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Environmental concern elements in coal and coal combustion residues

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Feed coals of studied thermal power plants contain several environmental concern elements (Cu, Cd, Cr, Pb). Enrichment in concentration of these elements in fly and bottom ash takes place during combustion. Combustion residues containing these elements are a potential source for ecological disrupt. Controlled emission technology and discarding process of ashes in power plants are vital from environmental aspect. Appropriate and secure recycling of ashes is a good alternative of its disposal for financial moreover environmental benefit.

Keywords: Coal, coal combustion residues, environmental concern elements.

Introduction

Energy is the key for industrial and domestic progress of a country. Both conventional and renewable energy is essential for the fulfilment of energy demand[1,2]. Still present, coal has significant share (40%) in power generation in the world. India has reliable coal reserve (~118 billion tons) and 75% of country's power supply is shared from different thermal power plants[3,4]. This fossil fuel contains several environmental concern elements (Hg, As, Cd, Cu, Cr, Sb, Pb, Ni etc.) which may cause environmental pollution and contamination due to combustion[5,6]. Power plants generate large amount of fly and bottom ash in different composition[7,8]. This variation of physical and chemical constituents of these coal combustion residues (CCR) are principally influenced by coal source and burning process[9]. Generally, trace elements have low concentration (ppm) in coal however, CCR depict an attention for the cumulative build up of elements through combustion[8]. The long life and mobility of these elements from ashes may cause contamination in different segment of environment due to disposal and utilisation[10]. The CCR, which are the anthropogenic source of various elements, put a great concern of ecology and health hazardous[6,9]. Aggressive research on characterisation and management of these combustion residues are essential to control the negative impact of coal combustion from environmental aspects.

Assessment of environmental concern elements in coal and coal combustion residues collected from thermal power plants of West Bengal, India are carried out in this study to understand the fate and distribution of environmental concern elements in combustion residues. Analyses of these elements in the surface water of the vicinity of the studied thermal power plants are performed to predict the mobility of the elements from ashes. Finally, proper disposal practice and reuse of this solid waste is discussed for sustainable environment.

Material and method:

The coal and coal combustion residues (fly and bottom ash) were collected from Farakka Super Thermal Power Station and Sagardighi Thermal Power Station of West Bengal, eastern state of India (Fig. 1). The coals were collected from feeders of the boiler. The fly and bottom ashes were collected from hoppers of the precipitator and asher of the boiler respectively. In order to maintain the representativeness of sampling, all the materials were collected weekly for a pe-

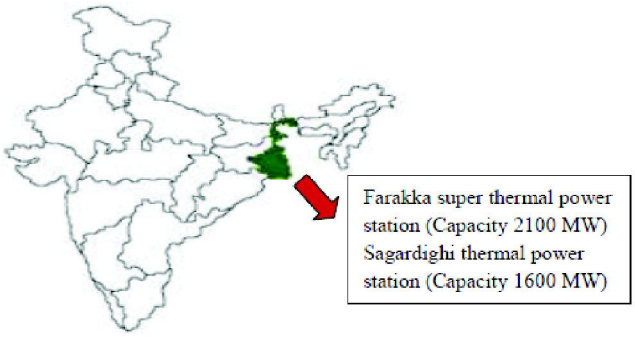

Fig. 1. Studied thermal power plants.

riod of one month from the each thermal power plant. The samples were ground and mesh following ISO recommendation and then stored in PVC zip lock bag for further analysis. The surface water was collected in precleaned plastic bottle from the vicinity of the thermal power plants within 3 km radius.

Indian Standard (IS: 1350, Part I, 1984) was followed for the analysis of proximate parameters (ash, volatile matter, moisture, fixed carbon) of the feed coal samples. The results of proximate analysis were represented as a percentage of air dried materials. The moisture was determined by two stage process. In this case coal sample was air dried under atmospheric condition followed by the removal of remaining moisture by drying in an oven 108±2ºC. Then the total moisture was calculated from the difference of air and oven drying. The method of analysis of volatile matter was consisting of heating of weighted quantity of air dried sample at 900±10ºC for seven minutes in absence of air. Determination of ash was done by heating the sample in air at 500ºC for 30 min and also for another 30 min at 815ºC. Fixed carbon was calculated by deducting the sum of moisture, ash and volatile matter from 100.

