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Evaluation of Thrace Region fine coal tailings

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Research Article

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ABSTRACT

79.9% of the lignites in our country have a calorific value of less than 2500 Kcal/kg. In order to reduce energy dependence of the country, it would be right to use these lignite reserves of 11.8 billion tons by use of effective coal preparation methods and with clean coal combustion systems together with developing technology. A typical coal preparation plant produces 20% of the feed coal, all below 0.5 mm. Generally, due to high cost, the product under this size is not used but thanks to the developing coal cleaning technology, this size group can be utilized with low ash content. Within the framework of this study, the discarded fine fraction coal sample which was below 0.5 mm was taken from Uysal Mining Company in Tekirdağ and subjected to enrichment and dewatering experiments to obtain a marketable product. In experimental studies, in order to produce a high quality product, the slime portion which contains mainly clay minerals was removed with 81.25% ash content using screen with aperture of 150 microns. Afterwards, the coal having 49.09% ash content was subjected to multistage Reichert Spiral tests and a clean coal product with 24.1% ash content was produced. In settling experiments, the product below 150 microns was used and at the end of these tests the slurry with 30% solid in pulp ratio was produced. It can be concluded that the clean coal which is produced after enrichment tests could be used in energy sector, power plants, briquetting plants, cement plants etc.

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1. Introduction

In developed countries, the coal produced from mine is not directly burned. Using physical, chemical and heating processes the quality of coal is upgraded and the negative effects originated from coal burning is diminished. To succeed this the main impurities such as ash, sulfur and moisture contents are decreased. In this manner, the maintenance and repair costs in mills and boilers, ash storage problems, particulate matter emissions and heavy metal emissions are reduced in thermal power plant operation. The enrichment methods are generally divided into two categories according to particle size, coarse and fine (Aslan et al., 1999; Önal, 1994).

In fine coal enrichment, the gravity techniques (jigging, shaking table, cyclone, spirals) is widely utilized because of its high effectiveness and low cost. The flotation method is preferred where the gravity methods cannot be applied for removing clays and pyrites captured in thin sections of coals. Because the flotation method is ineffective for oxidized coal and a good separation performance cannot be obtained in significantly high clay bearing coals, this led to the development of new technologies in coal enrichment. In fine coal processing, currently, Reichert spiral, column flotation, multi-gravity separator and the Falcon separator are mainly used (Baştürkcü and Acarkan, 2011, Parekh and Abdel Khalek, 2002, Ateşok, 2009, Honaker, 1995, Honaker et al., 1996).

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Nowadays, the need for energy is increasing more and more due to the development of the industry. Fossil fuels are not only the raw materials for energy but also they are needed for main inputs of different industries (Sharpe, 2007). One of the most important points that separates the coal from oil and natural gas is its homogeneous distribution on the earth. In addition, given the current visible reserves and the fact that petroleum will be consumed in 40 years, natural gas in 60 years, and coal will be consumed in 200 years, the strategic importance of the coal is even more evident. Coal has a very big share in the energy sector in terms of current production levels, its excess amount relative to other fossil resources, price stability, ease of transport and storage and its low cost to user (Ateşok, 2009).

The world coal production has doubled within the last thirty years. The increase in the coal production is largely due to demand for electricity in Asia, especially in China. The electricity generation of this country has increased 2.6 times over the past decade, reaching around 5.650 TWh in 2014 and 81% of this production is derived from the coal-based thermal power plants. In the last decade, the increase in electric energy production in the Asia-Pacific region has been about twice, and the coal has been the most heavily used source in the electricity generation (TKİ, 2016; British Petroleum, 2012; BGR Report, 2016).

Approximately 80% of Turkish lignites contain calorific value lower than 2500 kcal/kg. In order to diminish the energy dependency of our country, it would be right way to evaluate these lignite reserves which is about 11.8 billion tons using an effective coal preparation method and apply clean coal combustion systems together with developing technology. It is well know that a typical coal preparation plant produces below 0.5 mm fine coal that accounts 20% of the total feed. Generally, due to the high cost, the recovery of fine coal under this size is not preferred by many coal producers, however, with the developed coal cleaning methods this fraction can be evaluated (Ateşok, 2009).

