Biodesulphurization As A Complement To Flotation For Cleaning Coal

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ABSTRACT

For fine particles, one of the most effective concentration methods is froth flotation. Froth flotation technique is widely used to recover fine coal particles, particularly from the waste waters of coal preparation systems/coal washing plants for years. Currently, the application of coal flotation is not practiced in Turkey. Therefore, the fine fraction of coal processing plants either directly sent to the nearby power plants without any processing or stored in waste dams. The waste water of plants that include fine coals is discarded as waste. The other important problem for coals is the sulphur content due to the emission of sulphur dioxide that causes serious environmental problems.

This study is about the cleaning the Mihalıççık Region lignites by bio desulphurization after flotation. The strain of *Alternaria* sp. isolated from coal itself was used for biodesulphurization. Sulphur measurements of coal were performed before and after flotation-desulphurization sequential system. The elimination yield of the desulphurization was 32% of sulphur.

Keywords: Low Rank Coal, Coal Flotation, Biodesulphurization, Alterneria Sp.

1. INTRODUCTION

The coal is preferred the primary energy source out of reserves are large, cheap and guaranteed. About 70% of coal is used to generate electricity which produces in the world. For electricity generation in 2030 is estimated to rise to the level of 79% (WCI 2005). In Turkey, there are reserves of coal in significant quantities that can be used to generate electricity (TEIAS, 2007). Our country's coal reserves, is given in the form of brown coal by the resources of the General Directorate of Mineral Research and Exploration, that 1.1 billion tons good quality coal, 8.3 billion tons of 868-5000 kcal / kg with a minimum calorific value (MTA, 2007). Thermal values of our country lignite are low generally (Anaç, 2003). Therefore, reducing ash and sulphur content is necessary because of environmental problems.

There are several methods for fine coal washing. Heavy medium cyclones and flotation are the common techniques that are utilized worldwide. Multi Gravity Separators have been used in some countries at the same size as flotation (Ateşok, 1996; Venkatraman et al, 1995; Rao et al, 2000; Laskowski, 2001) Most of the conventional methods in coal cleaning is effective only in ash reduction. Desulphurization is important from the environmental point of view and can be obtained effectively only by pyrolysis, magnetic separation, chemical and biological cleaning methods (Wills, 1997; Wheelock, 1978). But these methods are not commercially applied mostly under laboratory research. Therefore desulphurization is commercially obtained by flue gas desulphurisation methods after combustion at high processing expenses.

Froth flotation originally patented in 1903 and has permitted the mining of low-grade and complex ore bodies which would have otherwise been regarded as uneconomic (Fuerstenau et al, 2007). Afterward its application range was well widened in most areas, among them coal flotation has been always an important part due to coal is accepted as the naturally hydrophobic material (Wills, 1997).

The biodesulphurization of coal was first investigated with pure cultures of *Acidithiobacillus ferrooxidans* (Andrews and Maczuga, 1982; Lungrend and Silver, 1980), *Acidithiobacillus thiooxidans* (Lizama and Suzuki, 1987) and *Sulfolobus acidocaldarius* (Kargi and Robinson, 1985; Blackmore et al. 1995), with widely differing results. As *At. ferrooxidans* is a chemolitoautotrophic bacterium, the presence of organic matter inhibits its growth and deters biodesulphurization, so to solve this problem, mixed cultures of *At. ferrooxidans* and heterotrophic bacteria, or those capable of metabolizing certain organic substances, were used.

A part of this study involves in microorganism isolation from lignite itself collected from the region and

desulphurization of lignites by using these microorganisms. In this study, lignites were cleaned by multi gravity separator and flotation. The concentrates of MGS and flotation were also exposed to microorganisms for obtaining desulphurization. This work contains the optimization of flotation parameters and bio desulphurization of flotation concentrates.

2. MATERIALS AND METHODS

2.1. Materials

Lignite samples were taken from Mihalıççık region coal mine for both microorganism isolation and concentration works separately. The methods explained for both works individually. Minus 0.100 mm fraction was separated by wet sieving and used in the flotation experiments. Over 0.100 mm fraction was not used in this particular study. The sample contains over 54 % ash and 2152 cal/kg lower calorific value.

