

Cleaner Production Options at a Coal Preparation Facility in Vietnam

L.B.V. Bach^{1,2}, S.H. Gheewala^{1,*}

^aThe Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, 126 Pracha-uthit Rd, Bangmod, Tungkru, Bangkok, Thailand 10140

²Institute of Mining Science and Technology, 3 Phan Dinh Giot, Phuong Liet, Thanh Xuan, Ha Noi, Vietnam

Abstract: This paper highlights the current status of the largest coal preparation plant in Vietnam and suggests Cleaner Production (CP) options to address some problems of the plant. In the year 2005, about 30% of run-of-mine (ROM) coal was washed in coal preparation plants, the remaining treated in coal mining companies. The plant considered in this study had a production capacity of 6.1 million tons of ROM coal in 2005. Results of the preliminary assessment showed that the plant was facing several problems such as high amount of fine coal in ROM coal, high amount of magnetite loss, low efficiency operation of the cyclone classifier system, high ash content in the fine coal product, and high amount of coal slurry. CP options along with a simple economic analysis have been suggested to address all these issues.

Key words: Cleaner Production; Coal preparation; Vietnam.

1. Introduction

Coal has been playing a key role in the development of Vietnam. It is estimated that the total amount of anthracite in Vietnam is 3.2 billion tons and has been extracting for more than 120 years. It is now managed by Vietnam National Coal - Mineral Industry Group (Vinacomin). In the year 2004, Vinacomin exploited 27 million tons of run-of-mine (ROM) coal and was projected to extract 42 million tons in the year 2010 [1-2]. Currently, coal is the main energy source for many industries in Vietnam such as paper, cement, power, etc. Demand for clean coal is increasing sharply every year. Table 1 shows the demand of coal in Vietnam at present and in the future.

To reach the quality requirement of the demand holders, ROM coal is cleaned up. In the year 2005, 30% of ROM coal was washed up in coal preparation plants, the remaining is processed in coal mining companies. Vinacomin had 2 coal preparation companies with 4 coal preparation plants. The fifth coal preparation plant belongs to a coal mining company [3].

Coal preparation plants of Vietnam are located near the sea (China Sea), in the residential areas and facing some problems with regards to old technology, management, and especially environmental issues. The main problems are high amount of solid waste (6 million tons per year), coal slurry (4.5 million tons per year) and fresh water consumption. To address these issues, the companies have been investing in environmental protection but still have many environmental problems. Therefore, a different approach is encouraged for the comprehensive environmental and economic achievement.

Cleaner Production may be an option for addressing the environmental issues associated with coal cleaning. In the year 1999, Cleaner Production was defined for the first time to help the industry to address environmental issues in a way other than end-of-pipe solutions. UNEP defines Cleaner Production (CP) as the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency. It has eight main techniques that are improving process control, recycling, process modification, input substitution, redesigning technology, and product modification. By the definition of CP above, the industry can achieve comprehensive targets of environment and economy which are different from the traditional end-of-pipe technologies in waste treatment. The end-of-pipe technologies, designed to treat wastes after release, do not prevent the increasing of wastes and loss of material and energy. Moreover, the traditional technologies, in

actuality, only transfer waste from one kind or medium to another [4].

Table 1. The estimated demand of coal in Vietnam [1-2].

Unit: million ton

No.	Demand holder	2003	2004	2005	2010	2015
1	Domestic holder	10.20	10.50	12 – 13	20 – 21	24 – 25
	Power plant	3.00	3.90	5.3 – 5.6	11.6 – 11.9	13.2 – 13.5
	Cement	1.45	1.52	2.5 – 2.7	3.8 – 4.06	5.0 – 5.2
	Construction Materials	0.47	0.56	1.4 – 1.6	1.6 – 1.8	1.8 – 2.0
	Other Industries	0.20	0.23	1.1 – 1.2	1.2 – 1.3	2.0 – 2.1
	Other	4.68	4.69	1.7 – 1.9	1.8 – 2.0	2.1 – 2.2
2	Export	3.80	3.60	4 – 5	2 – 3	2 – 3
3	Total	14.00	14.50	16 – 17	24 – 24.5	26 – 27

In Vietnam, the CP center was established since 1999 with the help of UNDP and UNEP. There have been some CP projects implemented mainly in textile, paper, cement, etc. However, the coal sector still has no CP project [5].

