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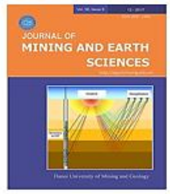

Recovery of clean coal from the contaminated waste of Coc Sau coal mine

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ABSTRACT

The contaminated waste is a by-product generated during coal mining process. This type of waste may contain about 20% of clean coal and its ash content may vary in a wide range of 60% to 75%. The waste is normally stockpiled separately at "temporary disposal dumps". This waste is not regarded as a waste but it is very costly to process. A large quantity of representative samples from Coc Sau waste disposal dump have been collected and a number of experiments for clean coal recovery have been carried out using a combination of low cost and highly efficient semi-industrial movable screen jig, fluidized bed separator and flotation machine. From this waste, the obtained clean coals of the separation processes have met the Vietnam quality standards requirements (suitable for trading) and the tailings have ash content of over 80%. The study results showed that the application of these new machines could allow significant recovery of clean coal from contaminated wastes. This may significantly contribute to the reduction of environmental pollution while ensuring the production viability and economic efficiency for the miners.

1. Introduction

The contaminated waste, also known as low-quality coal, is a mixture of waste rocks and coal, collected from intermediate layers between the coal seam and roof or floor rocks. In general, it is a special by-product generated in the coal mining process, and in some particular cases, it may be a reject from coal screening plants, which prepare run-of-mine coal at mine sites and it is known as "coal screening reject". Characteristics of the contaminated waste include high ash content of between 60% to 75% for small size fractions while it may reach over 80% for coarser sizes (International Energy Agency, 2010). This waste is normally stockpiled separately at "temporary disposal dumps" as this product cannot be regarded as waste. Currently however, it is not economically viable and efficient to process such contaminated waste by traditional methods (Vinacomin, 2016).

According to the data of Coc Sau Coal Join Stock Company, the amount and quality of the contaminated waste at Coc Sau Coal Mine as shown in the Table 1. (Coc Sau Coal Join Stock Company - Vinacomin, 2014).

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Table 1. The mass and ash content of of the contaminated waste in Coc Sau Coal Mine.

Source	Mass, T	Ash content, %
Year 2013		
Stockpiled +160B	543 698	69.20
Stockpiled +45	1 092 275	72.87
Year 2014		
Stockpiled N0 5	410000	63.77
Stockpiled +160	300000	67.54

2. Material characteristics

The contaminated waste samples collected from Coc Sau Coal Mine were analyzed for size distribution, density distribution and ash content. Results of the particle size and ash content analysis of the studied sample are presented in Table 2.

Table 2. Dry sieve analysis result of sample of Coc Sau Coal Mine.

Particle size fraction, mm	Yield, %	Ash content, %
+50	11	84.76
35 - 50	15.44	75.89
15 - 35	15.52	68.92
6 - 15	13.63	64.47
3 - 6	10.19	55.28
1- 3	7.04	52.48
0.5 - 1	7.72	49.5
- 0.5	19.46	48.21
Total	100	63.06

Comments:

The size fraction +50 mm of Coc Sau coal mine sample have ash content over 84%, thus this size fraction can be removed and disposed directly or otherwise additional clean coal from these sizes can be recovered by using hand sorting method;

- The size fractions 0.5 - 3 mm have ash content more than 50% that which is equivalent to the ash content of the traded fine coals 7bHG. The fine coals of 0 - 0.5 mm have ash content of less than 50% which is equivalent to the ash content of the traded fine coals 7aHG thus they can be commercialized, but the value of the trade is low;

- Particle size fractions 3 - 50 mm have ash content from 55% to over 75% were float-sink analyzed for the assessment of the gravity washability. The assessment of the gravity washability is based on the amount of middling fraction yields (the yield of S.G. fractions from 1.5 to 1.8). The results indicated that these particles size fractions were of average to difficult gravity washability (Pham Huu Giang, 2012).

The machines used for test include: semi-industrial movable screen jig, fluidized bed separator and flotation machines.