Microwave acid digestion of coal, fly and bottom ash (0.1 g of each sample) was done by acid mixture (HNO_3:HF:HCl = 3:1:1)[1] and the solution were analysed by inductively coupled plasma mass spectrometry for the estimation of trace elements (Cu, Cd, Cr, Pb) in the samples. Water samples were filtered by membrane filter and analysis of these filtrate were also performed by inductively coupled plasma mass spectrometry. The concentration measurement of each element was carried out in triplicate run. The accuracy of analysis and validation of digestion was verified by reference material (SRM 1632d).

Results and discussion

Proximate parameters of feed coal:

The Table 1 represents the ash, volatile matter, moisture, fixed carbon value of coal samples of thermal power plants. The feed coal have high ash yield while low moisture content. The average volatile matter and fixed carbon value is 26.35% and 26.79% respectively. These proximate parameters reflect that the feed coals of thermal power plants are subbituminous in rank[2,11].

Table 1. Average proximate parameters of coal (%, dry basis)

Ash	Moisture	Volatile matter	Fixed carbon
41.28	5.58	26.35	26.79

Environmental concern elements in coal and CCR:

The average concentration of analysed trace elements (Cu, Cd, Cr, Pb) in coal, fly and bottom ash are represented in the Table 2. Cu has the highest and Cd has the lowest concentration in coal. However, the concentration of rest two elements Pb and Cr are in between. The studied feed coals have considerably enhanced concentration of these environmental concern elements compared to world coal average[12].

Table 2. Average concentration (µg/g, on dry basis) of environmental concern elements in coal and coal combustion residues

Elements	Coal	Fly ash	Bottom ash
Cu	30.56	63.42	44.75
Cd	1.55	2.84	1.92
Cr	24.64	38.35	32.55
Pb	22.85	39.15	31.75

During combustion, trace elements are usually retained into solid ashes or emit as particulate bound with flue gas[7,9]. In the present study, the distribution of the elements also follows the decreasing trend Cu > Pb > Cr > Cd in both fly and bottom ash (Table 2) similar to coal. However, all the elements have higher concentration in CCR than the parent coal (Table 2). The result reflects an enrichment of these elements due to combustion[3,8]. This cumulative build up of elements is determined by enrichment factor (EF) (Table 3). EF is the ratio of elemental concentration in ashes to its parent coal[7]. Calculated EF delineates the affinity of elements towards ash and gaseous phase[1]. Content, mode of occurrence and reactions of combustion process primarily control the fate of the elements in CCR during combustion[13,14]. In this study, the EF (Table 3) shows that the analysed elements have low volatility and have significant affinity to ash[8]. The concentration (Table 2) as well as the enrichment factor (Table 3) of all the analysed elements is relatively higher in fly ash than bottom ash. These reveal that the Cu, Cd, Cr

Table 3. Enrichment factors of elements in coal combustion residues

	Cu	Cd	Cr	Pb
Fly ash	2.08	1.83	1.56	1.71
Bottom ash	1.46	1.24	1.32	1.39

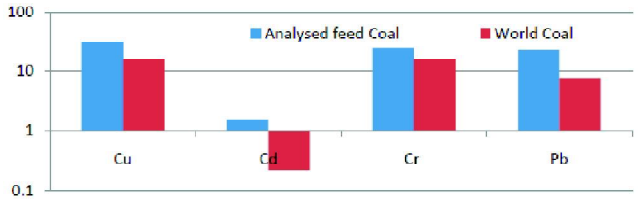

Fig. 2. Comparison of analysed elements with world coal average reported by Ketris and Yodovich, 2009.