Not all techniques of CP presented earlier are applicable in every case. In the context of mining, CP refers to the management and organizational measures that put a firm in a better position to handle, minimize, and anticipate problems with wastes. To achieve CP, the mining industry should continuously improve, the design of operations, reducing energy, and material inputs, and waste disposal techniques. Moreover, the mining industry should concentrate on its characteristics to improve the technology and the design. Finally, the mining industry should pay more attention in managerial and policy-making aspects [6].

The environmental impacts resulting from mining industry have been recognized since 1970, when strict environmental legislation was passed for the first time, particularly in North America and Europe. Moreover, with the help of modern technologies, the environmental impacts of mining industry are more

clearly observed. The results of monitoring have assisted policy makers in setting environmental legislation for industries [7].

Additionally, demand for products of mining industry has increased significantly with the development process. Consequently, the total waste of mining industry has been increasing too. Therefore, it is necessary to try fresh approaches to minimize waste emission and ensure environmentally sustainable development.

This paper focuses on the largest coal preparation plant in Vietnam, identifies the current environmental aspects and uses CP options to address the environmental issues.

2. Experimental

To apply CP in the coal preparation plant, the methods used in this research are as follows:

- Pre-assessment: This process was implemented to investigate and evaluate the coal preparation plant by surveying and collecting data.

- Interview: Interviews were conducted of shift leaders, engineers, and operation workers for overview of the coal preparation plant before making inventory.

- Inventory: It was implemented by surveying, interviewing, and taking and analyzing samples for the coal preparation process. The samples were taken and analyzed according to the Vietnamese Standard TCVN 1693: 1995 (ISO 1988); 251-67; 251-1997; 252-1999. Moreover, to assess the coal preparation process, the operation efficiency and product quality of the machines and equipment were studied. The methodology followed was as per [8].

3. Results and Discussion

3.1. Profile of the coal preparation plant

The object of this study is the largest coal preparation plant of Vietnam. It was designed in 1979 and upgraded twice to increase the capacity from 3.2 million tons to 6.1 million tons. Coal preparation process of the plant can be divided into 3 processes that are ROM coal pre-treatment (screening, hand picking, grinding), washing process (jig system, DM system), and subsequent product treatment (cyclone classifier system, cyclone thickener system, thickener tank, dewatering screen system, dam system). Figure 1 shows the diagram of coal preparation technology of the plant No. 1. In the year 2005, it produced 376,000 tons of coarse coal, 3.49 million tons of fine coal, 1.36 million tons of coal slurry, and 194,000 tons of by-product.

3.2. Problems and cleaner production options

3.2.1. High amount of fine coal in ROM coal

a) Problem status

At present, the ROM coal of the coal preparation plant is supplied from seven coal mining companies. The ROM coal is exploited by different methods (open pit, underground and bed). Then, it is treated by screening, grinding, and blending before being sold to coal preparation plants. Therefore, its quality is not stable with high rate of fine coal. Table 2 shows the quality of the ROM coal.

Table 2. Quality of the ROM coal.

No.	Size (mm)	Percentage (%)	Ash content (%)
1	0 – 0.1	14	22 – 31
2	0 – 1	30 – 37	22 – 31
3	0 – 15	70.58 – 86.63	22 – 31
4	>35	3.21 – 6.1	47.5 – 77.7

In comparison with the standard for the coal preparation plant in the design (the year 1989), the quality of ROM coal is worse. The fine coal (0 – 1 mm) accounts for 30 – 37% (the standard for the plant is less than 28%), especially the fine coal (<0.1 mm) is two times higher than the standard. It results in several problems in the coal preparation plant such as: high amount of magnetite loss (1.5 – 2 times); high amount of coal slurry (1.7 times than the standard), and low efficiency operation of the machines and equipment of the subsequent product treatment.