3. Results and discussion

3.1. Tests on the moving screen jig

Moving screen jig (ROM jig) is an equipment developed at the end of the 20th century for the treatment of run-of-mine coals (Sanders et al., 2002). To the present time, this equipment is widely accepted in many countries such as China, Germany, South Africa and Australia. The advantages of this machine type are: low energy cost, low water consumption, suitability to high-ash content coals (Nhu Thi Kim Dung, 2011). This is why a semi-industrial moving screen jig was chosen to process coal samples of Coc Sau coal mine. Particle size fractions used for tests include: size fractions 15 - 50 mm and 3 - 15 mm.

The procedure for the factoral experiments on the semi-industry moving screen jig is as follow: to adjust the setting of one operating parameter while keeping the others fixed, thus optimal operating parameters can be applied. Experiment results of the particle size fractions are presented in Table 3; Table 4; Table 5 and Table 6.

For size fraction of 15 - 50 mm: Optimal overflow height and amplitude are respectively 64 mm and 55 mm;

For size fraction of 3 - 15 mm: Optimal overflow height and amplitude are respectively 34 mm and 45 mm;

In optimal processing conditions obtained clean coal have ash content less than 40% and ash content of reject is more than 80%.

Table 3. Experiment results to define optimal overflow height for size fraction of 15 - 50 mm.

Overflow height (mm)	Products	Yield, %	Ash content, %	Combustible matter recovery, %
56	Clean coal	36.14	41.72	62.81
	Reject	53.72	84.61	
	Fines	10.14	58.51	
	Feed	100.00	66.46	
60	Clean coal	35.34	39.67	62.76
	Reject	56.65	83.46	
	Fines	8.01	59.09	
	Feed	100.00	66.03	
64	Clean coal	28.50	37.49	53.63
	Reject	67.35	79.69	
	Fines	4.15	58.51	
	Feed	100.00	66.78	
68	Clean coal	16.83	34.44	31.44
	Reject	81.59	71.3	
	Fines	1.58	59.09	
	Feed	100.00	64.91	

Table 4. Experiment results to define optimal amplitude for size fraction of 15 - 50 mm.

Amplitude (mm)	Products	Yield, %	Ash content, %	Combustible matter recovery, %
47	Clean coal	36.8	46.87	60.23
	Reject	54.72	82.45	
	Fines	8.48	61.01	
	Feed	100	67.54	
51	Clean coal	31.63	43.78	56.20
	Reject	61.51	81.82	
	Fines	6.86	61.01	
	Feed	100	68.36	
55	Clean coal	28.58	39.63	53.72
	Reject	62.27	81.86	
	Fines	9.15	61.01	
	Feed	100	67.88	
59	Clean coal	28.5	37.49	53.63
	Reject	67.35	79.69	
	Fines	4.15	58.51	
	Feed	100	66.78	

Table 5. Experiment results to define optimal overflow height for size fraction of 3 - 15 mm.

Overflow height (mm)	Products	Yield, %	Ash content, %	Combustible matter recovery, %
30	Clean coal	34.51	28.78	57.86
	Reject	51.51	78.92	
	Fines	13.98	49.59	
	Feed	100.00	57.52	
34	Clean coal	31.02	22.89	53.5
	Reject	54.20	75.70	
	Fines	14.78	48.44	
	Feed	100.00	55.29	
38	Clean coal	26.83	18.64	49.67
	Reject	57.77	72.90	
	Fines	15.4	45.07	
	Feed	100.00	56.06	
42	Clean coal	21.57	15.90	43.19
	Reject	71.56	68.73	
	Fines	6.87	49.23	
	Feed	100.00	57.99	

Table 6. Experiment results to define optimal amplitude for size fraction of 3 - 15 mm.

Amplitude (mm)	Products	Yield, %	Ash content, %	Combustible matter recovery, %
37	Clean coal	23.45	15.06	45.12
	Reject	45.60	76.80	
	Fines	30.95	55.88	
	Feed	100.00	55.85	
41	Clean coal	32.05	21.90	56.49
	Reject	40.60	78.82	
	Fines	27.35	60.93	
	Feed	100.00	55.69	
45	Clean coal	41.05	32.06	63.91
	Reject	35.80	82.70	
	Fines	23.15	58.71	
	Feed	100.00	56.36	
49	Clean coal	35.20	26.50	59.48
	Reject	42.08	80.14	
	Fines	22.72	59.18	
	Feed	100.00	56.50	

3.2. Tests on the fluidized bed separator

Fluidized bed separator HSBS has an inclined plate structure. The equipment was invented by the late 20th and early 21st century for the processing of fine coals (Humboldt Wedag). This device has also been implemented in full industrial scale. Fluidized bed separator is a well suited equipment for processing of coal particle sizes of 0.5 - 3 mm. Compared to other processing equipment of coal particle size fraction -3 mm, fluidized bed separator has higher capacity and requires little construction area etc (Pham Van Luan, 2012).

