Characterization of Coal Samples from Dasal-I Coal Mine

[1]FAZAL WAHID, [1]IMDAD ULLAH MOHAMMADZAI*, [1]NAUMAN ALI,
[2]MUHAMMAD TAHIR SHAH AND [3]HIZBULLAH KHAN
[1]Institute of Chemical Sciences, University of Peshawar, Peshawar, Pakistan.
[2]National Centre of Excellence in Geology, University of Peshawar, Peshawar, Pakistan.
[3]Department of Environmental Sciences, University of Peshawar, Peshawar, Pakistan.
imdadmo@yahoo.com*

(Received on 19th July 2011, accepted in revised form 13th December 2011)

Summary: Characterization of coal from Dasal coal mine Khyber pukatunkwa, Pakistan. Coal samples were collected from 50, 100, 150, 175, 200 and 250 feet. Coal samples were crushed, grounded and screened through 250 µm sieves shaker. Proximate and ultimate analysis of coal showed that these coals were of low grade from sub-bituminous to bituminous. Sulphur content from Dasal coal mine was less as compared with other mines in Pakistan. Leaching of coal led to significant amount of mineral matter with hydrochloric acid (HCl), ammonium acetate (CH_3COONH_4), nitric acid (HNO_3), hydrofluoric acid (HF), sodium hydroxide (NaOH). Among the leachants HCl was most effective for copper, iron, chromium and cobalt. In case of CH_3COONH_4 no significant leaching was made. HNO_3 and NaOH also resulted average leaching while, HF was found to be a good leachant for lead, nickel and zinc. Most of inorganic elements were effectively leached by digestion as compared to other leachants.

Introduction

Fossil fuels like coal, petroleum and natural gas are non renewable sources of energy [1]. They were formed from plants and animals remain (millions of years ago) and their deposits are found beneath the earth. Energy is essential to modern society. Over 85% of our energy demand is met by the combustion of fossil fuels. Coal is increasingly considered as the main source of energy and regaining its position. Coal is primarily classified into four major types: lignite, sub-bituminous, bituminous and anthracite [2].

Most valuable content of coal is its carbon content which supplies most of its heating value. However, various other factors as moisture content, ash content and sulphur are also important in determining the rank of a particular coal. Anthracite is top ranked coal, with highest carbon content that ranges between 86-98 per cent and has a heat value of nearly 15,000 British Thermal Unit (BTU) per pound. Bituminous and sub-bituminous 'ranks' of coal are inferior to anthracite. The bituminous variety is used primarily to generate electricity and to make coke for the steel industry. The discovery of coal in Balochistan during the late 18th century led to its commercial utilization mainly by the north-western railways during the colonial regime. At present, our total coal reserves in Pakistan are estimated around 184.5 billion tons which include the recently discovered deposits of low sulphur coal at Thar [3].

Mineral matter represents the different metals present in coal in different association. Coal combustion produces significant quantities of solid residues such as bottom and fly ash. During transport, disposal and storage phases these wastes are subjected to the water agent, as a result of which, toxic elements existing in the ashes like lead , nickel, cadmium, zinc, mercury and chromium may leach out and contaminate soils, surface and ground waters [4].

The major constituents of mineral matter in coal are:

i. Clay minerals (aluminosilicates), which occur mostly as illinite, kalinite, and mixed illinite-montmori, ilinite makes up a high percentage of the total mineral matter contents.
ii. Carbonate minerals principally calcite ($CaCO_3$), dolomite ($FeCO_3$ $MgCO_3$) But frequently also present as variously composed mixed carbonates of Ca, Mg, Mn and Fe. Sulphides which are mainly present as pyrite, but have been reported form as galen (PbS) and sphalerite (ZnS).
iii. Sulfates are reactively rare and when present exist mainly as variously hydrated iron suphates ($FeSO_4.nH_2O$) or as mixed Na, K, Fe Sulfate (Jarosite).

While, minor inorganic constituent, only present in ppm concentrations and therefore properly termed trace constituents cover an even wider spectrum but may be conveniently grouped according to their tendency to associate with mineral of a class. Chalocophilic elements which tend to form sulfides and therefore associated with $FeSO_4$ include Potassium, sodium, titanium, yttrium and zirconium.

*To whom all correspondence should be addressed.

Some more studies [5-6] indicate that B, Be and Ge are predominantly combined with organic substances. As, Cd, Hg, Mn, Mo, Pb, Zn and Zr occur mostly in associated with inorganic matter. Other elements shows varying affinities for association with organic and inorganic matter, Ga, P, Sb, Ti and V are preferentially allied with elements [6]. The essential and toxic metals may both be present in a variety of environmental substances, such as water, soil, air and food etc. Their actual concentration in the body depends on a number of factors, of which their actual local concentration, the food habits, the geological and industrial environment and profession of the population segments are important [7].

