Research Article

# Physiochemical Assessment of Pakistani Thar Coal, A Solution for Sustainable Energy Crises and Reduced Environmental Impacts

**Jawad Abdullah Butt[1*], Yasmin Nergis[1], Ahmad Hussain[2] and Mughal Sharif[1]**

*[1]Environmental Research Center, Department of Earth and Environmental Science, Bahria University, Karachi Campus, Pakistan; [2]Department of Mechanical Engineering, DHA Suffa University Karachi, Pakistan.*

**Abstract**: Pakistan has enormous coal reserves and needs to recognize the latest technology concerning coal. Coal combustion is receiving too much attention about electricity production and pollution control. This study is aimed to evaluate the characteristic parameters of Thar local coal samples from Block-II and adjacent Block-VI for toxicity consideration and to estimate the potential of Thar coal assets for environment-friendly consumption in power production. In the current study, forty Thar coal samples from each Block II and adjacent Block VI were analyzed for their physicochemical and pyrolysis properties with the chemical configuration of coal ashes. The mean moisture content found in both Thar coal blocks (44.28-47.76%) respectively high as a similar volatile matter (31.06-32.54%) and low ash (6.71-6.95%). The mean sulfur percentage in both Thar coal (0.79-1.05%) was also found moderate to low. Mean calorific values (5260-6339 Btu/lb) of local coals show their potential as a future fuel. In the coal ash analysis, it can be realized that mostly ash contents are comprised of organic substances and the major compounds are $SiO_2$, $Fe_2O_3$, $Al_2O_3$, and CaO. In Thermo Gravimetric Analysis (TGA) analysis, Pyrolytic heating rate and temperature were established to have important effects on the pyrolysis of Thar Coal. Kinetic constraints (frequency factor and activation energy) were gained by curve-fitting the investigational data. For electricity generation, the utilization of Thar coal assets is not limited to their burning, but additional steps must be taken to utilize the tools to reduce the pollution volume of coal and its harmful impacts on the environment. Innovative tools with advanced efficacy and fewer environmental impacts are essential to handle these low-rank coals and to transform them into energy e.g., Circulating Fluidized Bed Combustor (CFBC) and other Clean Coal Technologies (CCT).

**Received:** August 26, 2020; **Accepted:** 20 November 2021; **Published:** 28 December 2021
***Correspondence:** Jawad Abdullah Butt, Environmental Research Center, Department of Earth and Environmental Science, Bahria University, Karachi Campus, Pakistan; **Email:** jawadbutt.bukc@bahria.edu.pk
**Citation:** Butt, J.A., Y. Nergis, A. Hussain and M. Sharif. 2021. Physiochemical assessment of Pakistani Thar coal, a solution for sustainable energy crises and reduced environmental impacts. *Journal of Engineering and Applied Sciences,* 40(2): 100-109.
**DOI:** https://dx.doi.org/10.17582/journal.jeas/40.2.100.109
**Keywords:** Thar coal, Power generation, Physiochemical analysis, Ash, Thermo gravimetric analysis



## Introduction

Coal is the preferred energy fuel for power production all over the world. Easily availability of coal in the vicinity and continuously elevated prices of oil and natural gas, make electricity from coal-fired plants more economically attractive and feasible (Moti *et al.*, 2012). Pakistan's energy needs are vast, and chronic electricity shortages are one of the key issues for the government (EIU, 2017).

The ambition for fast economic growth, the key to rapid industrialization combined with increasing urbanization and development in technology are responsible for increasing the energy demand (Moti *et al*., 2012). To meet this energy demand, fossil energy sources are used and various pollutants are generated. These pollutant gases cause different effects on the environment including the greenhouse effect, air pollution, global warming and climate change (Bariani *et al*., 2020; Atimtay, 2003). The severe energy crisis also causes adversative economic, social and environmental impacts. This directly affected industrial, commercial and population activities (Naseem, 2015).

Sustainable delivery of power to meet the present and upcoming industrial and domestic requirements in Pakistan will depend on full-scale production from the different energy sources to create major inputs to the supply chain. Present power production has an enormous financial load on the country's economy because of the importation of oil to maintain the existing energy mix, and the condition is heightened by the fast decline of gas assets (Raheem *et al*., 2016). As per the Pakistan Economic Survey 2019–20, the installed electricity generation volume touched 37,000 MW in 2020 (Bhutta, 2020). The extreme total demand is approximately 25,000 MW; however, the transmission and supply volume are stuck at around 22,000 MW (Rehman, 2020). This shows a shortfall of about 3,000 MW at peaks demand. To meet up the predictable requirement exploiting local resources, such as Thar coalfield, a 100,000 MW production capability reserve, could be the feasible answer (Masih, 2018). Pakistan has wide reserves of coal. Overall Pakistan coal assets are more than 185 billion tons, of which only 175.5 billion tons reserves from Thar coal. In the fuel mix for Pakistan 2020, only 12% of its total power has been generated using coal (IEA, 2020). Pakistan has the world's seventh-largest reserves of lignite coal that can produce 100,000 MW of electricity each year for 200 years (EIU, 2017).

Quality of coal is now important on coal-burning particularly in various capacities of the power plant process. The factors of coal rank, proximate analysis, ultimate analysis, heating value and thermogravimetric analysis (TGA) in coal involve distinctive attention as they illustrate the ignitibility and reactivity of coal and easiness of reaction (Demirbas, 2005). Ash content of coal study will deliver the technical source for their widespread consumption and decreasing environmental pollution (Rizvi *et al*., 2015). Hence, physicochemical assessments of the Thar Block II and VI coal are imperious, regarding the upcoming probable environmental exposures to adjacent populations. Harmful impacts of coal on the surrounding environment are due to the emission of different pollutants like sulfur and nitrogen oxides, particulate matter, carbon monoxide, carbon dioxide, etc. (Diego, 2015). Current use of coal, make a challenge for reducing air pollutants from the coal power plant. Therefore, it is essential to make a control mechanism or tools to decrease these harmful coal emissions (Zheng, 2011). Clean coal technology provided an economically viable solution to greenhouse gases and other pollution from coal-based power generators. Research data on the newly discovered Thar coal from Pakistan is relatively limited. Present work describes different samples from Block II and adjacent Block VI for coal characterization. This study is aimed to add new knowledge for efficient utilization of Thar coal with minimal environmental impacts.