The research group have tested the coal particle size 0.5 - 3 mm on the laboratory fluidized bed separator at the optimal operating parameters as defined by the conditional experiments. The results are shown in the Table 7.

Table 7. Experiment results to define optimal water flow rate for size fraction of 0.5 - 3 mm.

Water flow (L/s)	Products	Yield, %	Ash content, %	Combustible matter recovery, %
2.0	Clean coal	18.81	7.05	36.61
	Reject	60.01	71.4	
	Middling	21.18	38.1	
	Feed	100	52.24	
2.2	Clean coal	21.91	12.4	41.45
	Reject	57.3	74.8	
	Middling	20.79	39.05	
	Feed	100	53.7	
2.4	Clean coal	35.21	16.43	60.42
	Reject	44.8	78.92	
	Middling	19.99	45.8	
	Feed	100	51.3	
2.6	Clean coal	40.01	17.89	67.36
	Reject	41.2	82.3	
	Middling	18.79	54.1	
	Feed	100	51.23	
2.8	Clean coal	45.3	25.8	68.15
	Reject	39.42	84.12	
	Middling	15.28	38.2	
	Feed	100	50.68	

For particle size of 0.5 - 3 mm, when water flow is 2.6 L/s the obtained clean coal has ash content of less than 20% (maximum limits of ash value for the traded fine coal 3a), combustible matter recovery of clean coal is over 67% and this product is suitable for both export and domestic uses; the reject has ash content over 82% which is regarded suitable for disposal. The best result is achieved the water flow of 2.6 L/s.

3.3. Flotation tests

Table 8. Experiment results to define optimal collector dosage.

Colletor dosage (Kerosene) (g/t)	Products	Yield, %	Ash content, %	Combustible matter recovery, %
80	Clean coal	49.22	15.13	79.58
	Reject	50.78	78.8	20.42
	Feed	100	47.51	100
1000	Clean coal	54.31	15.88	84.81
	Reject	45.69	82.08	15.19
	Feed	100	46.13	100
1200	Clean coal	55.6	16.1	86.64
	Reject	44.4	83.8	13.36
	Feed	100	46.16	100
1400	Clean coal	57.73	16.88	89.74
	Reject	42.27	87.03	10.26
	Feed	100	46.53	100
1600	Clean coal	59.37	17.12	91.32
	Reject	40.63	88.5	8.68
	Feed	100	46.12	100

Table 9. Experiment results to define optimal frother dosage.

Frother dosage (Pine oil) (g/t)	Products	Yield, %	Ash content, %	Combustible matter recovery, %
60	Clean coal	55.43	16.04	86.88
	Reject	44.57	84.22	13.12
	Feed	100	46.43	100
80	Clean coal	57.73	16.88	89.74
	Reject	42.27	87.03	10.26
	Feed	100	46.53	100
100	Clean coal	57.88	16.98	90.97
	Reject	42.12	88.67	9.03
	Feed	100	47.18	100
120	Clean coal	60.39	17.88	92.57
	Reject	39.61	89.95	7.43
	Feed	100	46.43	100
160	Clean coal	61.06	17.98	92.78
	Reject	38.94	89.99	7.22
	Feed	100	46.02	100

The flotation experiments were conducted used the laboratory flotation machine 1 litre for fine coal (particle size of 0 - 0.5 mm). The research has found the optimal flotation operating conditions. Froth flotation results of the coal sample are presented in Table 8 and Table 9.

Choose optimal collector and frother dosage are respectively 1400 g/t and 100 g/t, obtained clean coal have ash content of less than 20% that is equivalent to the coal fines 3a and the combustible matter recovery is over 90%;

The reject has ash content over 88% and can be disposed.