The dewatering and drying are the obligatory processes for the use of coal. As it is known; a 1% increase in moisture in coals reduces the thermal efficiency equivalent to 4% increase in ash. To increase the capacity of transport, storage, crushing, grinding and burning systems and to provide coal in accordance with technological requirements also demonstrates the importance of dewatering and drying. With the processing of -0.5 mm fraction, the removal of the moisture from final products with an effective dewatering and drying technique must be executed. Because, the dehydration of the particles in small size is more difficult due to the increased surface area (Ateşok and Kangal, 2011; Ford and Fleming, 2002; Gallego-Juárez et al., 2003; Keller and Stahl, 1997).

In recent years, the privatization process of coal-based thermal power plants together with coalfields has gained momentum and thus the share of the private sector in production has begun to increase. The thermal power plants have the largest share in lignite consumption with 76%, 10% in the industry and 14% in the heating sector (TKİ, 2016).

The total annual ROM production capacity of the projects created for the public lignite sites is 78.735 million tons. The project capacity of TKİ is 46.150 million tons on a rom basis and the project capacity on the marketing basis is 41 million tons. 34.035 million tons of this salable capacity are for thermal power plants with an installed capacity of 4209 MW and of 6.73 million tons are for heating and industrial sectors. The lignite to take place in the second raw after the hydraulics in terms of cost in the electricity production, and besides giving importance to domestic resource production and use gives the impression that lignite will increase the share of electricity production in next years (TKİ, 2016).

As fuel in the cement sector; petroleum coke, imported hard coal, imported and domestic lignite, small amount of fuel-oil and natural gas are used and fuels constitute 30% of the cost. The petroleum coke has a thermal value of 7.500 Kcal/kg, an imported hard coal product of 6.300 Kcal/kg, a domestic hard coal product of 6.000 Kcal / kg and a domestic lignite of 3.500 to 4.500 Kcal/kg. The industry has an annual fuel requirement of 5.500 Kcal/kg and 6.5 million tons of coal with 3% sulfur content.

In addition, there are a total of 30 Sugar Factories in our country, 21 of which use coal as fuel. In factories which use coal as the fuel utilize two classes of coal as; low (2.200-3.800 Kcal/kg) and high calorific (4.000-4.500 Kcal/kg and above). The annual lignite needs of these factories are around 900,000 tons (TKİ, 2016).

It is known that in the soil sector, there are nearly 600 brick and tile factories in our country, most of them produce bricks and some of them produce both bricks and tiles. Their production capacity increases and decreases depending on the developments in the construction sector. The fuel used in soil industry in Turkey is the lignite in 3000 to 4000 Kcal/kg thermal value and the ovens have been designed accordingly with few exceptions.

It seems possible to maintain the market share of lignite in the heating sector by increasing the number and quality of plants related to coal remediation, preparing coal according to environmental criteria, developing smokeless boiler and stove technology, and maintaining competition with imported coal.

Besides, the lignite needs of industrial enterprises (chicken, oil, textile, salt factories etc.) in medium and small scales tend to show an increase parallel to the growth rate of the country and economic development. However, given the fact that some industrial plants established in big cities are required to pass natural gas due to environmental regulation, it is expected that the coal demands of this sector will continue in the range of 2.5-3 million tons.

Within scope of this study, the spiral beneficiation and dewatering studies were carried on waste character fine size lignite coal (-0.5 mm) obtained from coal washery that belong to Uysal Mining Co. in Tekirdağ.

