Cleaner Production in the Coal Preparation Industry of Vietnam: Necessity and Opportunities

Le Ba Viet Bach and S. H. Gheewala*

Environment Division,
The Joint Graduate School of Energy and Environment,
King Mongkut's University of Technology,
91 Pracha-uthit Rd, Bangmod, Tungkru, Bangkok, Thailand 10140
*Corresponding author: Shabbir_g@jgsee.kmutt.ac.th

Abstract: Coal has been playing key role in the development process of Vietnam. It is estimated that the total coal reserves in Vietnam are 3.2 million tons down to 300 meters. The productivity is expected to reach about 31 million tons and 42 million tons in the year 2005 and 2010 respectively. To reach the requirement of demand holders, run-of-mine (ROM) coal must be cleaned up. At present, there are 5 coal preparation plants that can wash up 30% of ROM coal in 2004 (about 9 million tons). The remaining 70% is treated by screening, grinding, and blending in coal mining companies. However, the coal preparation process has certain environmental

problems, especially a large amount of by-product with loss of coal. From 1995 onwards, the Vietnam National Coal Corporation (Vinacoal) set up a fund allocating 1% of total revenue of all the member companies for environmental protection. However, Vinacoal is still facing many problems of pollution, especially the high amount of wastes. Hopefully, Cleaner Production would be the way to help Vinacoal to achieve comprehensive targets of environment and economy. This paper overviews the situation of the coal preparation industry in Vietnam and points out main problems of the coal preparation and opportunities for application of Cleaner Production in the industry.

Key words: Cleaner Production, Coal preparation, screening and treatment system, environment.

1. Introduction

In the progress of development, the human kind has been recognizing the significance of environment. That is why we have been changing our activities from natural pollution self recovery reliance to pollution control by implementation of the end-of-pipe technology. But the results so far are not efficient in both environmental and economic terms. Therefore, new

ways are being sought to reach sustainable development. Cleaner Production is one of such new way. In the year 1989, Cleaner Production (CP) was defined by UNEP as "the continuous application of an integrated preventive environmental strategy to processes, products and services to increase overall efficiency" [1]. The main techniques of CP are: improve process control, recycling, process modification, input substitution, redesigning technology, and product modification [1].

A Cleaner Production center was established in Vietnam in 1999 with help of UNIDO and UNEP [2]. The center has been implementing CP projects in some sectors of the industry such as textile, paper, food, and metal. For the coal preparation industry, there is still no CP project implemented.

The coal preparation industry of Vietnam is under the management of the Vietnam National Coal Corporation Company (Vinacoal) of the Ministry of Industry, Vietnam. In 2004, the industry cleaned up 27 million tons of run-of-mine (ROM) coal for Vinacoal [3,4]. However, the industry has been facing problems with the amount of wastes and mounting expenses of environmental treatment as the productivity increases swiftly year by year. Hopefully, the CP techniques could provide a way for Vinacoal to reach the comprehensive targets of environmental and economy for the coal preparation industry.

This article highlights the necessities to implement CP in the coal preparation industry of Vietnam. Moreover, it also points out the opportunities for CP application in the industry.

2. Profile of the coal preparation industry

Coal has been playing key role in the development process of Vietnam, being exploited locally and used for more than 120 years. In Vietnam, coal is located mainly in the northern province of Quang Ninh with estimated reserves of 3.2 billion tons down to 300 meters, a large portion being anthracite coal [4]. Vinacoal has been raising the productivity year by year with the help of modern technologies. Since the year of establishment (1995) to 2004, Vinacoal has exploited 103 million tons of ROM coal accounting for 30% of the total exploited productivity in the period of 120 years. In 1995, 7 million tons of ROM coal were exploited but the amount increased to 27 million tons of ROM coal in 2004. As per the strategy of Vinacoal, the productivity will reach about 31 million tons and 42 million tons of ROM coal in the year 2005 and 2010, respectively [3,4].