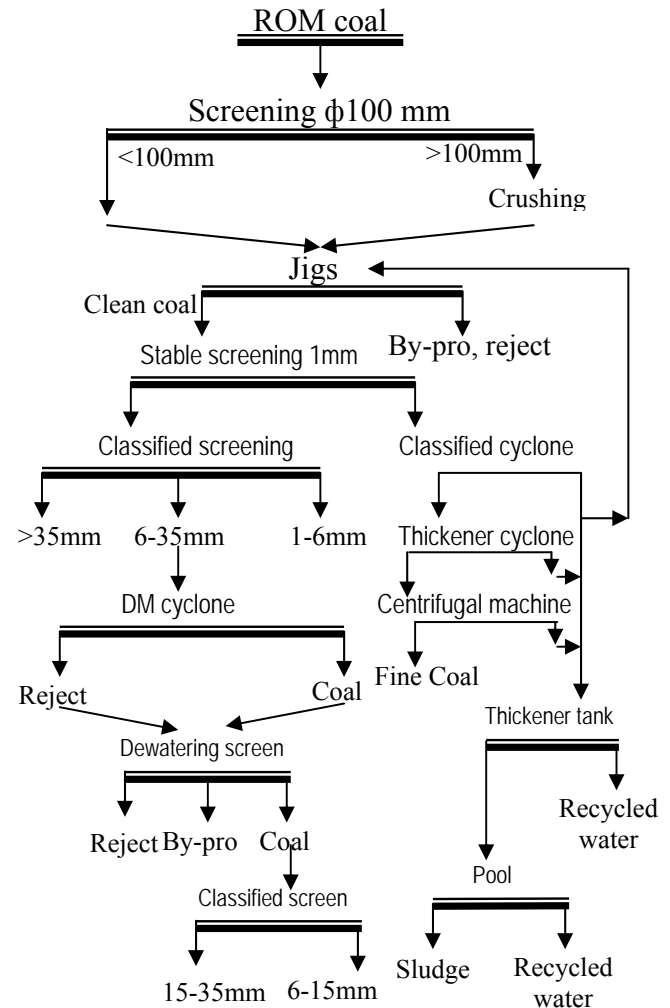


Figure 1. Schematic of the coal preparation plant.

b) CP option

Vinacomin supplies fine coal to all power plants in Vietnam. Therefore, it is suggested that Vinacomin should classify fine coal (<6 mm) for selling to the power plants.

Vietnam had 7 coal power plants with 1,170 MW of total production capacity. They used fine coal 5 (HG 100) or fine coal 6a (HG 11A) (according to Vietnamese standard: TCVN 1790 - 99) with ash content of 26 – 33%. It is estimated that the total fine coal demand for the power plants was 5.02 million tons that accounted for 15.1% of total exploited coal in 2006 [1-2].

Additionally, all coal mining companies of Vinacomin owned coal screening and treatment systems with 22.25 million tons of total production capacity [9]. Therefore, the coal mining companies can implement classifying fine coal from the ROM coal at a rate of 15% without additional investment.

It is expected that the amount of fine coal (<1 mm) would be reduced from 30–37% to less than 28% as per the standard of the coal preparation plant. This will result in reduced amount of coal slurry, slurry treatment, magnetite loss, and improving the operation of subsequent product treatment. Thus operating costs will be reduced and benefit obtained from using the fine coal for power production.

