Global Scientific JOURNALS

GSJ: Volume 9, Issue 8, August 2021, Online: ISSN 2320-9186

www.globalscientificjournal.com

Desulfurization and demineralization of high sulfur Mianwali Coal using Flotation and Leaching

Adnan Miran[1], Muhammad Abid[1], Shahid Imran Anjum[1], Rana Nabeel Amjad[1], Muhammad Hamid Butt[1*]

[1] *Department of Chemistry, University of Management and Technology, C-II, Johar Town Lahore 54770, Pakistan*

Corresponding author.
E-mail address: hamidbutt28@gmail.com (M. Hamid Butt).

Abstract

High sulfur low-grade lignite coal of Mianwali was carried out under flotation and leaching process to improve its properties by lowering its sulfur and ash content. After performing the proximate analysis of the Mianwali coal, the sample was processed under flotation and leaching process, respectively. The flotation process reduces the ash and sulfur content up to 30.9% and 20.8%, respectively. Furthermore, the floated sample was carried out under the leaching process in which $Ca(OH)_2$ was used as a leaching agent which effectively reduced the ash and sulfur content up to 53.5% and 54.9%, respectively. The overall reduction in the ash and sulfur content is about 67.6% and 65.7%, respectively which also manifests a positive effect on the gross calorific value of coal. This effort may help on an industrial scale to reduce the ash and sulfur content of Mianwali coal to improve the quality of coal.

Keywords: desulfurization, demineralization, flotation, leaching, Mianwali Coal

Introduction

With the swift increase in the population of the world, the energy demand is also on a crucial stage to fulfill their needs (Hasanuzzaman, *et al.*, 2020). Therefore, coal is one of them that is considered a cheaper energy source (Hasanuzzaman, *et al.*, 2020). Pakistan has a coal reserve of 185 billion tons which is mainly of lignite-A to subbituminous-C in rank (Malkani, *et al.*, 2016). In the Punjab province, the Mianwali coal reserve is more prominent which is of lignite in rank (Rehman, *et al.*, 2016). The Mianwali coal is characterized by high sulfur content (3.2-9.94%), high ash content (6.26-38.51%), and high heating value. The high ash and sulfur content present in the coal manifest the inferior quality of coal and also harm the environment (Chou, 2012). Because the excessive ash of coal is somehow difficult to dispose of. The sulfur content also acts as a pollutant for the environment and living things (Liu, *et al.*, 2001, Munawer, 2018). The reserves of superior quality coal are being depleted day by day. Therefore, it is the need of the hour to utilize the inferior quality coal by manipulating them. The treatment of coal by desulfurization(Pollak, *et al.*, 1986) and demineralization (Meshram, *et al.*, 2015) techniques improve the quality of coal. The treatment techniques are based on physical (Ayhan, *et al.*, 2005), chemical (Baláž, *et al.*, 2001), and biological (Luthy, *et al.*, 1980) methods. The choice of treatment techniques is merely based on the compositions of mineral matter that are associated with coal. In Mianwali coal, silica and alumina are the major constituent in the mineral matter (Khan, 2011). Therefore, physical and chemical treatment techniques are effective for the removal of the mineral matter in the coal.

This research work aims to investigate the effect of flotation and leaching with $Ca(OH)_2$ on the desulfurization and demineralization of Mianwali coal using fixed temperature (100°C) at varying concentrations (0.5, 1.0, 1.5, 2.0, and 2.5 molars) and time (30, 60, 90, 120, and 150 minutes). The selection of Mianwali coal is due to its low-grade lignite nature with high ash forming mineral and sulfur content, huge reserves, and easy accessibility.

Experimental Work

The lumpy coal was collected as a sample from the Mianwali coal mine and stored in plastic bags. The sample was prepared by crushing it through a jaw crusher and pulverized up to the desired size using the pulverizer. The sample was ground to 60#, collected, and performed its proximate analysis according to ASTM standard procedures (Speight, 2005). The heating value was determined using Bomb Calorimeter (Edie, *et al.*, 2018). Furthermore, the sulfur content of the Mianwali coal was also determined by adopting the Eschka method for sulfur determination (Mott, *et al.*, 1953).