Coal mainly consists of organic material but also contains inorganic elements in variable concentration depending upon the plants origin from which coal has been formed. These inorganic elements are undesirable in most coal utilization process because of their deleterious effects on the environment. The environmental impacts of coal usage can be grouped into three categories: air, water and land pollutions. The pollutant emissions from coal utilization may cause serious environmental and health risks.

In this paper our emphasis are to characterize the sample and conclude its industrial utilization and compare their environment effects. The emissions of CO_2, SO_x, NO_x and some of volatile inorganic elements (especially As, Be, Cd, Co, Cr, Hg, Mn, Ni, Pb, Sb, Se) and their compounds in flue gases from coal combustion, may have important environmental impacts such as global temperature rising and direct hazards of volatile compounds to agriculture, soil, water and human health. The inorganic constituents in fly ash, bottom ash and slag disposed are other types of land pollution. Once released into the atmosphere, these pollutants can be transformed by a variety of chemical reactions. For this particular propose we have employed Atomic absorption spectrophotometric analyses to determine inorganic elements in the coal [8-9].

Results and Discussion

Moisture Contents

Table-1 shows moisture content in C1 to C5 coal sample were 1.30%, 4.24%, 3.34%, 9.70% and 5.29%, respectively. Higher amount of moisture represents higher amount of mineral present in coal due to their oxides or hydroxides. Increased moisture content is also an identification of lower coal ranking. Moisture content is a good parameter in deciding about the quality of coal. High amount of moisture was found in sample C-4 collected from 175 feet depth *i.e.*, 9.70%. Other coal samples indicate that they contain acceptable levels of moisture.

Table-1: Amount of Moisture and Ash Content present in various samples of Coal.

S.No.	Sample	Moisture %	Ash Content %
1	C-1	1.30	20.96
2	C-2	4.24	33.55
3	C-3	3.34	14.09
4	C-4	9.70	30.23
5	C-5	5.29	15.23

Ash Contents

The excluded mineral matter, the mineral matter embedded within the coal matrix and the organically associated compounds produce ashes of varying character. During coal combustion or gasification the coal minerals undergo many transformations to form ash. The ash is classified in two ways depending on its size. Residual ash, formed from excluded minerals or coalescence of included minerals, ranges in diameter from 1 to 100 micrometers (µm). Submicron ash, formed by vaporization of volatile components of the ash followed by condensation and coagulation, or extensive fragmentation of minerals, varies in diameter from 0.01 to 1 µm. Combustion conditions such as temperature, oxygen concentration and residence time have a significant influence on the ash formation process.Table-1, shows all coal samples, collected from Dasal I, C-3 and C-4 samples showed low percentage and high percentage of ash content, respectively.

Volatile Matter

It is evident from Table-2 that the volatile matter in some samples is too high, particularly in samples, C-1 and C-2. Volatile matters in other samples are within range. Based on the volatile matter content the coal samples, C-3 to C-5 are of good quality as compared to C-1 and C-2 in term of fixed carbon. Fixed carbon content depends on the volatile matter, the higher the volatile matter, the poorer is the fixed carbon.

Table-2: Amount of Volatile Matter present in various samples of Coal.

S. No.	Sample	Volatile Matter %
1	C-1	20
2	C-2	18
3	C-3	6
4	C-4	7
5	C-5	10

Fixed Carbon

Table-3 shows percentage of fixed carbon in coal samples. Sample C-3 and C-5 showed high percentage of fixed carbon 76.57 and 69.57, respectively. Plant matter changes into coal in stages. In each successive stage, higher pressure and heat from the accumulating overburden increase the carbon content of the plant matter and derive out more of its moisture content. Coal has been classified according to it fixed carbon content, or the amount of carbon the coal produces when heated under controlled conditions. Higher grades of coal have higher fixed carbon content.

Table-3: Amount of Fixed carbon present in various samples of coal.

S.No.	Sample	Fixed Carbon %
1	C-1	40.04
2	C-2	44.21
3	C-3	76.57
4	C-4	53.07
5	C-5	69.57

Sulphur in Coal

Table-4 shows the sulphur content in the coal samples collected from Dasal-1(Abbottabad). Only one sample C-1 contains high percentage of sulphur (2.918) and the rest of these samples show less than 1% sulphur with increasing depth. This data suggests that the use of this coal will cause less pollution as compared to previous reported [12-14]. With increasing depth, higher pressure and heat from the accumulating overburden increase the carbon content of the plant matter and derive out more of its moisture and sulphur content. Pyritic sulphur and most of organic sulphur are unstable at high temperature and convert into SO_x and H_2S.

Table-4: Amount of Sulphur present and various samples of coal.