2. Experimental Studies

2.1. Materials and Method

Within the scope of this study, fine lignite coal in waste character obtained from the coal preparation plant of the Uysal Mining Co., which is located in the Pirinççesme village of Malkara inTekirdağ, was used. In this coal washing plant, where fine coal is sieved and removed, and the enrichment with heavy medium in coarse size is carried out, and the final produced clean coal is used for heating. However, the fine coal is not subjected to any enrichment process and is stored at the end of the dewatering process. Within context of this study, which aims the recovery of coal in the composition of this residual material obtained as a fine-sized object, the chemical and physical characterization of the tailing, and the possibilities of enrichment with Reichert coal spiral were investigated. At the end of the enrichment, the coal analyses of the products were carried out and the results were evaluated. In addition to the enrichment experiments, settling tests were carried out for the dewatering of the slurry containing mostly clay minerals, and a process flow diagram was generated. The Reichert coal spiral was used in the experimental works and it is made of polyurethane and has a capacity of 1.2 ton/h. It consists of six 1000 mm diameter troughs wrapped around a vertical hub and the height of spiral is about 2380 mm. Solid in pulp ratio was adjusted as 25%. The upper heating value analyses of the products obtained in studies were carried out according to ASTM-D 5865, in the ICA calorimeter C700; the sulfur analysis according to ASTM-D 4239, in X-MET C-S device; and volatile matter and ash analyzes were made by burning in MF-120 Nuve oven in the crucible. Lower thermal values were calculated according to ISO 1928. All analyzes were given based on dry basis.

2.1.1. Physical Properties of the Sample

The screen analysis was carried out in order to determine the size distribution of the tailing sample obtained from the plant as a pulp with 73.6% moisture content, and the particle characteristics of the sample were determined according to the wet screen analysis. The results are shown in figure 1. The upper size of the representative sample was found as 1 mm. d_{80} and d_{50} sizes were found as 600 microns and 150 microns, respectively.

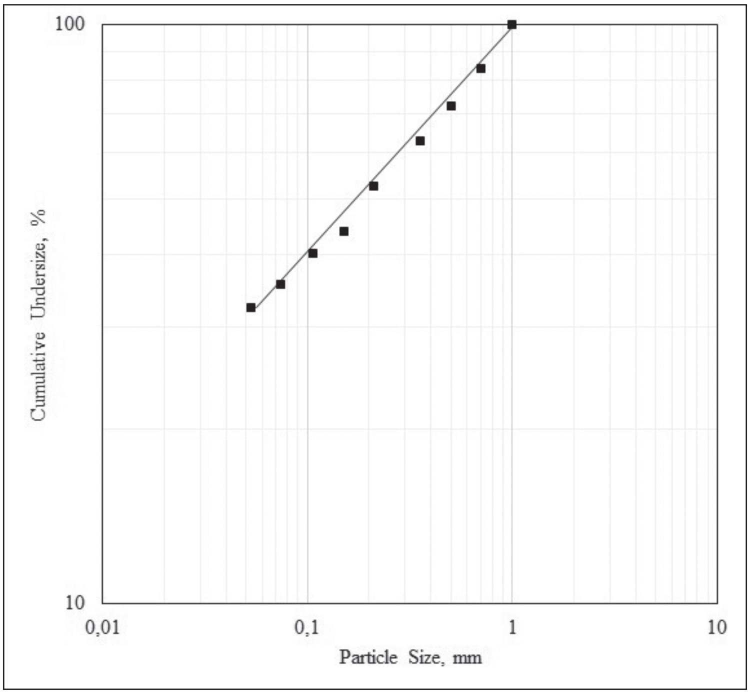

Figure 1- Undersize curve of the sample.

2.1.2. Chemical Properties of the Sample

The results of the chemical analysis performed to determine the composition of the test sample that is under 1 mm, and results are given in table 1.

Table 1- Chemical analysis of original coal sample.

Category	Analysis in dry basis
Ash %	61.48
Volatile matter, %	27.56
Fixed Carbon, %	10.96
Total sulfur, %	2.44
Lower thermal value, Kcal/kg	1689.0
Upper thermal value, Kcal/kg	1950.1

According to the chemical analysis results; it was found that the sample contains 61.49% ash with 1950 kcal/kg upper heating value. This thermal value, along with a constant carbon content of 10.96%, indicates the presence of coal in this tailing character material.