The demand for clean coal has been increasing in Vietnam because coal is the main energy source for many sectors and industries such as power, cement, paper, etc. As per the development strategy of industry, the demands of coal will reach

about 24.5 million tons of clean coal in 2010 in which includes 21 million tons for domestic demand and 3.5 million tons for export [3,4].

To meet quality requirement of consumption holders, ROM coal is screened and cleaned up. At present, the ROM coal is screened and cleaned up by five coal preparation plants, and screening and treatment systems of the coal mining companies. To raise productivity of clean coal, Vinacoal has been constructing 3 new coal preparation plants with total production capacity of 22 million tons of ROM coal until the year 2010 [4]. Development strategy of the coal preparation industry in Vietnam is shown more detail in Table 3.

2.1 The management status

Vinacoal has two coal preparation companies that operate independently with 23 coal mining companies. These coal mining companies sell ROM coal to the coal preparation companies on a contractual basis. To reach quality requirements of ROM coal for coal preparation plants, coal mining companies implement ROM coal pre-treatment by screening, grinding, and blending. However, the total capacity of coal preparation plants accounts for only 30% of total amount of ROM coal of Vinacoal. Therefore, to treat the remaining part of ROM coal, Vinacoal permits coal mining companies self-producing and

selling clean coal directly to the domestic market. Recently, all the coal mining companies own coal screening and treating systems. Figure 1 shows diagram of the management system of coal preparation industry.

2.2 The technology status

At present, technology of the coal preparation industry can be divided into 2 groups that are screen and treatment system, and washery technology.

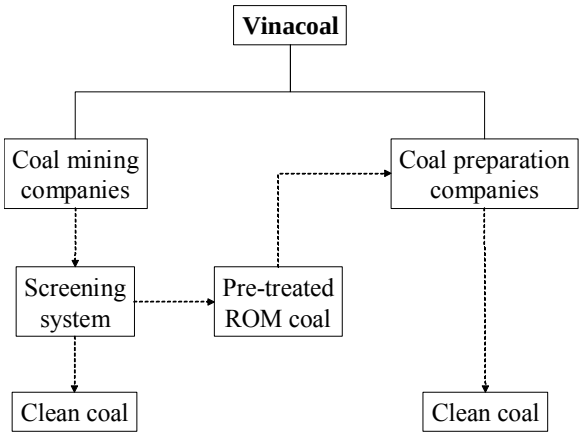

Figure 1. Management system of the coal preparation industry of Vietnam.

2.2.1 Screen and treatment system

All coal mining companies of Vinacoal have their own screen and treatment systems to pre-treat ROM coal. The

technology includes dry screening, hand picking, grinding, and blending. At present, the total production capacity of the systems is 21 million tons of ROM coal per year [4]. Table 1 shows the production capacity of the screening and treatment system at present and future.

Table 1. Production capacity of the screening and treatment system of Vinacoal [4].

Unit: million tons

No.	Region	Year			
		2005	2010	2015	2020
1	Cam Pha	9.160	5.425	2.850	2.205
2	Hon Gai	4.920	6.850	7.800	7.435
3	Uong Bi	5.920	4.500	5.900	5.680
4	Internal	2.245	3.015	3.965	7.965
5	Total	**22.245**	**19.790**	**20.515**	**23.285**

The screening and treatment systems of the coal mining companies can be divided into 2 categories. The first is the simple system to pre-treat ROM coal before selling to coal preparation companies. The total amount of ROM coal are pre-treated by this system accounts for 30% of total ROM coal. The system uses screening with size 100 mm, 70 mm or 50 mm to classify coarse coal. Figure 2 shows the flow diagram of dry

screening process for pre-treatment of ROM coal for coal preparation companies. The product (with size <70 mm) is sold to coal preparation companies. The coarse coal product (>70 mm) is grinded into fine coal, then blended with good fine coal to be consumed by domestic holders.