In the flotation process, the 200 g of prepared sample of coal was mixed with 800ml of dist. water to make 20% solid/liquid slurry. The slurry was added into the flotation tank and turn on the impeller. The slurry was agitated for 5 minutes and then added 5-10 drops of kerosene oil as a collector. After that, 2-3 drops of pine oil as a frothier were added and agitated again for 5 minutes. The concentrate was removed continuously with the help of a scrapper and the tailings were left to settle down. Then, this concentrate was dried and processed under the proximate analysis and Eschka method. The gross calorific value was also determined using a bomb calorimeter.

In the Leaching process, the concentrate of Mianwali coal obtained from the flotation process was carried out in a three-neck flask in the presence of $Ca(OH)_2$ as a leaching agent. A 5g of concentrate was added into 95ml of $Ca(OH)_2$ of specific molar concentration in the three-neck flask fitted with a reflux condenser and constant stirring for the desired time. The flask content was filtered and washed with hot distilled water. The effect of the concentration of the leaching agent was determined at different times by fixing the temperature (100°C) and stirring rate (1000 rpm). The concentrations of the leaching agent were varied from 0.5, 1.0, 1.5, 2.0, and 2.5 molar against the time varied from 30, 60, 90, 120, and 150 minutes. Each time, the sample was dried at 105°C. Then, all the samples were carried out under proximate analysis, sulfur, and calorific value determination.

Results and discussion

Flotation and leaching methods are well-known processes in terms of coal cleaning (Önel, *et al.*, 2020). The alumina and silica are the main constituent of ash content in the coal (Senthil Kumar, *et al.*, 2019). When these minerals come in contact with $Ca(OH)_2$, these are converted into calcium aluminate and calcium silicate, respectively (Fincham, *et al.*, 1954). While sulfur is mostly found in coal in the form of pyritic sulfur that formed calcium sulfide while treating with $Ca(OH)_2$ and removed in the filtration process (Anshariah, *et al.*, 2020).

$$Al_2O_3 + Ca(OH)_2 \rightarrow Ca(AlO_2)_2 + H_2O$$

$$SiO_2 + Ca(OH)_2 \rightarrow CaSiO_3 + H_2O$$

$$FeS_2 + Ca(OH)_2 \rightarrow Fe(OH)_2 + CaS_2$$

Equation 0.1. *Reaction of alumina, silica, and pyritic sulfur with calcium hydroxide*

The proximate analysis was carried out according to relevant ASTM standard procedures. The results of proximate analysis of the sample of Mianwali coal on as-received basis are as follow

Table 0.1: *Proximate analysis, sulfur, and gross calorific value determination of Mianwali Coal*

					Proximate Analysis (wt % as-received basis)
Moisture	*Volatile matter*	*Fixed carbon*	*Ash*	*Total Sulfur*	*Gross Calorific Value (cal/g)*
9.23	*28.81*	*28.99*	*34.03*	*6.96*	*5,471*

Froth Flotation Process

Table 0.2: *Proximate analysis, sulfur, and gross calorific value determination of flotation concentrate*

	Proximate Analysis (wt % as-received basis)				
Moisture	*Volatile matter*	*Fixed carbon*	*Ash*	*Total Sulfur*	*Gross Calorific Value (cal/g)*
8.79	*32.74*	*34.57*	*23.75*	*5.30*	*5,616*

Leaching Process of the Flotation Concentrate

Table 0.3: *Proximate analysis, sulfur, and gross calorific value determination of the concentrate after leaching process*

	Proximate Analysis (wt % as-received basis)				
Moisture	*Volatile matter*	*Fixed carbon*	*Ash*	*Total Sulfur*	*Gross Calorific Value (cal/g)*
7.91	*37.08*	*40.39*	*11.03*	*2.39*	*5,953*