Thar coal reserves total estimated areas about 9000 sq. Km. Depth of total reserves about 155-200 meters and total estimated reserves about 175 billion tons. The collective thickness of the coal seam is about 24 meters. The total area of drilled 12- blocks is 1192 Sq. Km. Coal reserves at each block are approximately 2.0 billion tons. Each block can produce electricity approximately 4000-5000 MW for 30 Years (TCEB, 2017). As on the existing setup and promising geology, Thar coalfield has been distributed into twelve blocks (I–XII), whereas Block-II and adjacent Block-VI are relatively important for energy production, shown in Figures 1 and 2.

Sindh Coal Authority (SCA) has granted a 95.5 square kilometer ($km^2$) vicinity of the coalfield, known as Thar Block II, to Sindh Engro Coal Mining Company (SECMC) for exploration and development of the coal resources in the block. SECMC is set up a 660 MW (2×330 MW, that is, two units of 330 MW each) mine-mouth power plant within Block II. A (2 × 330 MW) power plant in the first stage utilizing circulating fluidized bed (CFB) boiler technology (Hagler, 2014). Thar block VI has sited in the southern part the Thar coal and center of the coalfield occupied an area of 66.1 square kilometers. A reserve of 529 Mt has been sanctioned over a 20 square kilometer area. For exploration and progress of Block VI, Oracle Power PLC structure coalmine mouth power plant up to 1200MW capability and initiative to build a 600MW plant at the site (NTS, 2017). Following are the Thar coal Block II and VI-based power projects shown in Table 1.

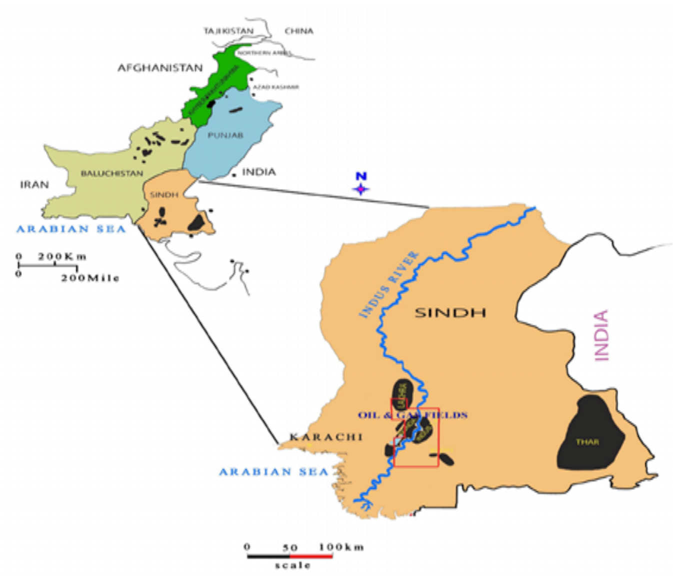


**Figure 1:** *Map of the coal deposits of Pakistan and Thar coalfield (Ahmed et al., 2015).*

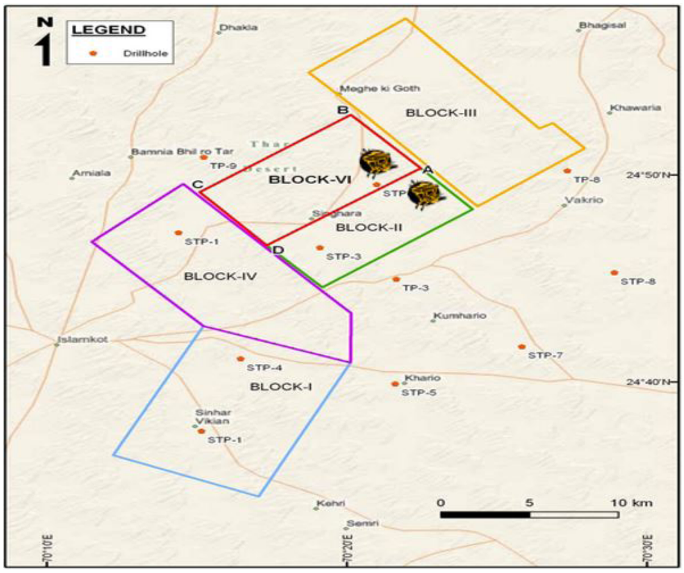


**Figure 2:** *Study Area Map of Thar Block-II and VI.*
**Source:** https://www.beltroad-initiative.com/bri-factsheet-series-thar-engro-coal-power-project/ accessed on 15/03/2020.

The objectives of the study are: To evaluate the characteristic parameters such as proximate, ultimate, ash analysis, heating or calorific value and thermogravimetric analysis (TGA) of Thar local coal samples from Block-II and adjacent Block-VI for toxicity consideration and to estimate the latent consumption of Thar coal assets for the environment-friendly consumption in the power production. The quality of coal, guide us to evaluate their environmental impacts throughout energy production. The result of this evaluation will not be limited to local utilization, but also be helpful in the local environment and to reduce power or electricity shortage in Pakistan.