2.2. Flotation Method

Denver laboratory scale flotation machine was used in the experimental work. The sample was conditioned at a desired pulp density in the flotation cell in the presence of flotation reagents. Float and sink fractions were dried and analyzed for ash. Collector type and amount, pH, pulp density and dispersant amount were optimized to determine the best separation conditions.

Adding excessive amount of collector reagent to the pulp affected adversely the dispersion of collector in the pulp. Additionally a stable froth zone could not be obtained during the flotation stage. To avoid these problems, one more test was carried out in which collector fed gradually.

2.3. Biodesulphurization Method

For biodesulpurization studies, in our previous studies obtained isolate were used (Aytar et al., 2012). Microorganisms were isolated from Mihalıççık region (Eskisehir, Turkey) lignites with low rank and high ash and sulphur content. In our previous study, optimum conditions were obtained with Taguchi's methodology. Under optimized conditions, effective strain in terms of biodesulpurization was utilized for biodesulphurization studies. Total sulphur analysis was done with Eltra CS-530 sulphur analyzer.

3. RESULTS AND DISCUSSION

3.1. Results of Flotation Studies

The effects of collector type and dosage, pH, pulp density and dispersant dosage on the cleaning of lignite fines were studied. As a final experiment high dosage of collector was added gradually to increase the combustible recovery. The experimental conditions and studied ranges are given as Table 1;

Table 1. Flotation Conditions

Particle size (mm)	-0.1+0.038	**Collector type**	Fuel-Oil, PhilFlo, PhilFlo+Kerosene (2/1 w/w)
Pulp pH	6, Natural (8), 9	**Collector dosage**	1500, 3000, 4500, 6000
Pulp density (w/w %)	5, 10, 15, 20	**Frother**	Pine Oil
Dispersant type	Na_2SiO_3	**Floatation time (s)**	90
Dispersant dosage	0, 500, 1000, 1500		

Results are given in graphs in terms of ash content and combustible recovery in the concentrate fraction.

The effects of collector type on flotation are studied at above conditions. Pulp pH, pulp density, dispersant and collector dosages were set as 8, 15 %, 1000g/ton and 3000g/ ton, respectively. As it can be seen from Figure 1, ash content of the concentrates is not affected from collector type significantly. On the other hand, fuel oil produced the highest combustible recovery.

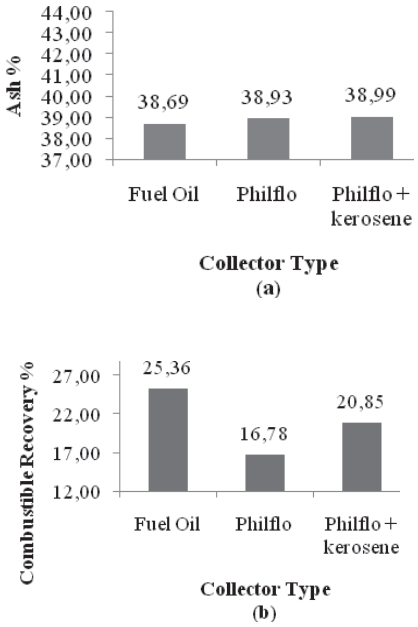


Figure 1. The effects of collector type on ash content (a) and combustible recovery (b)

The effects of pulp on ash content and combustible recovery are illustrated in Figure 2. Fuel oil is used as a collector and the other parameters were set as the first experiment. Acid addition to the pulp for decreasing the pulp pH resulted in a significant decrease in combustible recovery. But it did not affect the ash content significantly. All the experiments were carried out at natural pH afterwards.