4. Conclusions and recommendations

4.1. Conclusions

Coarse size fractions 50 mm in contaminated wastes of Coc Sau mine have ash content over 84% thus they can be scalped and disposed in permanent waste dumps or can be hand sorted for additional recovery of clean coal;

The tests on the semi-industry moving screen jigging of particle size fractions 3 - 50 mm created clean coal equivalent to coal fines 5a;

The fines from jigging could be used in whole or in part depending on the quality of fines and the clean coal quality from jigging;

When ash content of the raw coal size 0.5 - 3 mm is higher than 50% then it is required to be washed by the fluidized bed separator to produce clean coal with quality equivalent to 3a fine coals. Clean coal of the fluidized bed separator can be mixed with coal fines of jigging together with fines coals -0.5 mm of the raw coal to produce fine coal 6a;

The contaminated waste fines -0.5 mm can be treated by froth flotation to recover additional clean fine coals.

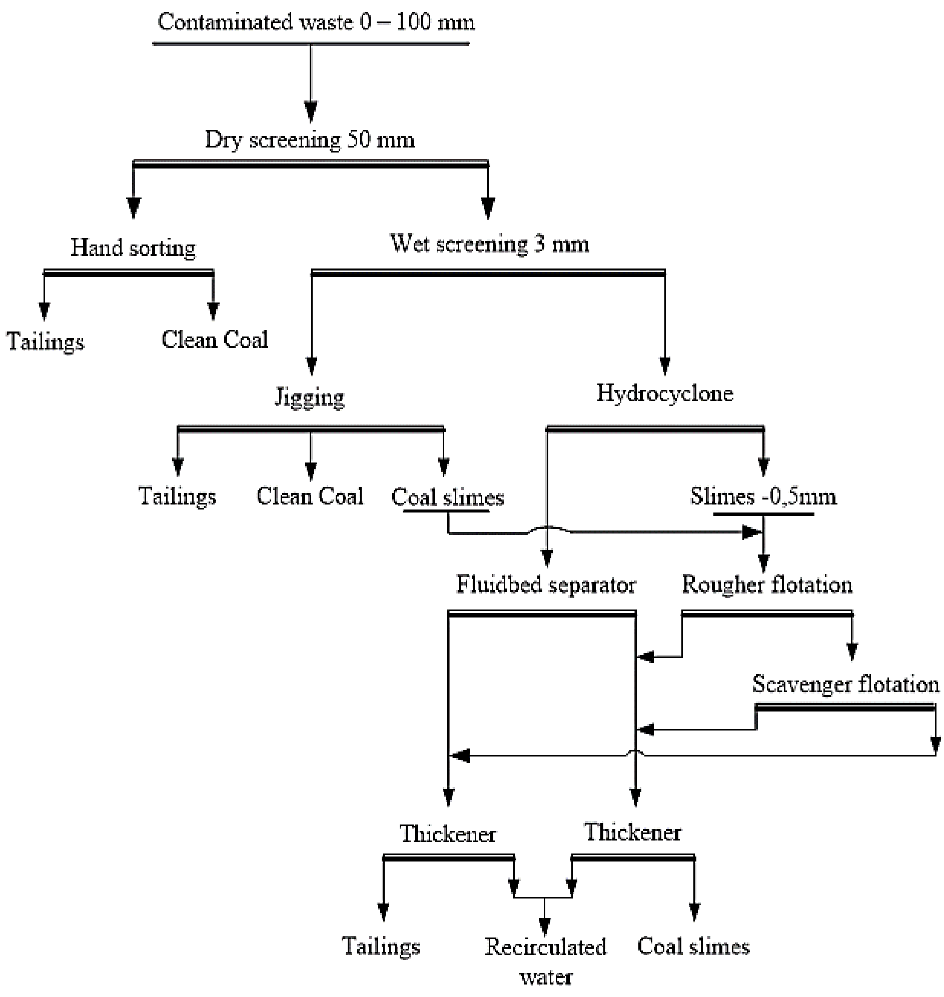

Figure 1. Washing flowsheet for contaminated waste of Coc Sau mine.

4.2. Recommendations

Based on the data from study of Coc Sau samples of contaminated waste, it allows to develop technological flowsheet as Figure 1.

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