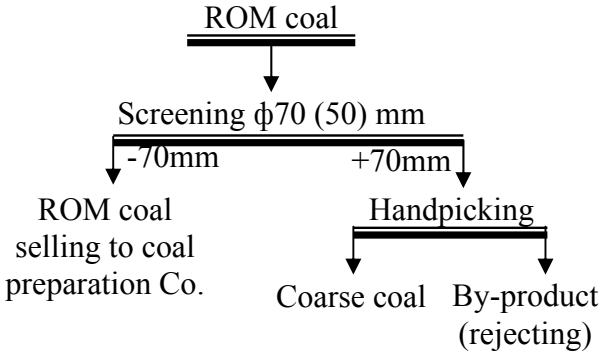

Figure 2. Flow diagram of ROM coal pre-treatment [5].

The remaining 70% of ROM coal is cleaned by simple technologies in coal mining companies. Figure 3 shows flow diagram of clean coal production in coal mining companies.

The technology of dry screening has some problems associated with it as follows:

- The efficiency is low, especially it is affected by weather because most screening and treating groups of the coal mining companies are located in open-air.
- Producing high volume of by-product. At present, Vinacoal has not got any technology to reclaim coal from the by-

product. Most of the by-product is stored to reclaim coal in future.

- The by-product includes high rate of coal. Table 2 shows the quantity and quality of by-product in some coal mining companies of Vinacoal.
- It is difficult to manage the by-product.
- Environmental pollution (will be discussed further in the next part).

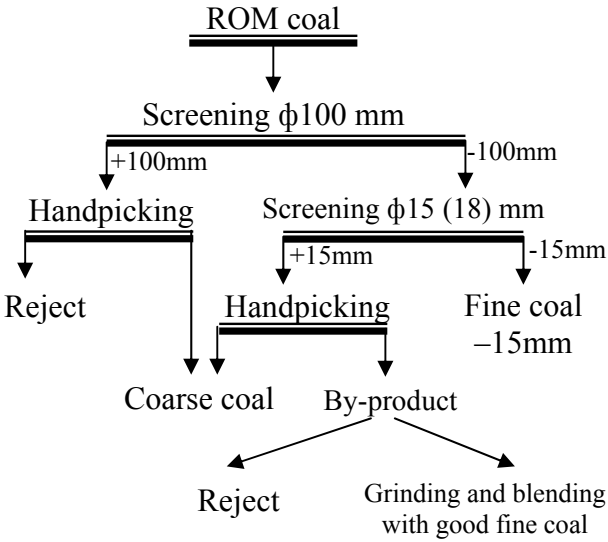

Figure 3. Flow diagram of clean coal production in coal mining companies [5].

2.2.2 Coal washery technology

At present, Vietnam has 5 coal preparation plants with different technologies viz., jig, washery, washery plate, spiral

cyclone, and heavy density cyclone. The total production capacity is 9 million tons of ROM coal that accounts for 30% of the total ROM coal in 2004.

Table 2. Quantity and quality of by-product in some coal mining companies of Vinacoal [5].

No.	Coal mining Co.	Productivity (1000 tons)		Quality of by-product		Remained by-product (1000 tons)
		ROM coal	By-product	Size (mm)	Ash (%)	
1	Mao Khe	800	45.4	<70	40 ÷ 60	5
2	Uong Bi	650	130	<100	40 ÷ 55	40
3	Ha Lam	600	110	<70	45 ÷ 60	80
4	Ha Tu	1,000	150	<70	45 ÷ 65	150
5	Nui Beo	500	80	<70	50 ÷ 65	10
6	Coc Sau	1,300	190	<100	50 ÷ 65	1,500
7	Deo Nai	1,400	220	<100	50 ÷ 65	3,000
8	Cao Son	1,500	110	<100	40 ÷ 60	550
9	Khe Cham	400	60	<100	35 ÷ 50	5
10	Duong Huy	670	50	<100	35 ÷ 55	10
11	Thong Nhat	400	35	<100	40 ÷ 60	5
12	Total	9,220	1,930.4	-	35 ÷ 65	5,355

• Cua Ong coal preparation company [5]:

Cua Ong Coal Preparation Company is located in Cam Pha region with a production capacity of 7 million tons. The company has 3 coal preparation plants.