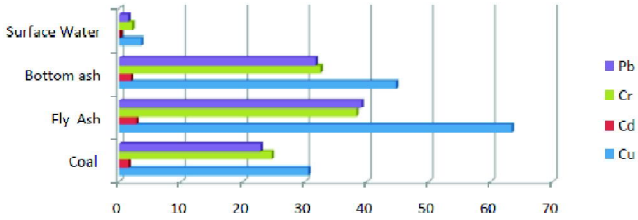

Fig. 3. Environmental concern elements in coal, fly ash, bottom ash and surface water.

and Pb are greatly captured by finer fly ash particles which have greater adsorption area than coarse bottom ash[7]. The prominent enrichment of these elements in CCR also reflects their low emission tendency with flue gas. Electrostatic precipitator (ESP), frabic filter, baghouse, scrubber are generally used in the thermal power plants to control particulate emission[8,9]. Trace elements bound to small particles have a fat inclination to remove which may cause air pollution and health hazards[6]. Monitoring of the efficiency of particulate control device is essential to reduce the emission of particulate bound trace elements into the atmosphere[5,6].

Environmental concern elements in surface water:

The presence of these environmental concern elements in combustion residues is an apprehension because a lump sum amount of ashes is produced due to huge combustion. Disposal of these combustion residues is a critical problem for the coal based power generating units[5,10]. Mobilization of the environmental concern elements into the adjacent aqueous environment may cause adverse effect on the ecosystem[5,10]. The chemical analysis of surface water of nearby thermal power plants is depicted in the Table 4. The existence of these environmental concern elements in aquatic

Table 4. Average trace elements concentration (µg/L) in water

	Cu	Cd	Cr	Pb
Surface water	3.6	0.18	2.2	1.5

environment may be due to leaching from stored combustion ashes as well as sinking of the emitted particulate matter[5,6] (Fig. 3). The prolonged contamination may cause bioaccumulation and entering into the food chain which will be a threat to the live stock[5]. A regular monitoring and unloading of the disposed ashes is urgently required to control over aqueous pollution and suitable utilisation[4,15].

The CCR are generally recycled in construction material, ceramic industry and also in agricultural field[9,15]. Recycling of CCR is economically and environmentally beneficial option for coal based power plants[15,16]. However, chemical treatment of physiochemical composition is urgently needed before selection of utilization in different sectors especially in the agricultural field to limit the negative impact of environmental concern elements on ecosystem[9,15].

The emission and deposition during combustion as well as leaching of these elements from the stock ashes may contaminate air, soil and water of the adjoining thermal power plants[1,16] (Fig. 3). However, prolonged contamination may cross its border because environment is an excellent mobile machine[5]. A technology with efficient emission control device for coal burning and appropriate disposal of combustion residues (Fig. 4) are needed to resists the emission and leaching of the environmental concern elements into the environment as well as clean energy generation[6,10]. Safe and eco-friendly utilisation of combustion residues is a good alternative than disposal from environmental along with economic sight[1,4,16].

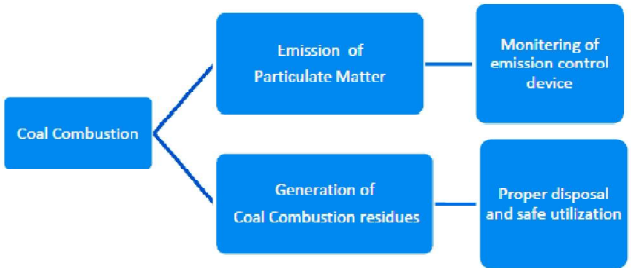

Fig. 4. Schematic diagram for clean energy generation.

Conclusions

The significant concentration of environmental concern elements Cu, Cd, Cr and Pb are noticed in the feed coals of the studied thermal power plants. An enhance concentration

of these elements are observed in the coal combustion residues (CCR) which focus their high affinity towards ashes than gaseous phase. The high enrichment factor (EF) of these elements in fly ash than bottom ash is due to greater accumulation on finer particles than coarse ash. The presence of these environmental concern elements in the surface water of the neighbouring thermal power plants drags an attention to alert regarding migration of these elements from the disposed waste.

Skilled emission control device in combustion process and suitable disposal practice of combustion residues are immediately essential to achieve the balance between energy generation and clean environment. Vast productions as well as improper dumping of this solid waste are a big concern for environmental contamination and pollution level aspects. Safe and quantum utilisation of coal ashes is a good remedy of harmful blow of coal combustion.

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