**Table 1:** *Thar Coal Block II and VI Based Power Projects (TCEB, 2017).*

| Block | Investment firm | Total coal potential of block billion tons | Power projects initiated/ Planned |
|---|---|---|---|
| Block-II | SECMC Pakistan | 1.584 | Phase-I 2X330 |
| | | | Phase-II 2X330 |
| | | | Phase-III 4X660 |
| Block-VI | Oracle coal fields (UK) | 1.423 | 2X330 |

## Materials and Methods

Coal is a mixture of different substances; its shows various physical and chemical properties. Coal composition describes by different analysis ultimate, proximate as well as burning properties, e.g., heating value and thermogravimetric analysis (TGA). Thar coal was obtained from Block-II and adjacent Block-VI used in this study. In the current study, 40 samples from each block in replicates were selected for assessment. The results are an average value of forty representative samples of each coalfield. The widespread study on the explored reserve is a focus of concern to deliver the solution of energy scarcity by an operative and effective consumption of Thar reserve. Data were conducted according to the ASTM standard methods as Proximate Analysis (D-3172-5, D-3302) was performed in a Memmert oven and a Vulcan muffle furnace to define moisture content, volatile content, fixed carbon, and ash content. Ultimate Analysis (ASTM- D-3176, D-5373) was performed in a Elementar CHNS vario MICRO cube analyzer for the analysis of carbon, hydrogen, nitrogen, and sulfur contents of the dried coal samples. Calorific Value/Heating Value (ASTM- D-1989) was determined by bomb calorimeter under controlled conditions. Sample collection, preparation and analytical procedures were also conducted according to the ASTM procedures. Coal samples were packed, sealed and stowed cautiously in a container to avoid any mixing and moisture addition or loss. The samples were determined for air-dry loss (ADL) in an air-drying oven (ASTM D-3302) as well as crushed, ground and pulverized to 60 meshes (ASTM D-2013).

The leading coal ash mineral constituents (ASTM D3174) are also defined in this study.

Thar coal pyrolysis was conceded out by thermogravimetric analysis (TGA) (ASTM D7582). At constant heating rates (5-50 °C/min) the furnace was heated to a set temperature of 900°C from the ambient temperature. For an inert atmosphere for pyrolysis purified nitrogen (99.9995% purity) was consumed as the purge gas to deliver and to eliminate any contamination. The investigational data of the As-determined (Ad) basis was changed into As-received (AR) basis (ASTM D-3180-89). Flow chart showing sequence of coal sample preparation and chemical analysis, shown in Figure 3.

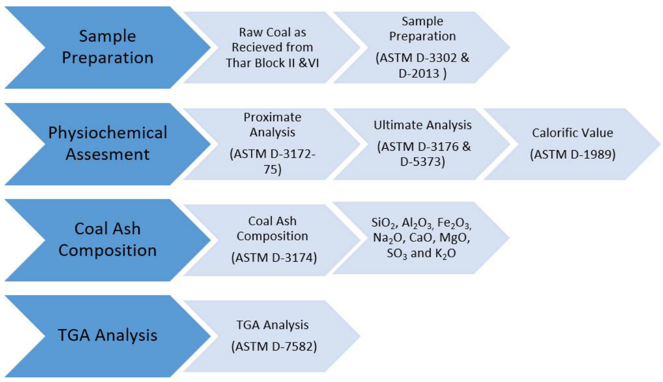


**Figure 3:** *Flow chart showing sequence of coal sample preparation and chemical analysis.*

## Results and Discussion

The properties of fuel normally formulated the basis for the technology selected for the burning course. The utmost significant fuel properties which provide the first impression of definite coal are set by proximate and ultimate analysis, thermogravimetric analysis (TGA), heating value and ash contents. Proximate analysis delivers moisture, volatile matters, fixed carbon and ash content in the coal whereas ultimate analysis provides exact elemental fractions of C, H, N S, and $O_2$. Further essential thermal and chemical properties include heating/calorific value, thermal properties, etc. The main coal ash minerals in coal are aluminum oxide, silicon dioxide, ferric oxide, magnesium oxide, calcium oxide, potassium oxide, sodium oxide and sulfur trioxide.

*Proximate analysis*

Proximate analysis and heating or calorific values of the samples are shown in Table 2 (Figures 4 and 5). The quality of coal was calculated on an as-received basis. The moisture content of Thar Block-II and VI samples almost high ranges between 34.78-51.90% (Mean 44.28%) and 40.19-55.89% (Mean 47.76%) respectively. The higher moisture content is observed in the Thar coal sample showing their lower heating value. Moisture shows a significant part in coal quality and usage characteristics. High water content in coal required additional time for heating and impacts the burning and the capacity of vent gases made per energy unit as well as a lesser calorific value (Sarwar *et al*., 2014). Moreover, high moisture content trends in more coal consumption and producing enormous vent gases volumes and requires huge equipment measurements. With the disadvantages of high moisture content, there is also an advantageous feature (Khan, 2007). Volatile Matter values are observed in Thar Block-II and VI samples range between 24.65-34.62% (Mean 31.06%) and 22.68-39.38% (Mean 32.54%), respectively. High volatiles in coal evaluates the ignition and burning efficiency. It supports the initial ignition and reactivity of coal for burning (Akowuah *et al*., 2012). Additionally, volatiles Fare sub-sectioned into gases such as light hydrocarbons, carbon dioxide, carbon monoxide, hydrogen and asphalts. The yields rely on the heating rate and temperature of coal to attain complete burning at high efficacy and to guarantee fewer emissions pollutants from the chimney (Anjum and Khan, 2017). Fixed carbon is the hard fuel remaining in the furnace when the volatile matter is extracted off. The fixed carbon percentage in Thar Block-II and VI samples range between 13.06-24.34% (Mean 17.70%) and 9.51-19.04% (Mean 13.25%), respectively. Thar coal samples contain low fixed carbon. The presence of fixed carbon in coal selects the grade of coal. The greater the heating values and fixed carbon greater will be the rank of coal (Hong and Slatick, 1994). The ash content in Block-II and VI samples range between 3.84-10.51% (Mean 6.95%) and 2.69- 26.26% (Mean 6.71%), respectively. Ash is the inorganic unburned portion of coal, which is leftward after the whole burning, comprising the majority of the mineral element. Due to high ash holding coal, a capable dust elimination arrangement must be there to control particulate releases. Moreover, high ash fractions lesser the heating value of the coal (Khan, 2007). The environmental distress of particulate matters is not only limited to release, however, but the removal of waste is also made due to the existence of other toxic materials in the ash (Anjum and Khan, 2017). The heating value, similarly named calorific value of the coal in Thar Block II and VI ranges between 5184.82-7136.8 Btu/lb (Mean 6339.38 Btu/lb) and 3263.01-6633.24 Btu/lb (Mean 5260.88 Btu/lb), respectively. Carbon and hydrogen tend to increase the heating value, whereas oxygen decreases it.