3.2.2. Dust treatment

a) Problem status

In the coal preparation plant, coal dust is a major pollutant in the ROM coal treatment process, especially in the screen system and feed sump. The ROM coal was poured into one feed sump, and then being classified by screen system. All machines, equipment, and workers operate in the underground area. This process produced high amount of coal dust ($0.2 \text{ mg/m}^3 - 124.95 \text{ g/m}^3$) that was 1–24 times higher than the Vietnamese Standard (TCVN 2934 – 1995). At that time, there was no dust reduction or treatment.

b) CP option

There common methods to reduce or treat coal dust are using water, chemical, machines, etc. However, in coal preparation process, it is necessary to ensure the moisture content for the ROM coal. Therefore, it is suggested that the plant should use water to prevent and treat the coal dust. The water will be used as a form of fog.

- Methodology: To create fog, air pressure machine and water pressure pump should be used. The water and air are pumped into a mixing box and then conveyed into special cocks. The cocks are designed specially to ensure that the mixed air-water comes out in a spiral at high speed (100 m/s) to create fog.

- Expected result: This dust treatment method has already been put in practice at several other locations. It has been seen to reduce 95%–99% of dust, especially the small dust (size <10 micrometer) [10-11]. Moreover, the water is in the form of fog can help the plant to improve the local atmosphere of this area. Additionally, experience has shown that this method does not affect the coal preparation or screening process because only 3.4 liters of water are used for dust treatment when screening 1 ton of ROM coal. The moisture content of the ROM coal is also not affected [10-11].

- Expense: Recently, the coal preparation plant has introduced one coal feed sump and one fine coal classifier screen system. It is estimated that the cost for dust treatment systems for feed sump and fine coal classifier screen is similar with dust treatment systems in other coal mining companies. The cost of dust treatment system for feed sump or the screening system is estimated at 400 million VND (25,000 USD). This expense can be borne by the environmental fund of the company (the Company annually contributes 8 billion VND, about 500,000 USD, to the environmental fund).

3.2.3. Stormwater management

a) Problem status

Stormwater is a problem for factories with large open-air areas. In the coal preparation plant, stormwater was a problem that needed to be addressed. The total floor area of the company was 57,500 m² including coal stockpiles, and 3 coal preparation plants and 12 supplementary mills.

Vietnam is located in the tropical area with high rate of annual rainfall. In the year 2004, the total volume of the rainfall in the coal preparation plant was 97,777 m³ [12]. At present, the company gathers all stormwater by gutter system to discharge directly into the sea.

Sine 2004, the Vietnamese Government has started to charge a wastewater fee. Moreover, the fresh water demand of

the company is high (about 3,000 m³ per day). Therefore, it is necessary for the company to reduce water usage and wastewater discharge.

b) CP option

It is suggested that the stormwater should be gathered for using in the coal preparation process. After gathering, the stormwater could be treated by the existing dam system before being used in the plant. However, the stormwater was gathered by a gutter system and discharged into the sea. Therefore, to use stormwater for the plant, some solutions are suggested as follows:

- Classifying the catchments of the company into sub-catchments: The whole area of the company can be classified into 3 smaller areas that are: area of stockpiles and coal preparation plants, area of supplementary mills, and area of railways.

- Constructing manholes: As per the theory, the fines could be trapped by manholes while running along gutter system. The existing gutter system was constructed with several manholes but some were operating with low efficiency because of their unsuitable location. Therefore, it is necessary to construct some more manholes and replace some existing manholes.

- Constructing one new tank to collect and store the stormwater: According to the rainfall rate, one new tank with 10 m³ storage capacity was suggested. After collecting into this tank, the stormwater could be pumped into the coal slurry dam system of the plant for treatment with the total wastewater of the plant.

Expected result

- Investment: 1,358 USD
 + Gutter construction: 15 USD/m x 200 m = 300 USD.
 + Manhole construction: 9 USD/hole x 12 holes = 108 USD
 + Tank for gather the stormwater (10 m³): 750 USD
 + New pump (<100 m³/hour): 200 USD
 - Benefit: 0.0625 USD/m³
 - Payback period: The estimated benefit and payback period are shown in Table 3.