- The plant No.1: This plant was constructed in 1924 and upgraded in 1961. The production capacity is 1 million tons of ROM coal per year. Figure 4 shows diagram of technology of the coal preparation plant No.1.

- The plant No. 2: This plant, with 3.2 million tons of production capacity, was constructed in 1980 and upgraded in 1990. The plant has been upgraded once again in 2004 to reach 5.2 million tons of production capacity. Figure 5 shows diagram of technology of the plant No.2.

- The plant No.3: This plant was constructed by the Cua Ong company. The main technology is dry screening and hand-picking up.

• Hon Gai coal preparation company [5]:

The plant was constructed in 1997 with 2 million tons of production capacity per year. The ROM coal from coal mining companies is screened to classify fine coal before washing. Then the ROM coal is cleaned up by jig systems, and heavy density cyclone. The coal preparation process in Hon Gai Coal Preparation Company is similar to the plant No.2 of Cua Ong Coal Preparation Company.

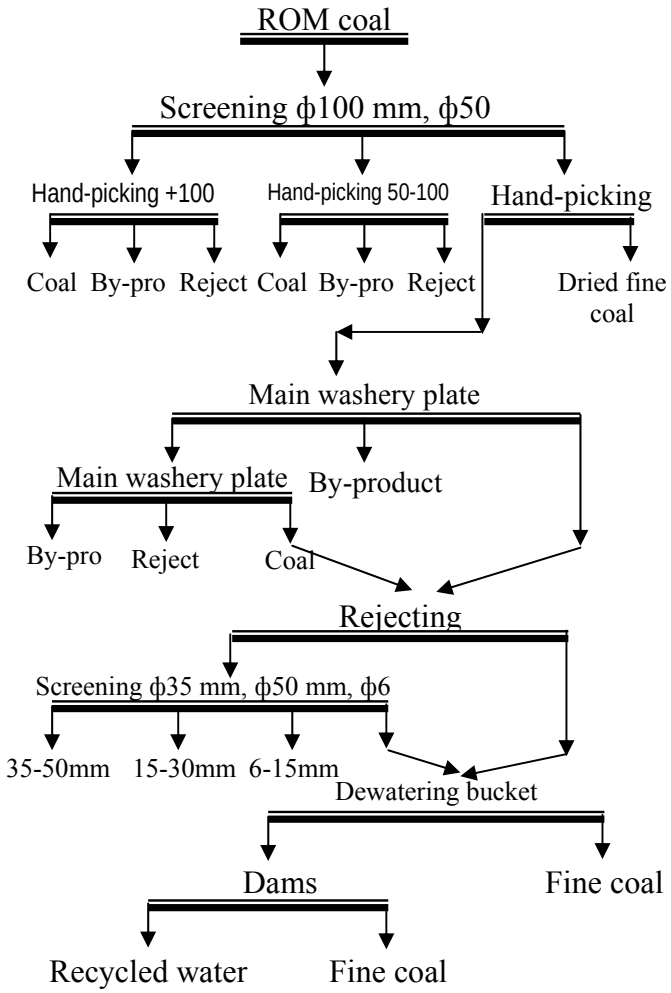

Figure 4. Flow diagram of coal preparation at plant No.1 of Cua Ong Coal Preparation Co [5].