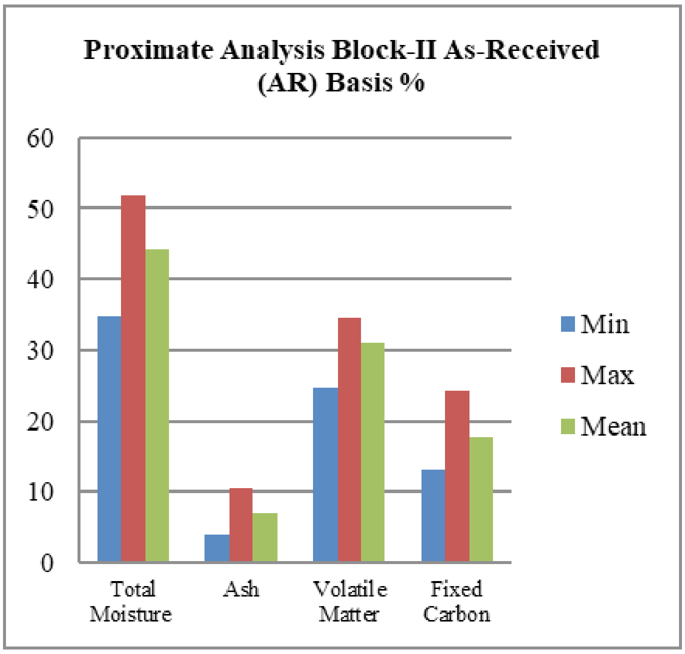


**Figure 4:** *Proximate analysis of the Thar block-II coal.*

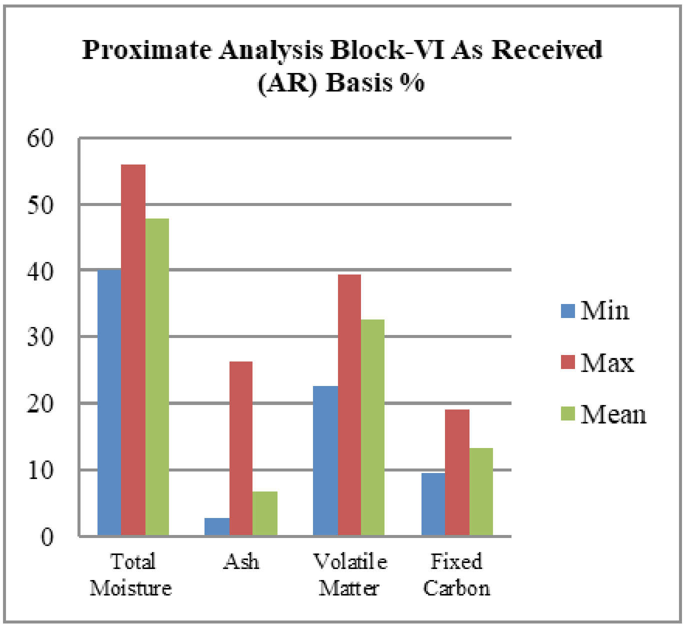


**Figure 5:** *Proximate analysis of the Thar block-VI coal.*

*Ultimate analysis*

The ultimate analysis of the Thar samples is shown in Table 3 (Figures 6 and 7). The quality of coal was calculated on an as-received basis. The ultimate analysis illustrates carbon, hydrogen, nitrogen and sulfur as well as oxygen percentage. Those amounts are very vigorous to assess the characteristics of coal for burning and emission purposes.