Table 3. Benefit and payback period from CP option of recycling stormwater.

Total stormwater (m ³)	Rate of recycling the water (%)	Total volume of recycled water (m ³)	Benefits (USD)	Expense in this CP option (USD)	Payback period (year)
91,777	10	9,178	573.61	1,358	2.37
91,777	15	13,766	860.41	1,358	1.58
91,777	20	18,355	1,147.21	1,358	1.18
91,777	25	22,944	1,434.02	1,358	0.95

3.2.4. Improve quality of fine coal

a) Problem status

In the year 2005, the plant produced high amount of fine coal having high ash content (18%–25%) per day. As per the design, the fine coal product quality was improved by the spiral cyclone system. However, the plant decided to not use the spiral cyclones since 1995 because of their low operation efficiency. The fine coal was conveyed directly into thickener cyclones from classifier cyclones. This resulted in high ash content in the fine coal product.

There are several methods for cleaning up fine coal such as gravity method, hydrocyclone, screening, flotation, etc [13]. In Vietnam, coal preparation plants were provided with spiral

cyclones to improve quality of fine coal. Spiral cyclones operate at the highest efficiency if the relative density of the feed coal is around 1.7 g/cm^3 . However, in Vietnam all coal is separated by DM cyclones with solution having 1.52 g/cm^3 relative density that causes low efficiency operation. They produced fine coal product (<1 mm) having high ash content. Therefore, all coal preparation plants of Vietnam have stopped operating spiral cyclone systems for the last few years.

The coal preparation plant being studied also has one spiral cyclone system. However, the plant did not operate this system since 1995 because of the reason mentioned above. Therefore, in this CP option it was suggested that the plant should not recover operation of the spiral system to clean up the fine coal product. Instead, froth flotation method was suggested to clean up the fine coal product.

b) CP option

In Vietnam, flotation is still a relatively new method to wash anthracite coal. Thus, it is necessary to evaluate efficiency of the froth flotation method in washing fine coal of Vietnam. Experiments were conducted on washing the fine coal product of the coal preparation plant by froth flotation method to evaluate the efficacy of the proposed method and find the optimal working conditions.

The experiments were conducted based on the theory and other experiments of froth flotation that are presented in [13-17]. Details of the experimental procedure and results are also presented in [18].

Results of the experiment show that optimal efficiency is obtained at the following conditions:

- + Feed fine coal solution: rate of solid/liquid is 250 g/L ;
- + Collecting agent: petroleum $1,500 \text{ g/ton}$ of coal;
- + Froth creator: turpentine oil 50 g/ton of coal;
- + Time for stirring the solution with petroleum: 3 minutes;
- + Time for stirring the solution with froth creator: 1 minute;
- + Time for removing the froth: 3 minutes

By froth flotation method, the plant can get 77.61% of clean coal (10.58% of ash) from the fine coal product. The slurry reject is 22.39% with ash content of 79.19% that can be discharged directly to the waste stockpile.

The coal preparation plant has 3 jig machines that operate independently from each other. Therefore, to evaluate efficiency of the froth flotation method, it is suggested that the plant should construct one froth flotation process to clean fine coal product of one of the jig machines.

As per result of the experiment, the fine coal washing by froth flotation should be designed as follows:

- Technical evaluation:

As seen earlier, fine coal product of the jig system still has high amount of fine coal (<3 mm) which affects strongly the froth flotation process. Therefore, the plant should separate the fine coal (<3 mm) from the fine coal product of the jig machine by screen system, then, conveyed directly it into clean coal stockpile. The under screen product (>3 mm) is conveyed into a tank to stir with petroleum for 3 minutes of stirring, then, continuously being stirred with turpentine in the froth flotation machine. In the froth flotation machine, froth of clean coal is sent via the belt conveyor to dewatering screen system. Over-product of the dewatering screen system is conveyed into centrifugal machine to reduce moisture content before being conveyed into clean coal stockpile. The under-product of the dewatering screen system and solution from centrifugal machine are conveyed into dam system to reclaim water. Slurry of the dam system can be discharged. Diagram of the froth flotation technology is shown in Figure 2.