2.2. Results and Discussion

The tailing sample is distributed over a wide range of sizes (0-1 mm). As seen in Table 2 that the ash contents in coarse fractions are lower compared to fine fractions. This suggests that the coal is scattered in coarse sizes and that the composition of the tailing is predominant in clay minerals as the ash-forming minerals. Particularly; it is observed that the material under 150 microns size contains clay in big amounts. The ash content of the material fractions at +150 micron fraction was determined as 44.13%, while the ash content of the material containing clay minerals under the -150 micron size was determined as 81.25%.

27.6% of the total feed is above 0.5 mm with 39.1% ash content could be beneficiated when heavy medium cyclones at -20 + 0.5 mm is effectively operated. From this point, it was decided to carry out the enrichment works using spiral concentrator with the sample below 0.5.

Actually in Uysal Mining Company's coal washing plant, where the representative sample is provided, is designed to discharge the sample below 0.5 mm as a tailing. Due to the fact that the vibrating screen does not work effectively +0.5 mm materials contaminated with this waste character material. This increases the amount of tailing being discharged and the amount of coal that is lost in fine size. Adapting efficient working conditions related with vibrating screen with the aperture size of 0.5 mm the material less than 0.5 mm in size can be produced successfully. Due to this reason, the enrichment tests were carried out with tailing material below 0.5 mm size.

Table 2- Screen and fractional ash analyses of the tailings.

Size range, mm	Amount, %	Ash, %	Ash distribution, %	Combustible portion, %
+0.700	15.8	36.33	9.5	25.4
-0.700+0.500	11.8	42.60	8.3	17.1
-0.500+0.355	9.3	45.80	7.0	12.7
-0.355+0.212	10.4	49.75	8.6	13.2
-0.212+0.150	8.8	51.80	7.5	10.7
-0.150+0.100	3.7	71.25	4.4	2.7
-0.100+0.074	4.6	75.80	5.8	2.8
-0.074+0.053	3.1	80.40	4.1	1.5
-0.053	32.5	83.25	44.8	13.9
Total	100	60.43	100.0	100.0

According to the results from screen analyzes performed on the sample, using a vibrating screen with the aperture size of 0.5 mm, +0.5 mm size group was removed from the system. The size distribution of all passing 0.5 mm is given in table 3.

As the particles larger than 0.5 mm will be evaluated in coarse size beneficiation unit and -0.5 mm fraction can be processed in fine size coal beneficiation unit. Therefore, the upper size was selected as 0.5 mm in the spiral enrichment process. According to the size distribution and ash contents of the material in Table 3, it is clearly seen that 60.7% of the sample is accumulated below 0.150 mm and consists of mainly clay minerals with 81.25% ash content. Because of this reason, the cut size of the sample to be used in the spiral enrichment experiments was determined as 0.150 mm and the samples within the range of -0.5 + 0.150 mm were prepared using the Mozley hydrocyclone.

The spiral beneficiation experiments were performed with Reichert Coal Spirals shown in figure 2 and the process flow diagram is given in figure 3.

As a result of the enrichment test performed by using three concentration stages, two clean coal, a mixed and a schist products were obtained. The results of the experiments in terms of amount, ash content,

Figure 2- Reichert spiral unit in the experimental studies.

Table 3- The particle distribution after removing +0.5 mm size from the system.