S. No.	Sample	Sulphur %
1	C-1	2.918
2	C-2	0.565
3	C-3	0.579
4	C-4	0.504
5	C-5	0.561

Mineral Matter

Table 5-9 show the amount of metallic elements leached with CH_3COONH_4, HCl, HNO_3, HF and NaOH. These samples were leached for the measurement of metal content with different leachants and the results are recorded in Tables 4-8. Most of metallic elements were effectively leached by digestion method as compared to other leachants. HCl was the most effective for maximum leaching of copper, iron and cobalt in all coal samples, chromium was effectively leached in four samples by HCl while in C-3 maximum leaching was made by HNO_3. Leaching of coal with ammonium acetate was of less significant as compared to NaOH. However, HF was found to be best lechant for lead, nickel and zinc.

Table-5: Metals (ppm) elements in Dasal 1 coal mine (50 feet) after leaching with different leachants.

Metal	Digestion	HCl	CH_3COONH_4	HNO_3	HF	NaOH
Cu	13.12	9.9	2.62	6.15	9.82	5.12
Fe	427.35	371.75	112.50	163.75	155.50	315.00
Cr	137.67	39.12	10.25	2.60	8.60	6.10
Ni	42.57	14.82	5.77	18.37	20.75	7.37
Zn	27.95	11.52	13.13	32.22	200.75	7.65
Co	24.45	18.65	2.52	10.45	12.55	6.97
Pb	34.87	19.2	4.40	16.95	23.7	1.32

Table-6: Metals (ppm) in Dasal 1 coal mine (100 feet) after leaching with different leachants.

Metal	Digestion	HCl	CH_3COONH_4	HNO_3	HF	NaOH
Cu	23.8	9.92	2.30	5.25	9.82	4.32
Fe	1329.75	570.75	402.50	317.50	440.50	127.50
Cr	189.55	46.12	8.27	2.60	30.57	9.90
Ni	44.32	20.07	1.57	16.35	22.07	6.17
Zn	31.85	25.67	33.5	25.87	131.95	5.35
Co	26.62	18.4	2.47	8.2	12.25	7.97
Pb	27.55	22.75	2.47	12.17	26.06	1.20

Table-7: Metals (ppm) in Dasal 1 coal mine (150 feet) after leaching with different leachants.

Metal	Digestion	HCl	CH_3COONH_4	HNO_3	HF	NaOH
Cu	9.2	7.22	1.45	6.42	6.05	5.02
Fe	532.32	277.50	132.50	103.25	147.00	27.50
Cr	44.77	15.12	6.52	24.77	9.87	8.65
Ni	12.62	10.02	1.87	4.77	15.05	6.6
Zn	12.85	10.37	11.32	98.27	152.02	9.47
Co	9.72	8.05	1.4	3.45	6.17	7.37
Pb	11.90	2.62	0.57	1.05	16.02	1.30

Table-8: Metals (ppm) in Dasal 1 coal mine (175 feet) after leaching with different leachants.

Metal	Digestion	HCl	CH_3COONH_4	HNO_3	HF	NaOH
Cu	16.075	6.30	1.62	4.85	2.47	4.40
Fe	457.00	310.00	380.00	142.00	98.50	44.50
Cr	34.80	11.90	8.42	2.60	6.95	0.27
Ni	7.75	6.4	2.30	3.30	7.47	6.22
Zn	9.72	5.17	16.97	46.72	54.07	5.97
Co	6.60	5.77	1.65	2.92	5.02	4.0
Pb	12.62	7.90	0.57	0.95	8.75	1.32

Table-9: Metals (ppm) in Dasal 1 coal mine (250 feet) after leaching with different leachants.

Metal	Digestion	HCl	CH_3COONH_4	HNO_3	HF	NaOH
Cu	13.35	6.45	2.22	2.75	2.25	4.65
Fe	358.25	94.50	42.50	69.00	57.25	17.75
Cr	95.50	12.80	8.42	2.60	6.50	10.05
Ni	18.05	7.97	0.87	4.70	8.10	7.75
Zn	15.67	5.35	6.72	61.62	42.15	4.57
Co	14.22	9.85	0.125	4.27	7.57	7.17
Pb	16.05	5.35	1.29	2.07	5.82	1.32

Experimental

Sample Collection

Coal samples were collected from selected area of Abbottabad and analyzed for moisture, ash, volatile matter and minerals contents. The following steps were taken to obtain the Coal samples.

1 Five samples of Coal from one mine were collected from 50, 100, 150, 175, 200 and 250 feet (Dasal).
2 Coal samples were taken in clean poly ethylene bags and transferred to the laboratory on the same day.
3 Sample and collection areas are given in Table-10.

Table-10: Study area, site depth and sample code.