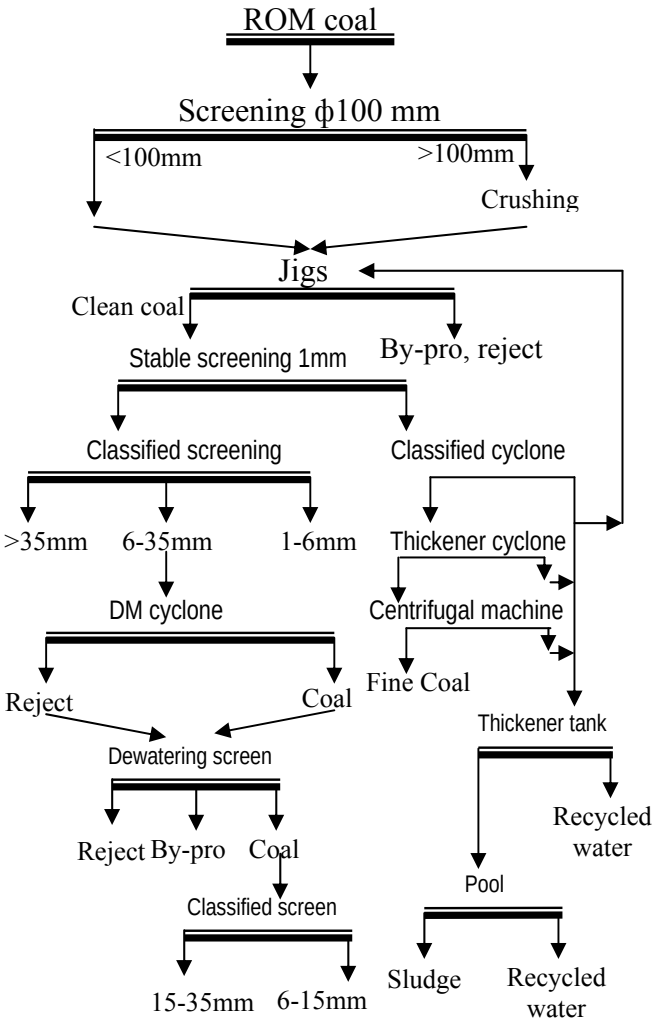

Figure 5. Flow diagram of coal preparation at plant No.2 of Cua Ong Coal Preparation Co [5].

• Vang Danh coal preparation plant [5]:

This plant is managed by Vang Danh coal mining company. The plant was constructed in 1963 with 600,000 tons of production capacity per year. The technology of this plant includes 3 processes as follows:

- Pre-treatment: this process is to screen ROM coal to classify fine coal 0 – 13 mm.
- Washery process: the pre-treated ROM coal is cleaned up by heavy density pool with 2 phases. At first, the coal is cleaned up by heavy density solution with relative density of 1.8 kg/dm^3. Then, it is conveyed to the pool having solution of relative density of 2.0 kg/dm^3.
- Subsequent product treatment.

However, at present the pre-treated ROM coal is cleaned up in solution having relative density of 1.9kg/dm^3. Therefore, the by-product and reject still have high rate of coal. The plant reclaims coal from by-product and reject by hand picking up. Figure 6 shows flow diagram of the technology at Vang Danh coal preparation plant.

As mentioned earlier, at present, coal preparation plants of Vietnam clean up only 30% of the total ROM coal. Therefore, the plants can not supply enough high quality coal to demand holders. To meet the demand, Vinacoal has made a strategy for coal preparation for the period until 2020 which is outlined in Table 3.