Size range, mm	Amount, %	Ash, %	Ash distribution, %	Combustible portion, %
-0.500+0.355	12.8	45.80	8.5	22.1
-0.355+0.212	14.4	49.75	10.4	23.0
-0.212+0.150	12.1	51.80	9.1	18.6
-0.150+0.100	5.1	71.25	5.3	4.7
-0.100+0.074	6.4	75.80	7.1	4.9
-0.074+0.053	4.3	80.40	5.0	2.7
-0.053	44.9	83.25	54.5	24.0
Total	100	68.62	100.0	100.0

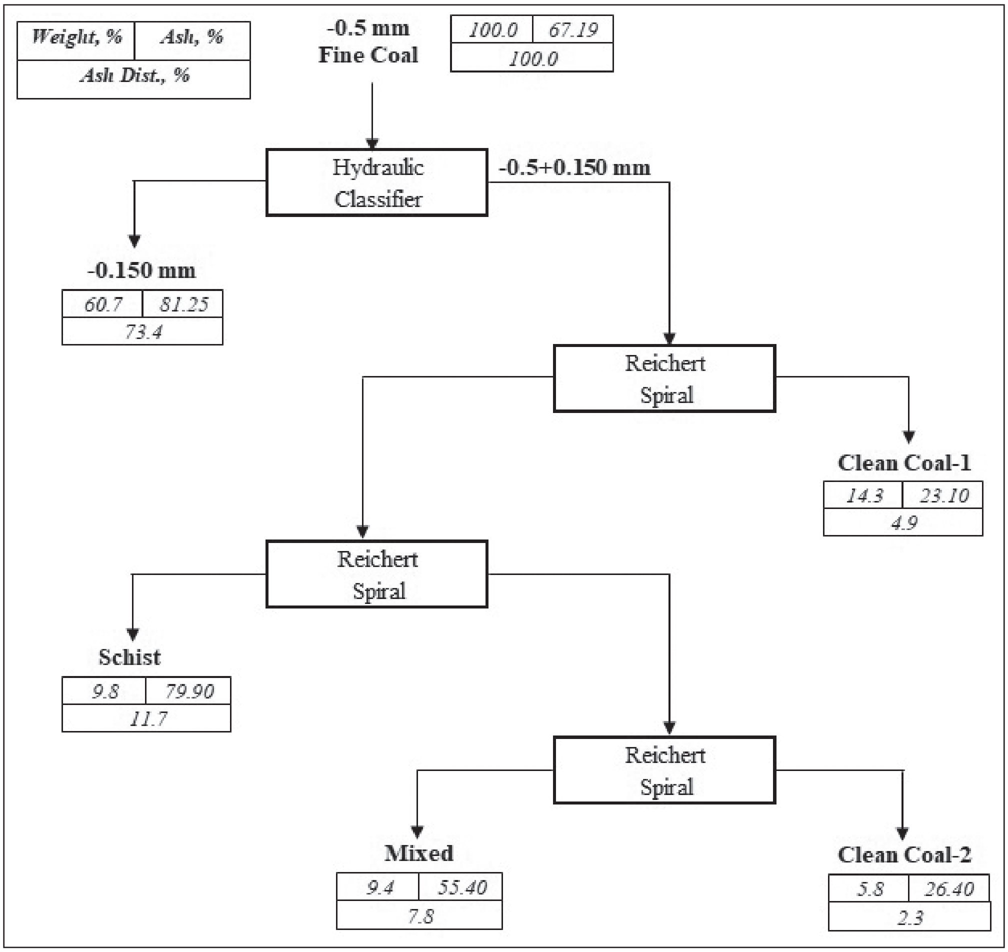

Figure 3- Process flowsheet of -0.5 mm fine coal.

ash distribution and combustible recovery are given in table 4.

According to the results given in table 4, the total clean coal is composed of Clean Coal 1 with 23.1% ash content at the amount of 14.3% and Clean Coal 2 with 26.4% ash content at the amount of 5.8%. As combined about 20.1% of the feed is taken with 26.4% ash content as a clean coal with 46.5% combustible recovery. The tailings from spiral is about 9.8% of the feed and contains about 80% ash. 60.7% of the total feed is obtained as slime with 81.3% ash content. When tailings from spiral and slime was combine the total tailings is found as 70.5% of the feed and assays 81.1% ash.

After the beneficiation process the slime materials must be thickened before filtration process. For this reason, the settling tests of slime having 5% solid in pulp ratio were carried out. An anionic flocculant commercially named as Fusifloc was used. It accelerates the settling and gives rise to obtain a clear

Table 4- Obtained final products.