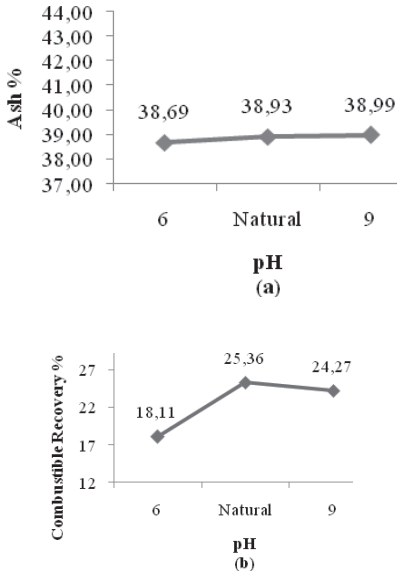


Figure 2. The effects of pH on ash content (a) and combustible recovery (b)

The effects of pulp density on flotation are given in Figure 3. The ash content of the concentrates did not change significantly up to 15 % pulp density. After this point, a remarkable increase was observed in ash content. This indicates that selectivity decreases in the flotation pulp and inorganic materials were carried to the froth zone by particle entrainment. It should also be noticed that an increase in pulp density caused an increase in combustible recovery as well. Therefore 15 % pulp density was chosen as the optimum value.

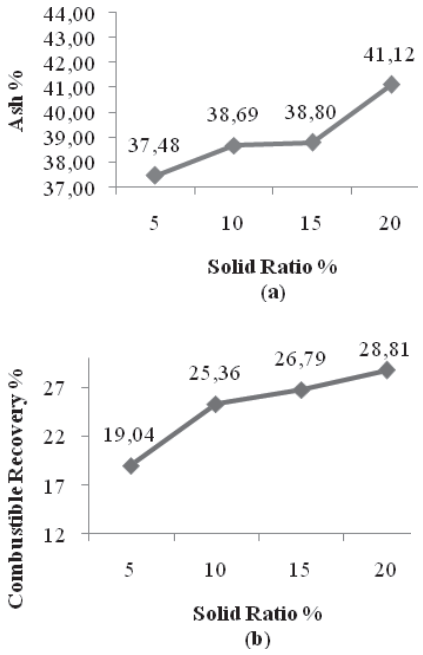


Figure 3. The effects of solid ratio on ash content (a) and combustible recovery (b)

The effects of dispersant dosage are given in Figure 4. It was observed that the selectivity in the flotation experiment was very low at the absence of dispersant. Combustible recovery at this particular experiment was less than 20 %. At 500 g/ton dispersant dosage, although ash content is still over 40 %, the combustible recovery was increased significantly. The lowest ash content and the highest combustible recovery were obtained at 1000 g/ton dispersant dosage. A sharp increase in ash content was observed at 1500 g/ton dispersant dosage. It was concluded that at this point silicate acted as a dispersant for carbon particles. Therefore 1000 g/ton dispersant dosage was accepted as optimum value.

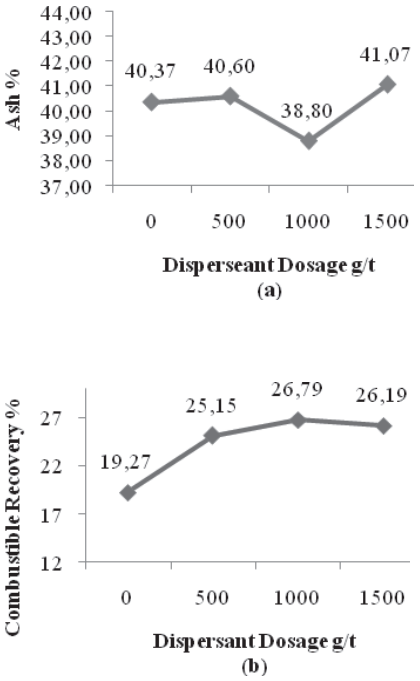


Figure 4. The effects of dispersant dosage on ash content (a) and combustible recovery (b)

Fuel oil was used as a collector in these experiments and the effects of fuel oil collector dosage are given in Figure 5 and 6.