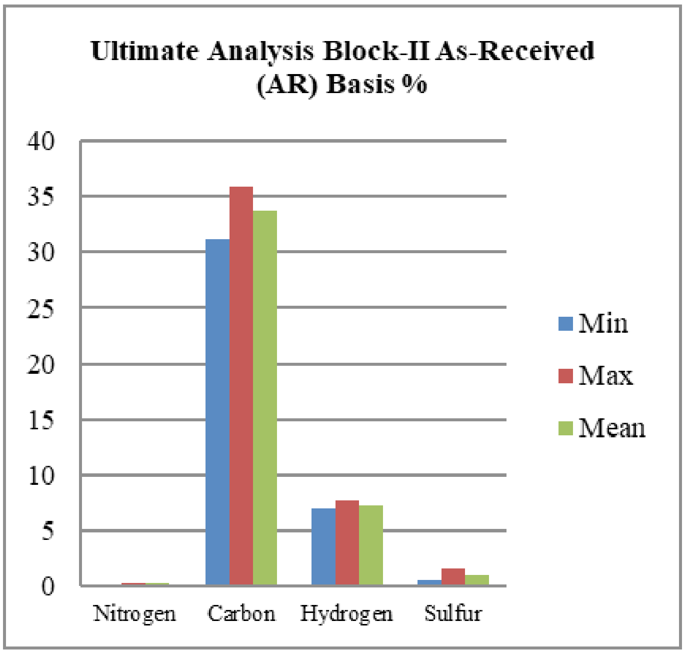


**Figure 6:** *Ultimate analysis of the Thar block-II coal.*

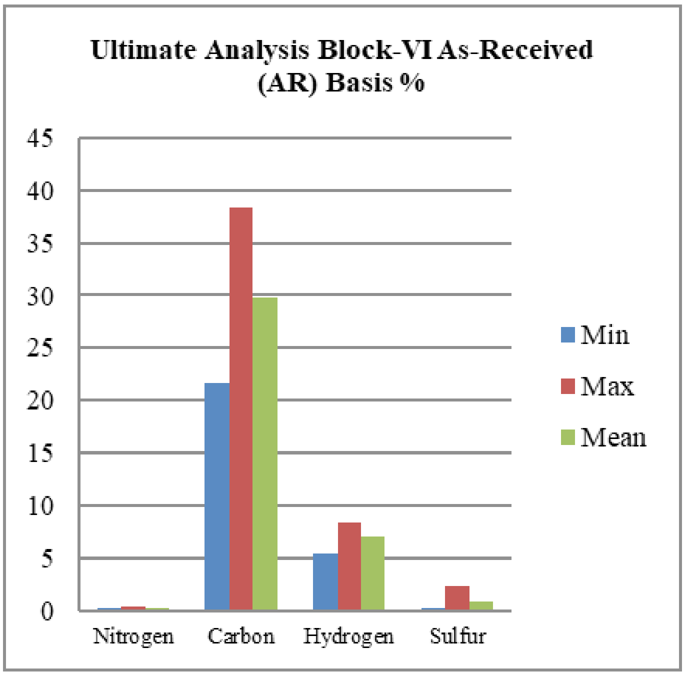


**Figure 7:** *Ultimate analysis of the Thar block-VI coal.*

Carbon value in Thar Block-II and VI samples range between 31.22-35.90% (Mean 33.65%) and 21.69-38.36% (Mean 29.77%), respectively. Greater carbon contents samples comprise more heating values. This bases a discharge of carbon dioxide ($CO_2$) in the air at a momentous level (Hong and Slatick, 1994). The hydrogen percentage in Thar Block-II and VI samples range between 7.02-7.74% (Mean 7.29%) and 5.43-8.43 (Mean 7.01%), respectively. The Hydrogen/ Carbon relation in coal has importance in coal transformation courses. Nitrogen percentages are nearly similar in all the Thar Block II and VI samples range between 0.20-

0.39% (Mean 0.28%) and 0.24-0.35% (Mean 0.30%) respectively. Nitrogen is liable for NOx creation in coal burning, which is one of the main pollutants in the atmosphere. After the creation of NOx and SOx, they are related to particulate matter ($PM_{2.5}$) (Querol *et al*., 1998). Adding of moisture in these oxides in the atmosphere, as a result, precipitation of acid called acid rain. Most countries are already using low NOx burners to lower the NOx release (You and Xu, 2010). Sulfur values from both Thar Block II and VI show the ranges between 0.66-1.66 (Mean 1.05%) and 0.26-2.32% (Mean 0.79%), respectively. Sulfur is called one of the benchmarks contaminants because of discharges the SOx in the course of burning and its bases, numerous environmental exposures (Nakicenovic *et al*., 2000). The lower-cost technique of decreasing the sulfur from coal and creating it environmentally friendly is washing coal before burning. It decreases up to 50% of sulfur, related to pyrite as well as usage of limestone (Basu, 2015). The oxygen percentage found in both Thar Block II and VI samples in the ranges between 39.41-48.31% (Mean 42.52) and 41.06-56.39% (Mean 47.69%), respectively. The higher oxygen percentage decreases the heat formation capability of coal through impulsive burning. The studied samples comprise higher oxygen and therefore lesser heating values.

*Assessment of Thar coal ash*

Assessment of Thar coal Block II and VI ash is shown in Tables 4 and 5 (Figures 9 and 10). In the coal ash analysis, it can be realized that coal ashes from both blocks are mostly comprised of organic substances and the major compounds are $SiO_2$, $Fe_2O_3$, $Al_2O_3$, and CaO as well as lower quantities of $Na_2O$, $SO_3$, and $K_2O$ observed. Ash characterizes the larger quantity of mineral substance afterward compelled off in burning. The coal yield ashes and their geochemical properties define the coal quality and its developing circumstances. The assessment of coal ash defines the configuration of coal ash. These facts are beneficial for environmental impact modeling. The configuration of coal ashes depends on the structure of organic matter and inorganic mineral deposits in coal.

**Table 2:** *Thar coal block-II proximate and ultimate analysis as received basis (AR).*

| Variable | Proximate analysis (%) | | | | Ultimate analysis (%) | | | | | Gross calorific value Btu/lb |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total moisture | Ash | Volatile matter | Fixed carbon | N | C | H | S | O | |
| Min | 34.78 | 3.84 | 24.65 | 13.06 | 0.20 | 31.22 | 7.02 | 0.66 | 39.41 | 5184.82 |
| Max | 51.90 | 10.51 | 34.62 | 24.34 | 0.39 | 35.90 | 7.74 | 1.66 | 48.31 | 7136.8 |
| Mean | 44.28 | 6.95 | 31.06 | 17.70 | 0.28 | 33.65 | 7.29 | 1.05 | 42.52 | 6339.38 |

**Table 3:** *Thar coal block-VI proximate and ultimate analysis as received basis (AR).*

| Variable | Proximate analysis (%) | | | | Ultimate analysis (%) | | | | | Gross calorific value Btu/lb |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total moisture | Ash | Volatile matter | Fixed carbon | N | C | H | S | O | |
| Min | 40.19 | 2.69 | 22.68 | 9.51 | 0.24 | 21.69 | 5.43 | 0.26 | 41.06 | 3263.01 |
| Max | 55.89 | 26.26 | 39.38 | 19.04 | 0.35 | 38.36 | 8.43 | 2.32 | 56.39 | 6633.24 |
| Mean | 47.76 | 6.71 | 32.54 | 13.25 | 0.30 | 29.77 | 7.01 | 0.79 | 47.69 | 5260.88 |

*Comparative analysis of Thar coal with Different Lignite Coal, shown in* **Figure 8**.

**Table 4:** *Thar coal block-II ash analysis.*

| | Thar block- I1 coal ash analysis (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $K_2O$ | $Na_2O$ | $SO_3$ |
| Min | 19.41 | 12.53 | 7.77 | 5.00 | 3.86 | 0.17 | 2.37 | 4.50 |
| Max | 33.93 | 26.24 | 18.84 | 18.22 | 8.10 | 0.54 | 4.73 | 14.83 |
| Mean | 28.51 | 18.62 | 13.25 | 10.68 | 5.78 | 0.34 | 3.40 | 8.89 |

**Table 5:** *Thar coal block-VI ash analysis.*

| | Thar block- VI coal ash analysis (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $K_2O$ | $Na_2O$ | $SO_3$ |
| Min | 43.29 | 9.54 | 7.16 | 4.39 | 2.27 | 0.47 | 0.48 | 0.016 |
| Max | 62.55 | 32.64 | 16.29 | 9.27 | 4.32 | 1.02 | 8.94 | 0.092 |
| Mean | 53.04 | 20.02 | 11.24 | 6.65 | 3.28 | 0.75 | 4.22 | 0.050 |