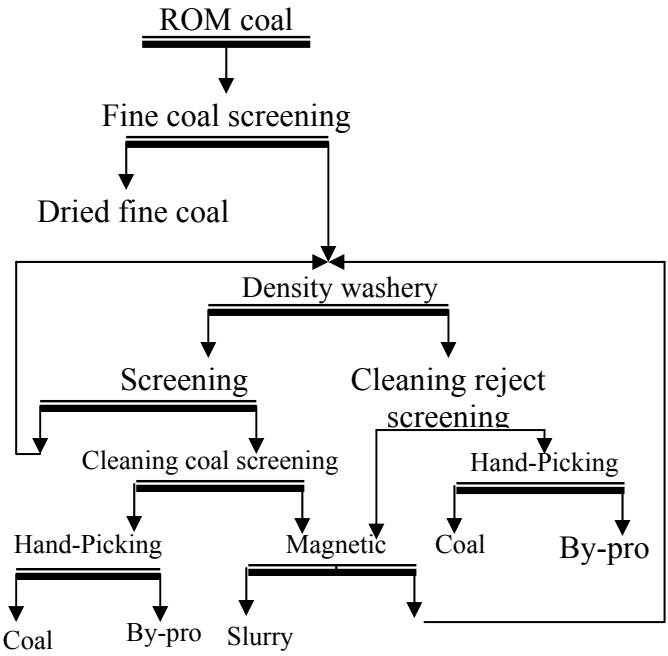

Figure 6. Flow diagram of coal preparation at Vang Danh coal preparation plant [5].

2.3 The environment

At present, Vinacoal has a department of environment to manage the environmental problems. However, all coal mining companies and coal preparation companies, except Cua Ong Coal Preparation Company, still do not have their own environmental department. Therefore, all problems in the branch companies of Vinacoal are managed by one staff in the technology department.

Table 3. The development strategy of coal preparation industry of Vietnam [4].

No.	Coal Preparation Plant	Production capacity (10^3 t/y)	Washery methods	Note
A	Cam Pha region			
1	Plant No.1 (Cua Ong coal preparation Co.)	3,500	Washing plate	Needs upgrade
2	Plant No.1 (Cua Ong coal preparation Co.)	5,000	Jig, DM cyclone, spiral cyclone	Needs upgrade
3	Khe Cham	12,000	Jig, and DM cyclone	Starts operating in 2008
B	Khe Tam region			
1	Lep My	5,000	Jig, and DM cyclone	Starts operating in 2008
C	Hon Gai region			
1	Hon Gai	2,000	Jig, DM cyclone, and spiral cyclone	Needs upgrade
D	Uong Bi region			
1	Vang Danh (Vang Danh coal mining Co.	2,000	Heavy density solution pool	Needs upgrade
2	Uong Bi	5,000 ÷ 7,000	Heavy density solution pool	Starts operating in 2008

In the year 1995, Vinacoal launched an environmental fund by using 1% of the total revenues of the Company [4]. The environmental fund has been used by the coal preparation industry for implementing environmental projects such as dust treatment for screening systems (in Duong Huy mining company, Nui Beo mining company), buying water-cart, waste water treatment (in Cua Ong Coal Preparation Company),

monitoring, etc. However, there are many problems resulting from coal preparation process, especially due to increase in productivity. Therefore, Vinacoal still meets many problems in balancing the environmental target with economic targets.

3. Necessity and opportunities for CP application in the coal preparation industry

3.1 The necessities to practice CP in mining industry

The definition of CP as presented by UNEP with guidance to put CP in practice was presented earlier. However, CP is put in practice with different priorities and methods depending on the actual situation. Hilson [6] indicated "CP practice", for the mining field, as "management and organizational measures that put a firm in a better position to handle, minimize, and anticipate problems with wastes". CP for mining industry was defined as "a superior level of environmental performance, which can only be achieved through improved strategy and housekeeping, sound process control, optimized plant layout, and the implementation of efficient management techniques" [6]. To achieve CP, the mining industry should continuously improve input materials, the design of operations,

energy, 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].

By the definition of CP above, mining industry can get comprehensive targets of environment and economy. This target is contrary to the target of traditional end-of-pipe technologies in waste treatment. The end-of-pipe technologies aim to treat wastes after releasing. Therefore, the technologies do not prevent the increasing of wastes and losing material and energy. Moreover, the traditional technologies, in reality, only transfer waste from one kind to another.

The mining industry has been facing with high pressure of legislation on environmental issues. For the mining industry, the environmental impacts were known fully 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 in the results of monitoring [6]. These results have been used for setting up legislation. Therefore, the industry must consider the environmental problems seriously.

Additionally, demand for products of the mining industry increases strongly with the development process consequently

increasing the total waste. Therefore, it is necessary to approach new ways to minimize waste emission and move towards sustainable development.