Products	Amount, %	Ash content, %	Ash distribution, %	Combustible productiviy, %
Clean Coal 1	14.3	23.1	4.9	33.5
Clean Coal 2	5.8	26.4	2.3	13.0
Mixed	9.4	55.4	7.8	12.8
Schist	9.8	79.9	11.7	6.0
-0.150 mm	60.7	81.25	73.4	34.7
Total	100	67.19	100.0	100.0

water in the settling test as the problems related with clarity of the water and settling rate were observed during tests performed without adding any polymers. The settling curves, which formed as a result of settling tests at natural pH values (7.1) of the pulp at different flocculant concentrations of 50 g/t, 100 g/t, 150 g/t and 200 g/t, are given in figure 4.

As shown in figure 4, the concentration of flocculant less than 150 g/t is not sufficient in terms of both the settling rate and the clarity of the water.

The size calculation of a thickener with a capacity of 25 tons/h, which will be used for the settling of -0.150 mm material with 150 g/t flocculant addition, were carried out. The settling distances and rates in such a way to obtain 20. 25 and 30% solid in pulp ratios using a feed with 5% solid in pulp ratio were calculated and given in table 5.

As a result of the calculations, a thickener with a radius of 17.33 mm is necessary to obtain 30% solid in pulp ratio material.

3. Conclusions

As the coarse coal (+0.5 mm) with heavy medium separators in the coal preparation plant located in Pirinççesme village in Malkara, Tekirdağ of the Uysal Mining Co. is enriched, the material below 0.5 mm with 61.48% ash content and 1950 kcal/kg upper heating value is processed as a tailing. However, within the scope of this study, it was understood that the material obtained from the plant in -0.5 mm size was actually below 1 mm. The presence of high clay minerals in the composition of material allows the removal of high amount of slime (60.7%) with 81.25% ash content using a simple size classification. The material within a size range of -0.5 + 0.150 mm is fed to 3-stages Reichert spiral and makes it possible to produce a clean coal with 14.3% amount.

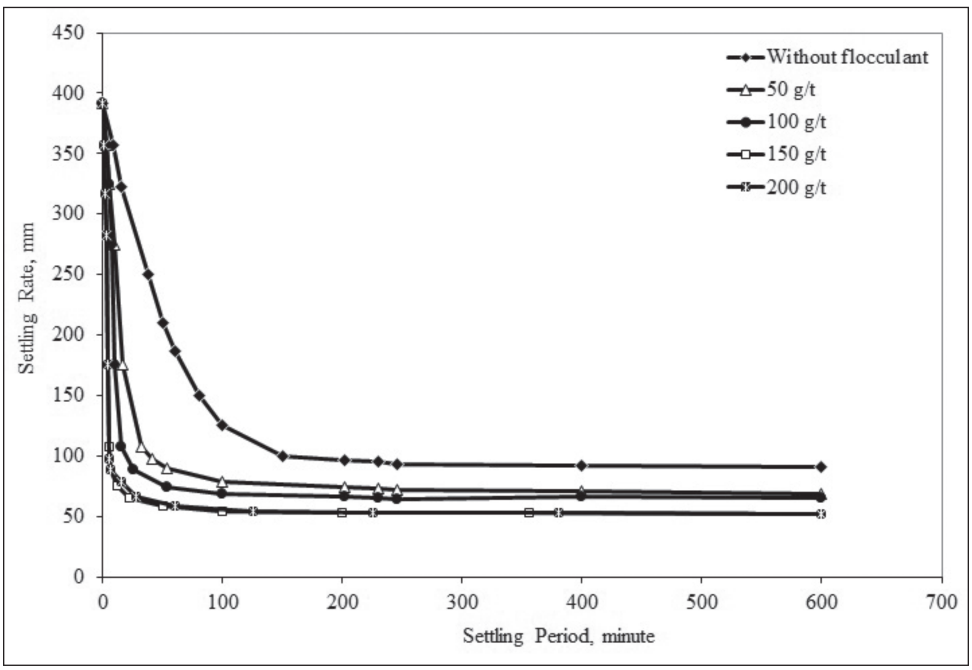

Figure 4- Settling experiments results with/without flocculant addition.