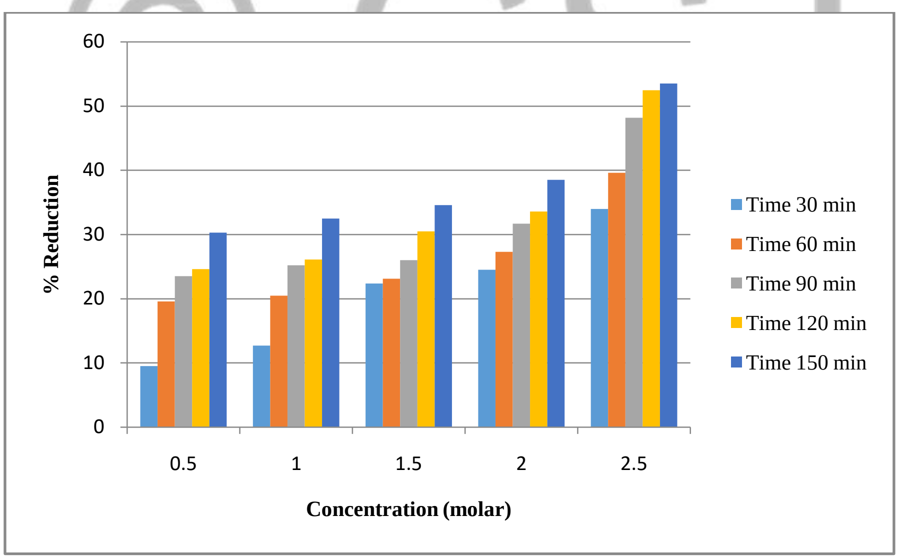

Figure 1: *Representation of effect of concentration (0.5, 1.0, 1.5, 2.0, and 2.5 molar) of calcium hydroxide on ash reduction at varying time period (30, 60, 90, 120, 150 minutes)*

In Figure 1, at a constant temperature of 100^{o}C for varying concentrations of calcium hydroxide (0.5, 1, 1.5, 2, and 2.5 molars), the ash reduction percentage varied from 10% to 54%. Since leaching of coal is a chemical process and as long as particles are fully suspended in the base, the concentration will influence ash removal rate. From experimental results, it was observed that at a higher time, removal of ash was comparatively greater than at the lower time. This may be due to the presence of even distribution of base and uniform temperature in the solution. The percentage of ash was found to be reduced at 150 minutes. More ash could be reduced if we increased the time. For the set of experiments performed in this study time of leaching 150 minutes was found to be the highest.

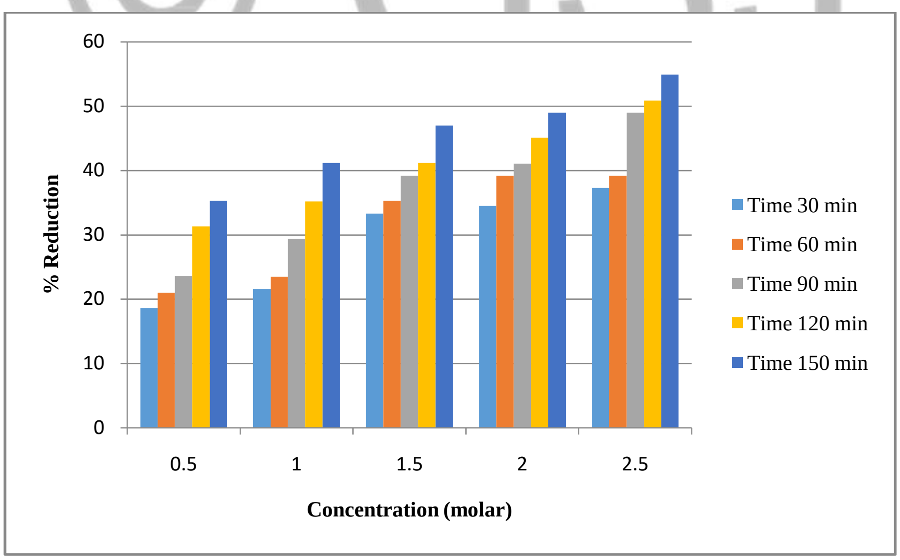

Figure 2: *Representation of effect of concentration (0.5, 1.0, 1.5, 2.0, and 2.5 molar) of calcium hydroxide on sulfur reduction at varying time period (30, 60, 90, 120, 150 minutes).*

In Figure 2, at constant temperature of 100^{o}C for varying concentration of calcium hydroxide (0.5, 1.0, 1.5, 2.0 and 2.5 molar), sulfur reduction percentage varied from 19% to 55%. Since leaching of coal is a chemical process and as long as particles are fully suspended in the base, the concentration will influence sulfur removal rate. From experimental results, it was observed that higher the time, the removal of sulfur was comparatively greater than at the lower time. This may be due to the presence of even distribution of base and uniform temperature in the solution. The percentage of sulfur was found to be reduced at 150 minutes. More sulfur could be reduced if we increased the time. For the set of experiments performed in this study time of leaching 150 minutes was found to be the highest.