3.2 Issues related to the coal preparation industry in Vietnam

- Old technologies

In future, demand for clean coal will increase strongly. However, at present, 70% of ROM coal in Vietnam is still cleaned by dry screening technology and hand picking.

Coal mining companies: most coal screen systems were designed and constructed in the 1960s and 70s [5]. These technologies include mainly screens, grinding machines, hand picking, and blending methods. Moreover, most of the activities are held in open air areas. Therefore, their efficiency is low and affected strongly by the weather [5].

Coal preparation companies: At present, Vinacoal has 5 coal preparation plants. However, they were designed and constructed a long time ago (except the plant No. 2 of Cua Ong Coal Preparation Company and Hon Gai Coal Preparation Company). Vang Danh plant was constructed in 1972, the plants No. 1 and No. 3 of Cua Ong Coal Preparation Company were constructed in the early 20^{th} century. Moreover, at present there are many machines, equipment which are approaching

the end of their operation time, for example 73% of equipment and machines of Cua Ong Coal Preparation Company has finished their period of discount [5].

- High volume of fresh water:

At present, demand of fresh water of coal preparation plant is high. For Cua Ong Coal Preparation Company with the capacity of 1,200 tons of ROM coal/day, it needs 3,000 m^3/day of fresh water. Similarly, Hon Gai Coal Preparation Company consumes 1,500 m^3 of fresh water for coal preparation in each day [7]. As the development strategy, there will be 3 new coal preparation plants in near future with total production capacity of 22 million tons (Table 3). Therefore, the demand for fresh water will increase strongly. Moreover, Quang Ninh province is located in mountainous and near the sea. So, the industry should pay more attention to finding fresh water sources and recycling the wastewater for ensuring its fresh water demand.

- High solid waste volume:

Coal screen system: It is estimated that the solid waste produced by the system is about 11 – 15% of the ROM coal [7]. At this rate, about 1.8 – 2.2 million tons of solid waste are produced each year.

Coal preparation plant: The solid waste produced from the plant accounts for 20% ÷ 25% of the ROM coal [7]. At this rate,

to clean up 10 million tons ROM coal in 2004, 2 – 2.5 million tons of solid waste was produced. Moreover, the solid waste still includes high amount of clean coal. The clean coal accounted for 10% – 20% (200,000 – 500,000 tons) of the total volume of solid waste [7].

- High volume of by-product:

Recently, 70% of the ROM coal is screened, grinded, and blended to produce clean coal. However, most screen systems use old technology [5]. Therefore, they produce high volume of by-product. The amount and quality of the by-product is shown in Table 2. Most by-product is stored in stockpiles to reclaim clean coal in future. The coal preparation industry of Vietnam produces ~5.4 million tons of by-product each year [5]. Therefore, it is necessary to find a way to minimize the volume of the by-product and reclaim the clean coal.

- High volume of magnetite consumption:

The coal preparation industry of Vietnam uses magnetite to clean coal in 3 coal preparation plants. However, magnetite is used at high rate. The plant No. 2 of Cua Ong Coal Preparation Company and Hon Gai Coal Preparation Company use 1 – 2.0 kg of magnetite for each ton of ROM coal. This number is 1-2 times as high as magnetite consumption in other coal preparation plants in the world. In Vang Danh coal preparation

plant, the number is 7.5 – 8.5 kg/ ton of clean coal [5]. Therefore, the industry uses a high amount of magnetite and consequently produces a high amount of waste.

- High volume of slurry:

Slurry coal is tailing product of the coal preparation process. The coal preparation industry of Vietnam produces 1.2 – 1.5 million tons of slurry each year that is 1.5 – 2 times higher than the design value [5]. Moreover, demand for slurry coal is low because it is consumed mainly domestically such as by brick producers and for daily usage in households. Therefore, it is a big problem for the industry.