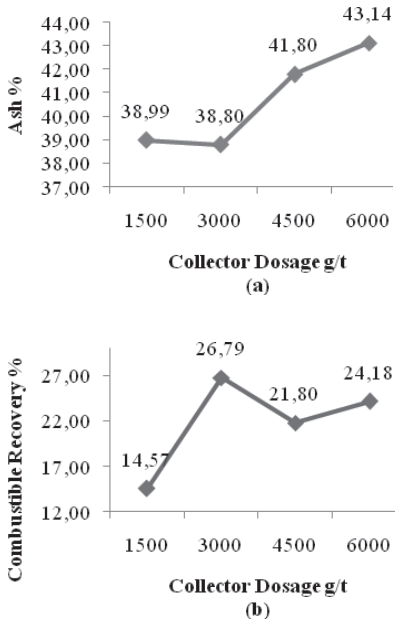


Figure 5. The effects of collector dosage on ash content (a) and combustible recovery (b)

It was noticed that both ash content and combustible recovery are at their best at 3000 g/t amount of collector (Figure 4). After 3000 g/t of collector, pulp became unstable due to the reasons that explained in material and method and one more test is carried out to obtain ash content and combustible recovery at high dosages of collector in which 4500 g/t of collector was fed into the pulp gradually. At each stage of test ash content and combustible recovery of concentrate is analyzed. Ash content of stages is represented as 'c' and ash content of whole concentrate is represented as 'd' in Figure 6 a. Furthermore, combustible recovery of stages is represented as 'c' and cumulative recovery of stages is represented as 'd' in Figure 6 b.

The effects of collector dosage are given in Figure 6.

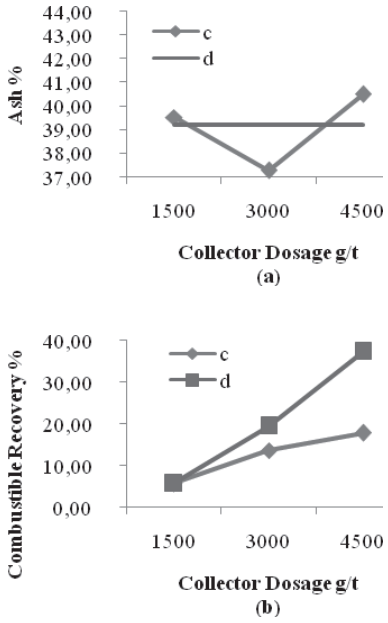


Figure 6. The effects of collector dosage on ash content (a) and combustible recovery (b)

3.2. Results of Biodesulphurization Studies

In our previous study, the several microorganisms including two bacteria, four fungi, and nine yeasts were isolated Mihalıççık coal itself (Aytar et al., 2012). Then, biodesulphurization studies were conducted by *Alterneria* sp., the most effective biodesulphurizing strain among our isolates (unpublished work). There are some reports about microorganisms isolated from coal itself. Acharya and coworkers studied desulphurization of three different types of coal using isolate of *At. ferrooxidans* (Acharya et. al., 2001). Besides, they tried to remove sulphur of the coal from North Eastern coalfields of Assam in India by utilizing the indigenous fungal culture (*Aspergillus* sp.) isolated from coal. Gomez et al. characterized of the microbial ecology of different Spanish coal and used them for biodesulphurization process (Gomez et. al., 1997, 1999). Aller et al. carried out desulphurization process for

various types of coal, using as inocula enriched cultures from the bacteria adhering to different the coal types (Aller et. al., 2001).

When flotation product was treated biologically, sulphur content was reduced by 32%. Martinez and coworkers combined physical and biological processes to reduce the sulphur and ash content of finely ground semianthracite coal. The elimination yield of the hydrocyclone was 22% of ash and 21% of sulphur. The figure for ash raised to 41% when the hydrocyclone and flotation equipment were both used, with no change in sulphur elimination. In turn, the biodesulphurization treatment applied in addition to the two processes raised the respective yields to 59 and 42% (Martinez et al., 2003). These differences in the values may be assigned to different coal used.

4. CONCLUSIONS

Flotation results show that a reasonable quality concentrate can be obtained by using fuel oil as a collector. Ash content of the concentrate can be reduced down to 39 % from a head sample of 54 % ash content with 30 % combustible recovery. This indicates the floatability of Mihalıççık region lignites is very low. The combustible recovery of the concentrate can only be increased over 40 % by the gradually collector addition. Combined with the biological treatment, this sequential process reduces the sulphur content by up to 32%. As a result of combining of physical and biological processes, the sulphur and ash content of finely ground coal was reduced.

Although these results seem to be low, it is acceptable due to the high amount of fine particles production. Moreover, a power plant is being erected in the region for electricity generation therefore the concentrate can be utilized in this plant.

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