Conclusion

The desulfurization and demineralization using flotation and leaching process have effectively reduced the ash and sulfur content by approximately 68% and 66%, respectively. These findings indicated that calcium hydroxide as a leaching agent has a significant effect on ash and sulfur reduction. The quality of low-grade lignite coals of Pakistani reserves may be improved by adopting such techniques.

References

1. Anshariah, A. M. Imran, S. Widodo and U. R. Irvan, **(2020)**. Correlation of total sulfur content to the percentage of pyrite content by microscopy in Mallawa formation coal, South Sulawesi Province, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 575, 012169.
2. Ayhan, F. D., H. Abakay and A. Saydut, **(2005)**. Desulfurization and Deashing of Hazro Coal via a Flotation Method. *Energy & Fuels*, 19(3), 1003-1007.
3. Baláž, P., R. B. LaCount, D. G. Kern and L. Turčániová, **(2001)**. Chemical treatment of coal by grinding and aqueous caustic leaching. *Fuel*, 80(5), 665-671.
4. Chou, C.-L., **(2012)**. Sulfur in coals: A review of geochemistry and origins. *International Journal of Coal Geology*, 100, 1–13.
5. Edie, S., Masturi, N. Safitri, D. Alighiri, Susilawati, L. Sari, P. Marwoto and R. Iswari, **(2018)**. The effect of using bomb calorimeter in improving science process skills of physics students. *Journal of Physics: Conference Series*, 983, 012205.
6. Fincham, C. J. B. and F. D. Richardson, **(1954)**. The Behaviour of Sulphur in Silicate and Aluminate Melts. *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences*, 223(1152), 40-62.
7. Hasanuzzaman, M., M. A. Islam, N. A. Rahim and Y. Yanping **(2020)**. Chapter 3 - Energy demand. Energy for Sustainable Development. M. D. Hasanuzzaman and N. A. Rahim, Academic Press**:** 41-87.
8. Khan, M. S., **(2011)**. Ranking of Patala Formation coal Salt Range Punjab and its application in coal fired power plants. *Science international*.

9. Liu, G., Z. Peng, P. Yang and G. Wang, **(2001)**. Sulfur in coal and its environmental impact from Yanzhou mining district, China. *Chinese Journal of Geochemistry*, 20(3), 273.
10. Luthy, R. G. and J. T. Tallon, **(1980)**. Biological treatment of a coal gasification process wastewater. *Water Research*, 14(9), 1269-1282.
11. Malkani, M. S. and Z. Malik, **(2016)**. Coal resources of Pakistan: new coalfields of Balochistan, Khyber Pakhtunkhwa and Azad Kashmir. *Journal of Himalayan Earth Sciences*, Volume ESP 2016, 102.
12. Meshram, P., B. K. Purohit, M. K. Sinha, S. K. Sahu and B. D. Pandey, **(2015)**. Demineralization of low grade coal – A review. *Renewable and Sustainable Energy Reviews*, 41, 745-761.
13. Mott, R. A. and H. C. Wilkinson, **(1953)**. The use of the Eschka method for the determination of high sulphur contents. *Journal of Applied Chemistry*, 3(5), 218-223.
14. Munawer, M. E., **(2018)**. Human health and environmental impacts of coal combustion and post-combustion wastes. *Journal of Sustainable Mining*, 17(2), 87-96.
15. Önel, Ö. and M. Tanrıverdi, **(2020)**. Flotation and leaching of hard coals for production of low-ash clean coal. *Physicochemical Problems of Mineral Processing*, 56, 528-537.
16. Pollak, H. and J. G. Stevens **(1986)**. Coal Treatment and Desulfurization. Industrial Applications of the Mössbauer Effect. G. J. Long and J. G. Stevens. Boston, MA, Springer US**:** 491-511.
17. Rehman, S. u., A. N. Shah, H. U. Mughal, M. T. Javed, M. Akram, S. Chilton and W. Nimmo, **(2016)**. Geology and combustion perspectives of Pakistani coals from Salt Range and Trans Indus Range. *International Journal of Coal Geology*, 168, 202-213.

18. Senthil Kumar, M., M. Vanmathi, G. Senguttuvan, R. V. Mangalaraja and G. Sakthivel, **(2019)**. Fly Ash Constituent-Silica and Alumina Role in the Synthesis and Characterization of Cordierite Based Ceramics. *Silicon*, 11(6), 2599-2611.

19. Speight, J. G. (**2005**). Handbook of Coal Analysis, Wiley.