As per the operation of the coal preparation plant at present, operating schedule for the froth flotation is as following:

- + The input: 91.17 tons of fine coal/hour
- + Total working week of year: 52 weeks;
- + Total working day of week: 7 days;
- + Total working time of day: 24 hours.

Expected productivity: 597,346 tons of fine coal per year (with expected operating efficiency of the machines was 75%).

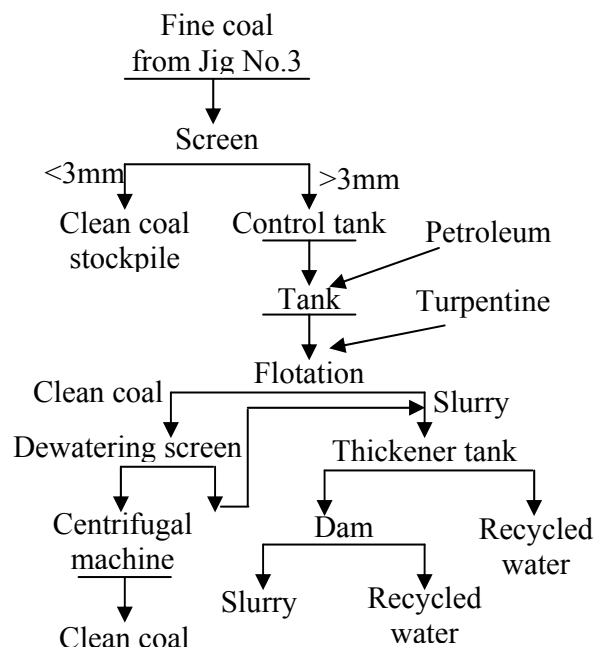


Figure 2. Schematic for washing fine coal by flotation method.

- Mass balance

At present, one jig machine produces 91.17 tons of fine coal (<1 mm) per hour. As per result of the experiment and the inventory, mass balance of the fine coal washing by flotation method for the jig machine was calculated. Moreover, to compare the product yield of the experiment, the mass balance was also done based on the product yield from some fine coal flotation plants.

To wash 91.17 tons of fine coal per hour, the coal preparation plant also uses some material as follows:

- + Petroleum: 136.76 kg of petroleum/hour.
- + Turpentine: 4.56 kg/hour .

The mass balance of the fine coal washing by flotation method is shown in Table 4.

+ Benefit from reducing coal slurry treatment: In this CP option, the plant can reduce 73,000–130,000 tons of coal slurry each per year. At present, the plant uses dam system to treat the coal slurry at 30,000 VND (1.87 USD) for each ton of the coal slurry. It is estimated that the plant can save 137,000–244,000 USD per year.

The benefit and payback period for this CP option are calculated in Table 5.

3.2.5. Some ideas for the development strategy of coal preparation in Vietnam

Vinacomin was planning to construct 3 new coal preparation factories for period of 2006–2010 [2-3]. This research shows some ideas for Vinacomin to make decision in the process of coal preparation plants construction as follows:

- Location: All coal preparation plants of Vinacomin now are located near the sea, especially near Ha Long Bay (world heritage site) and Bai Tu Long Bay and in the residential areas causing pollution. Therefore, Vinacomin should investigate and evaluate the location for the new coal preparation plants to get the highest benefit of environment, economy, and society.

Table 4. Mass balance of the fine coal washing by flotation method.

