposal and utilization. Fly ash characterization is one way of understanding this fly ash. This characterization helps us in taking decision at where to use and how to use this fly ash.

Based on the study of the characteristics of fly ashes from three thermal power stations of Damodar Valley Corporation it can be inferred that the fly ashes belong to SiO_2-Al_2O_3-Fe_2O_3 system and also fall in the category of class F ash, the major component observed was Quartz while the minor components were magnetite and hematite and fly ash particles are mostly in the range 1 μ to 100 μ and are spherical, solid spheres and cenospheres with less amount of plerosphere (spheres within a sphere).

The analytical study carried out here on fly ash has shown that fly ash has good potential for use in areas such as manufacture of Portland cement, mine backfilling, stowing, in the stabilization of soft soils, in the manufacture of paints, wood and plastic products, etc. Its pozzolanic nature, fineness and spherical nature can be gainfully exploited in areas as stated above. Also, as these thermal power stations are located in and around the mine areas, which have the potential of utilizing these fly ashes, as fill material in the abandoned mines, one can definitely think of using such prospects of bulk utilization of fly ashes. This will not only solve the problems associated with the disposal of fly ash but also will go a long way in conserving natural resources and reducing sand mining.

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