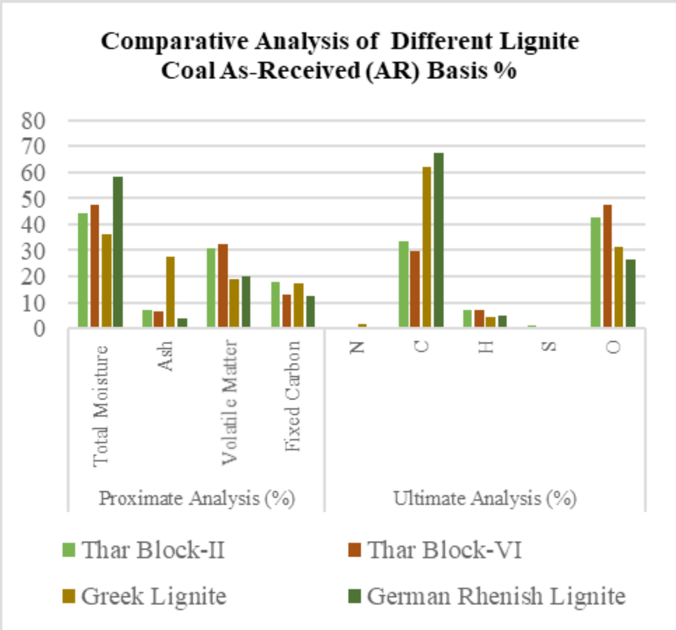


**Figure 8:** *Comparative analysis of Thar coal with different lignite coal as-received (AR) basis (%).*
**Source:** (Daood *et al*., 2014).

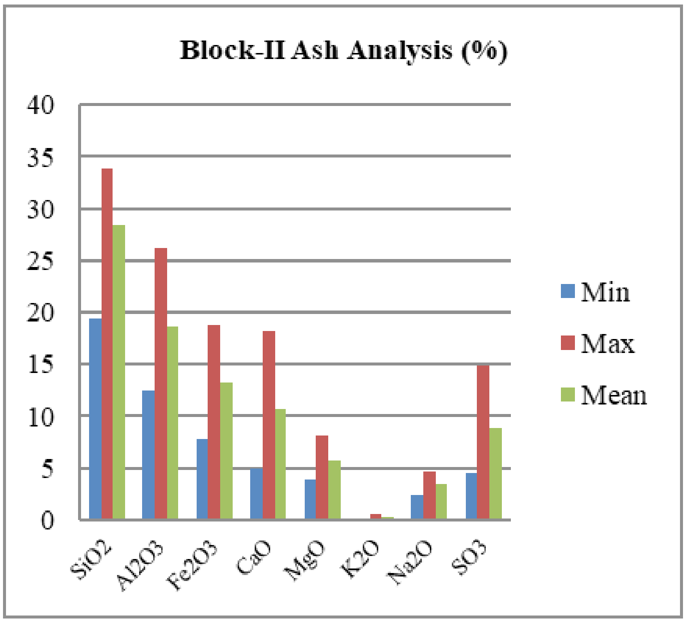


**Figure 9:** *Ash analysis of the Thar block-II coal.*

In coal burning course, both organic and inorganic materials will be released and reformed. Some portion of them will be discharged as volatiles with coal smoke into the air and other portions which are existent in dust, flying ash and small particles. Selected chemical constituents in the inorganic material of residues are resulting from organic material in the coal and will exist as a novel part and mineral constituents in the ashes (Choudry *et al*., 2010).

*Thermo gravimetric analysis (TGA)*

Figure 11 and 12 shows the remaining weight portions of 60 mesh size coal powder go through pyrolysis for heating rates variable from 5-50°C. It indicated a major weight loss in the key decomposition. At the start, CO and $CO_2$ were discharged as the major gaseous pollutants and at the main decomposition period, an enormous volume of gaseous pollutants such as CO, $CO_2$, $H_2$ and hydrocarbons (i.e. $CH_4$; $C_2H_6$; $C_2H_4$) were discharged, due to major weight loss.