Table 5- Thickener diameters calculated according to different concentrations.

Post settling product PKO, %	Settling distance, m	Settling time, hour	Area, m^2	Thickener radius, m
20	0.09373	0.097	121.859	6.23
25	0.07385	0.203	255.025	9.01
30	0.06059	0.75	943.053	17.33

Ash, 24.10%

Volatile Matter, 42.10%

Fixed Carbon, 32.97%

Total sulfur, 2.07%

Upper Heat Value, 5036 Kcal/kg

It was revealed that this type of coal obtained in these specifications could be used in energy sector, thermal power plants, briquetting plants, cement factories etc. and provide an economic gain.

As a result of these studies; the process diagram given in figure 5 is presented as an alternative for the purpose of recovering coals from fine coal slimes.

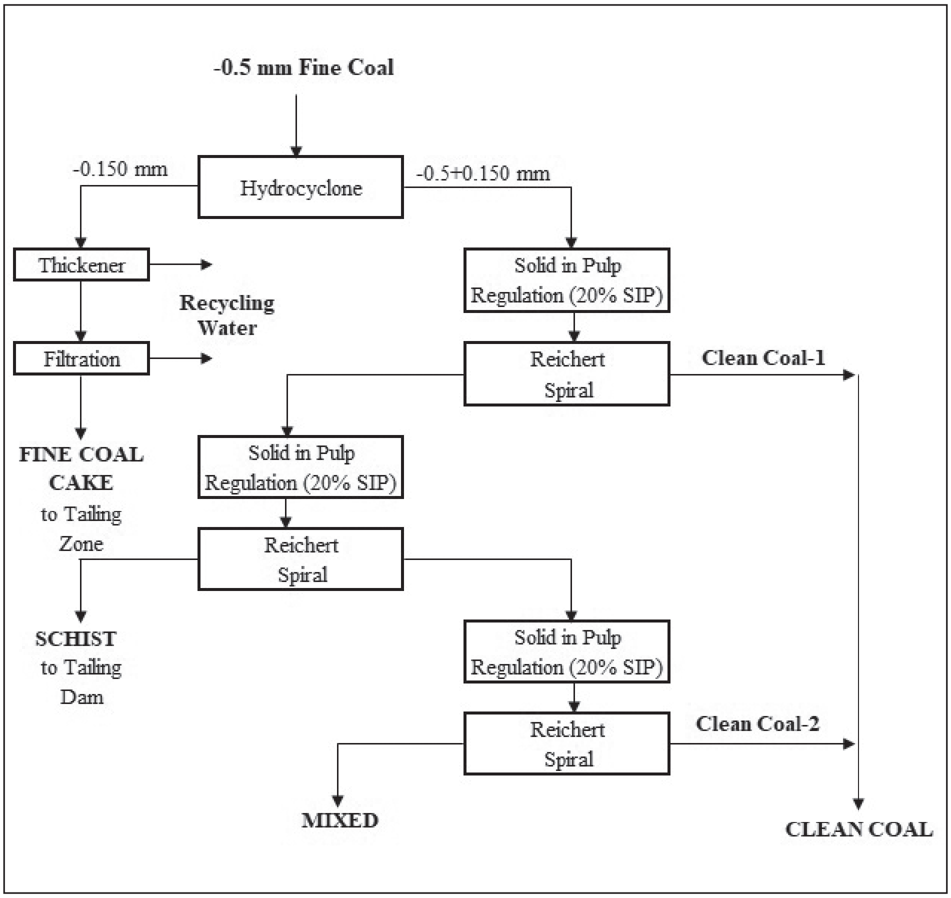

Figure 5- Proposed fine coal process flowsheet.

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