Area	Sample	Depth (Feet)	Sample Code
	1	50	C1
	2	100	C2
DASAL 1	3	150	C3
	4	175	C4
	5	250	C5

Preparation of Coal Samples

Coal samples were obtained from Dasal coal mine, crushed and ground in a pestle and mortar, screened through 250 µm sieves using a sieve shaker [10]. The definite sized coal samples were dried in an oven at 70 °C for one hour and cooled in a dessicator.

Leaching Procedure

A portion (2g) of each coal sample understudy was leached separately with sodium hydroxide, hydrochloric acid, nitric acid hydrofluoric acid and ammonium acetate. The specified amount of coal was stirred with 50 mL extracting solution in a conical flask which was placed on stirrer for two hours. The temperature was maintained at 25 °C throughout the extraction process. After being contacted for the specified duration of time, the slurry was filtered using Whatman filter paper 540 and diluted to 50 mL with distilled water.

Metal Analysis

Leaching and digestion methods were used for extraction of trace metals. Quantification of trace metals in each sample of coal was carried out using atomic absorption spectrophotometer available at National Centre of Excellence in Geology.

Proximate Analysis

Proximate analysis *i.e.* %moisture, %ash, % volatile matter and Fixed carbon were determined. For sulfur contents Eska mixture was used.

The coal sample was characterized according to ASTM methods [11]

Conclusions

Five coal samples were collected from Dasal coal mine situated on the Muree road, east of Abbottabad city. After studying the samples we came to the following conclusions:

Based on fixed carbon, the coal studied ranged from sub-bituminous to bituminous and comparatively of good quality because most of Pakistani coal ranged from lignite to sub-bituminous. Amongst the leachants employed, HCl was found to be effective for maximum leaching of copper, chromium, iron and cobalt. Most of metallic elements were effectively leached by digestion method as compared to other leachants. In case of CH_3COONH_4, no significant leaching was found while HNO_3 and NaOH resulted as an average leachsnt. Whereas, lead, nickel and zinc, were found to be the best in HF.

These coal samples contain less sulfur and mineral matter as compared with the previous coal sample analyzed in Pakistan, if this coal is used for electric power generation, fire bricks manufacture, steam generation, etc. will create less environmental as well as process problems like clinker formation, slagging and agglomeration during combustion. Also Pakistani coal contains significant amount of mineral matter as compared with good quality coal and also of low rank like that of South Africa, so it is recommended that it should be processed on the pattern of Sasole plant, situated in South Africa, in order to get maximum energy and safe environment[15, 16].

References

1. V. Kecojevic, *Safety Science*, **49** 658 (2011).
2. A. B. Waheed, *Pakistan's coal resources htt://DAWN.com* 20 September (2004).
3. I. Siddiqui and M. T. Shah *Journal of the Chemical Society of Pakistan*, **29** 222 (2007).
4. J. G. Bailey, Training course of Coal production, *Utilization and Environmental Protection.* UNDP/PACE-E, (1993).
5. P. Zuboic, *Advances in Chemistry Series*, **55**, 221 (1996).
6. R. R. Ruch, H. J, Gluskoter and N. F. Shimp, *Environmental Geology Note* **72**, (1974).
7. R. Adriana, S. Zenib, L. M. de-Portelaa, A. Patricia, D. J and de-Ferrera, *Trace Elements in Medicince and Biology*, **20**, 41 (2006).

8. Q. M. Sharif, M. Hussain and Q. Hilal, *Journal of the Chemical Society of Pakistan*, **27**, 213 (2005).
9. M. Ishaq, K. Saeed, I. Ahmad, M Shakirullah and M. I. Khan. Journal of the chemical society of Pakistan, **33**, 360 (2011).
10. L. Zhang, T. Takanohashi, T. Nakazato, I. Saito and H. Tao, *Energy Fuels* ***22***, 2474 (2008).
11. C. Karr, "Analytical methods for coal and coal products", Vol. 1, Academic Press, Inc. Ltd., London, (1978).
12. M. khan, I. Ahmad and G. Akhtar, *Journal of the Chemical Society of Pakistan.*, **27** 580 (2005).
13. K. Saeed, M. Ishaq, I. Ahmad, M. Shakirullah and S. Haider, *Journal of the Chemical Society of Pakistan*, **32**, 162 (2010).
14. K. Saeed, M. Ishaq, I. Ahmad, M. Shakirullah, S. Y. Park, H. Khan and N. Ali, *Journal of the Chemical Society of Pakistan*, **28**, 207 (2006).
15. S, Vander, D.S, Kosson, T. T. Eigmy, R and N. J. Comas, *Netherlands Energy Research Foundation*, **3** 94 (1994).
16. D. Hassett. *Test methods for evaluating solid waste*, *physical/ chemical methods* (SW-846), 18 (2000).