No.	Flotation methods	Coal Products (t/year)			
		Clean fine coal	Slurry fine coal	Reject	Total
1	According to Experiment [18]	294,073	169,527	133,755	597,345
2	According to the practice in Mountain Coal Co. [19]	286,652	156,462	154,231	597,345
3	According to the practice in CSIRO (72% of efficiency) [20]	275,249	150,172	171,924	597,345
4	According to the practice in CSIRO (82% of efficiency) [20]	309,647	168,976	118,722	597,345

Table 5. Benefit and payback period of washing fine coal by flotation.

No.	Flotation methods	Investment (1,000 VND)	Total saving (1,000 VND)	Payback period (year)
1	According to Experiment	14,414,000	20,264,760	0.71
2	According to the practice in Mountain Coal Co.	14,414,000	14,259,480	1.01
3	According to the practice in CSIRO (72% of efficiency)	14,414,000	8,345,997	1.73
4	According to the practice in CSIRO (82% of efficiency)	14,414,000	26,134,212	0.55

- Fresh water source: The inventory result shows that the coal preparation industry has high demand of fresh water. However, Quang Ninh province is located in the mountainous area and near the sea with rare fresh water source. Therefore, Vinacomin should find fresh water sources and use technologies which facilitate saving and recycling water.

- ROM coal management: The ROM coal was treated 2 times before being cleaned up. Moreover, the fine coal rate was increasing because of the methodology and technologies. Therefore, the coal preparation plants were facing problem of the fine coal washing but could be solved by supplying fine coal to power plants. In Vietnam, the power plants use fine coal with low quality (22–30% of ash content) and the demand of fine coal for power plants is increasing. Therefore, Vinacomin should require coal mining companies classifying fine coal (<6 mm) to sell to the power plants. By this method, the coal preparation plants could solve the problem of fine coal washing.

- Technology:

+ Jig and DM cyclone operate well for washing coal of Vietnam;

+ Spiral cyclone is not suitable to clean fine coal because the coal preparation plants of Vietnam now use relative density solution at 1.55 g/cm³ to wash up coal which is lower than the value for efficient operation of the spiral cyclone.

+ Vinacomin should study, research, and apply froth flotation method to clean up fine coal.

+ Dam system: In the year 2003, the coal preparation company started operation of a new modern dam system. This dam system was designed and constructed according to modern technology of Japan. Recently, it operates at high efficiency of coal slurry treatment and water recycle. Therefore, it is suggested that Vinacomin should apply the dam system in the new coal preparation plants in future.

- Coal slurry: At present, all coal preparation plants are facing problem of the coal slurry. It is suggested that Vinacomin should investigate and find out the way to use the coal slurry for the power plants (producing dried fine coal briquette, fluid-bed fire, etc).

5. Conclusion

This paper presents a case study of Cleaner Production application in a coal preparation facility in Vietnam. The coal preparation plant is the biggest one of Vietnam with technology including ROM coal pretreatment, jig system, DM system, and other equipment for the subsequent product treatment. Most machines and equipment operate well and with high efficiency

except equipment of the subsequent product treatment process. Therefore, the coal preparation plant faces some problems in the operation such as environmental problems (coal dust in the ROM coal pretreatment, noise), high amount of loss magnetite (1.5–2 times higher than the standard), low efficiency operation of the cyclone classifier system (86–88% of the designed capacity), low operation efficiency of the thickener cyclone system and centrifugal machines, high amount of fine coal loss (losing 0.93 ton of fine coal >1 mm in the coal slurry), high amount of coal slurry (2 times higher than the designed), low quality of the fine coal product (<1 mm), and water loss.

The paper suggests some CP options to address issues of ROM coal treatment, stormwater, dust treatment, and improving quality of the fine coal product. It is expected that the coal preparation plant can reduce the total volume of the fine coal in the ROM coal to the standard for the plant; treat 95 – 99% of total dust in the coal pre-treatment process and improve the atmosphere of the working area; and can save from 500,000 USD to 1.6 million USD each year.

Moreover, some ideas have also been suggested for Vinacomin to aid in the making decision process for the coal preparation development of Vietnam.

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