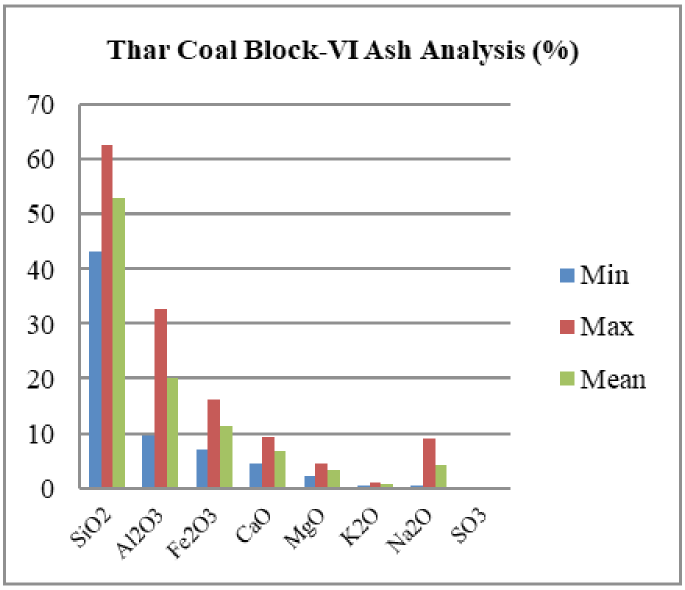


**Figure 10:** *Ash analysis of the Thar block-VI coal.*

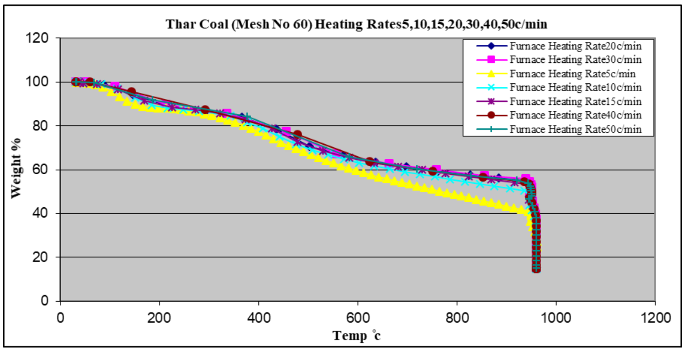


**Figure 11:** *TGA analysis of weight loss (%) for different heating rates for Thar coal of 60 mesh size.*

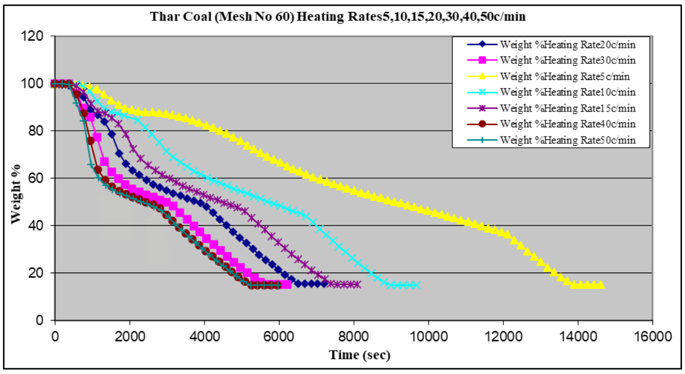


**Figure 12:** *TGA analysis of weight loss (%) as a function of time for different heating rates for Thar coal of 60 mesh size.*

By consuming Figure 11 statistics from the pyrolysis thermograms, the activation energy (*E*), the kinetic parameters and the frequency factor (*A*), were assessed by Figure 13 with elevated correlation coefficients (all beyond 0.94) and recorded in Table 6. For the pyrolysis of Thar coal, the orders of reaction for all the heating rates were first-order reaction mechanisms. Greater the heating rate was shown the activation energy also changed, but the frequency factor was reliant on heating rate, increasing gradually from $6.8\ x10^3$ to $6.2\ x\ 10^4\ s^{-1}$. This recommended that the pyrolytic reaction would be quicker and easier as greater the heating rate. These constraints can be used to forecast the time-changing profiles for the pyrolytic course of altered heating rates.

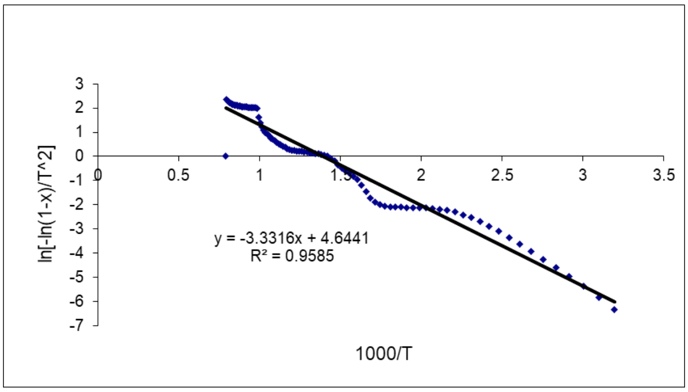


**Figure 13:** *Kinetic plot for a typical heating rate.*

**Table 6:** *Kinetic parameters for the pyrolysis of Thar coal of 60 mesh size.*

| Heating rate | Activation energy (kJ/mole) | Frequency factor ($min^{-1}$) |
|---|---|---|
| 5 °C/min | 80.16 | 6.8 x 103 |
| 50 °C/min | 102.01 | 6.2 x 104 |

## Conclusions and Recommendations

The data attained in Thar coal assessment, moisture and volatile matter content are higher in all samples, proposing that those variables which are correlating similar in both block analysis, indicating that values of energy are dependent on volatile matter, while the higher moisture content will decrease the efficacy of power production. The sulfur content in both Thar coal blocks was also found moderate to low as well as high to moderate carbon percentage. In the coal ash analysis, it can be realized that mostly ash contents are comprised of organic substances and the major compounds are $SiO_2$, $Fe_2O_3$, $Al_2O_3$, and CaO as well as lower quantities of $Na_2O$, $SO_3$, and $K_2O$ observed. Overall, both Block's coal has almost similar properties, but in view above, Thar Block II coal is some better than Block Block-VI coal for power generation.

In TGA analysis, pyrolytic heating rate and temperature were found to have important effects on the pyrolysis of Thar Coal. Kinetic parameters (frequency factor and activation energy) were gained by curve-fitting the investigational data. Using these kinetic parameters, a one-step universal model was consumed to forecast the pyrolytic transformation.

For electricity generation, the utilization of Thar coal assets is not limited to their burning, but additional steps must be taken to utilize the tools to reduce the pollution volume of coal and its harmful impacts on the environment. It comes to be necessary for the policymakers to propose guidelines for the implementation of suitable technologies in the coal energy sectors to reduce the harmful impacts on the environment. The most favorable and very effective technology for power production from Thar lignite coal is Circulating Fluidized Bed Combustor (CFBC) as well use of suitable Clean Coal Technologies (CCT) to minimize emissions.

## Acknowledgments

The authors would like to give special recognition to Environmental Research Center, Bahria University Karachi Campus Pakistan, for providing the facilities of Labs for this research work.

## Novelty Statement

This study is to provide the latest data on Thar coal quality for the upcoming new power plant in Pakistan for environment-friendly consumption.

## Author's Contribution

**JAB** conceptualization, lab analysis, data analysis, writing original draft.
**YN** conceptualization, visualization, review and editing, supervision.
**AH** visualization, review and editing.
**MS** visualization, data analysis.

*Conflict of interest*
The authors have declared no conflict of interest.

## References


Ahmad, A., M.H. Hakimi and M.N. Chaudhry. 2015. Geochemical and organic petrographic characteristics of low-rank coals from Thar coalfield in the Sindh Province, Pakistan. Arab J. Geosci., 8: 5023–5038. https://doi.org/10.1007/s12517-014-1524-6

Akowuah, J.O., F. Kemausuor and S.J. Mitchual. 2012. Physico chemical characteristics and market potential of sawdust charcoal briquettes. Int. J. Energy Environ. Eng., 3: 20. https://doi.org/10.1186/2251-6832-3-20

Anjum, G., and M.N. Khan. 2017. The power generation from coal in Pakistan: Assessment of physicochemical pollutant indicators in indigenous reserves in comparison to the foreign coal. Pak. J. Anal. Environ. Chem., 18(1): 54-63. https://doi.org/10.21743/pjaec/2017.06.05

Atimtay, A.T., 2003. A global outlook to the carbon dioxide emissions in the world and emission factors of the thermal power plants in turkey. Water, Air, Soil Pollut. Focus, 3(5-6): 335-345. https://doi.org/10.1023/A:1026086002856

Bariani, M., E. Boix, F. Cassella, and M.n. Cabrera. 2020. Furfural production from rice husks within a biorefinery framework. Biomass Conv. Biorefinery, pp. 1–14. https://doi.org/10.1007/s13399-020-00810-1

Basu, P., 2015. Circulating fluidized bed boilers design, operation and maintenance. Springer International Publishing Switzerland. ISBN 978-3-319-06172-6.

Bhutta, Z., 2020. Installed power production capacity rises. The Express Tribune. Retrieved 4 June 2020.

Choudry, M.A.F., Y. Nurgis, M. Sharif, A. Mahmood, and H. Abbasi. 2010. Composition, trace element contents and major ash constituents of Thar coal, Pakistan. Am. J. Sci. Res., 11: 92-102.

Daood, S.S., M.T. Javed, A.H. Rizvi and W. Nimmo. 2014. Combustion of Pakistani lignite (Thar coal) in a pilot-scale pulverized fuel down-fired combustion test facility. Energy Fuels, 28(2): 1541-1547.

Demirbas, A., 2005. Biomass co-firing for boilers associated with environmental impacts. Energy Sources, 27(14): 1385-1396. https://doi.org/10.1080/009083190523217

Diego P., 2015. A study of an oxy-coal combustion with wet recycle using CFD modeling. ATI 2015. Ener. Proced., 82: 900-907. https://doi.org/10.1016/j.egypro.2015.11.837

EIU Report, 2017. http://www.eiu.com/industry/article/825415066/betting-on-coal-to-solve-the-electricity-shortage/2017-05-11. The Economist Intelligence Unit. (Accessed 11th May 2017).

Hagler, B., 2014. Environmental and Social Impact Assessment (ESIA). Thar Coal power project block II final report. Hagler Bailly Pakistan. 1, 2(6-1): 6-24.

Hong, B.D. and E.R. Slatick. 1994. Energy information administration (DC quarterly coal report, Washington, DC). January–April 1994, DOE/EIA-0121(94/Q1) (Washington, DC, August 1994), 2: 1–8.

IEA, 2020. Global energy and $CO_2$ status report 2020. https://www.iea.org/geco/.and https://www.iea.org/countries/pakistan. Accessed on 5th January 2021.

Khan, A.A., 2007. Combustion and co-combustion of biomass in a bubbling fluidized bed boiler. Ph. D. thesis by Atif Ahmed Khan. Technische Universiteit Delft, Netherland.

Masih, A., 2018. Thar coalfield: Sustainable development and an open sesame to the energy security of Pakistan. IOP Conf. Series: J. Phys. Conf. Ser. 989 012004, Taiwan. https://doi.org/10.1088/1742-6596/989/1/012004

Moti, L., Mittal, C.S. Hemendra and S. Richa. 2012. Estimates of emissions from coal fired thermal power plants in India. Paper presented at the 2012 international emission inventory conference, Tampa, Florida, USA.

Nakicenovic, N., J. Alcamo, A. Grubler, K. Riahi, R.A. Roehrl, H.H. Rogner and N. Victor. 2000. Special report on emissions scenarios (SRES), a special report of working group III of the intergovernmental panel on climate change. Cambridge University Press. ISBN 0-521-80493-0.

Naseem, A., 2015. Biomass energy potential in Pakistan. Technol. Times, 6(14).

Non-Technical Summary (NTS), 2017. Thar coalfields block VI, 2x330MW coal-fired power plant. Oracle Coalfields PLC. http://www.oraclepower.co.uk/operations/thar-coalfield-block-vi/.

Querol, X., A. Alastuey, J.A. Puicercus, E. Mantilla, C.R. Ruiz, A. Lopez-Soler, F. Plana, R. Juan, and J. Atmos. 1998. Seasonal evolution of suspended particles around a large coal-fired power station: particulate levels and sources. Atmos. Environ., 32: 1963–1978. https://doi.org/10.1016/S1352-2310(97)00504-9

Raheem, A., S.A. Abbasi, A. Memon, S.R. Samo, Y.H. Taufiq, M.K. Danquah and R. Harun. 2016. Renewable energy deployment to combat energy crisis in Pakistan. Energy Sustain. Soc., 6: 16. https://doi.org/10.1186/s13705-016-0082-z

Rehman, M., 2020. Pakistan's electricity generation has increased over time. So why do we still not have uninterrupted supply. DAWN.COM. Retrieved 4 June 2020.

Rizvi, A.H., S.S. Daood, M.T. Javed, S. Munir, M. Pourkashanian and W. Nimmo. 2015. Reactivity analysis of Pakistani Thar lignite reserves in oxidizing thermogravimetric analysis atmospheres. Energy Fuels, 29(8): 5349–5360. https://doi.org/10.1021/acs.energyfuels.5b00748

Sarwar, A., M.N. Khan and K.F. Azhar. 2014. The physicochemical characterization of a newly explored Thar coal resource. Energy Sour. A Recov. Utiliz. Environ. Effects, 36(5): 525-536. https://doi.org/10.1080/15567036.2010.542447

TCEB, 2017. Thar coal energy board. (Accessed on March 2020). http://www.shamrockconferences.net/energy2017/presentations/energy17-04.pdf.

You, C.F. and X.C. Xu. 2010. Coal combustion and its pollution control in China. Energy, Elsevier, 35(11): 4467-4472. https://doi.org/10.1016/j.energy.2009.04.019

Zheng, L., 2011. Oxy-fuel combustion for power generation and carbon dioxide ($CO_2$) capture. Sawstone: Wood head Publishing Limited. ISBN: 9780857090980. https://doi.org/10.1533/9780857090980.3.335