- Location of coal preparation plants:

In Vietnam, all coal preparation plants are located in the special areas. Cua Ong Coal Preparation Company is located in resident area of Cua Ong town and near Bai Tu Long bay. Hon Gai Coal Preparation Company is located near Hon Gai town and beside Ha Long bay (world natural heritage site). Vang Danh coal preparation plant is located near Vang Danh resident group and near Vang Danh stream (the main stream of this area). Therefore, they have high ability to pollute environment of the areas, especially effect to resident areas and sensitive natural areas [4].

- High cost of environmental treatment:

It has been seen in practice that it is quite expensive to implement environmental protection projects. For example, in 2004, Duong Huy Coal Mining Company implemented a project of dust treatment for one coal screen system. It cost 400 million Vietnam Dong (VND) (~26,000 USD) [8]. Moreover, the company paid 15 million VND (~1,000 USD) for monitoring each quarter. At present, each coal mining company owns 2 or 3 coal screen systems. Therefore, the coal preparation industry must spend more money in the dust treatment. In 2004, Cua Ong Coal Preparation Company started operating a new wastewater treatment plant0. The total cost of the wastewater treatment is 123.03 billion VND (~8 million USD) [8]. Hopefully, CP will help the coal preparation industry to reach comprehensive targets of both environment and economy.

- Problem from waste stockpile:

Most coal screen systems of the coal mining companies are located in mountainous areas. However, all coal preparation plants are located in environmentally sensitive areas (such as Ha Long bay, Bai Tu Long Bay, Vang Danh river). Therefore, they meet a lot of trouble with waste stockpiling. In Cua Ong Coal Preparation Company, one area in the sea (in Bai Tu Long bay) is used as a waste stockpile. The area of the stockpile is 480,000 m^2 [5]. It is estimated that the company discharges more than 1 million tons of solid

waste into this area each year. It is a similar case with Hon Gai Coal Preparation Company. In near future, there will be 3 coal preparation plants constructed. Therefore, it is necessary to find a solution for this problem.

- Legislation pressure:

Vietnam has been considering environmental protection seriously. For example, recently Vietnam has issued several legislative documents (Environmental law in 1995, Environmental strategy for period of 2000 - 2010, the standard for environment, etc). The Vietnamese Government issued environmental fee for wastewater in 2003. Moreover, due to the development process, Vietnam will issue more legislation for environmental protection. Therefore, the coal preparation industry of Vietnam will be under strong pressure due to the high volume of wastes.

3.3 Opportunities for application of CP in the coal preparation industry

3.3.1 Managerial change

- Improving the ROM coal management

At present, coal preparation companies buy ROM coal from coal mining companies. As presented above, ROM coal is pre-treated before selling to coal preparation companies.

However, to get high quality for coal washery process, the ROM coal is pre-treated again in coal preparation companies.

- Both the coal mining companies and coal preparation companies are under the management of Vinacoal. Therefore, Vinacoal could require coal mining companies to sell coal directly to coal preparation companies. This solution could bring some advantages for Vinacoal as follows:

- At present, all equipment and machines of the pre-treatment ROM coal in Cua Ong Coal Preparation Company and Hon Gai Coal Preparation Company operate at 46% ÷ 75% of the design capacity. They have ability to pre-treat ROM coal.

- 9 million tons of ROM coal would not be pre-treated two times;

- Reducing rate of fine coal in ROM coal: The ROM coal is pre-treated two times. So it results in ROM coal being pulverized thus increasing the rate of fine ROM coal. At present, the rate of ROM coal supported to Cua Ong Coal Preparation Company has increased to twice that in the year of construction.

- Improving the production capacity of some phases of coal washery process: The increased rate of fine coal and consequently lower amount of coarse coal reduces the efficiency of the coarse coal washery phase. However, the fine coal washery operates with overload production capacity.

- Reducing the environmental protection cost: All screening and treatment systems of coal mining companies are in open air. Therefore, it is required to invest in dust treatment. In the year 2002, Nui Beo coal mining company installed 1 dust treatment system for one screening group with the cost of 160 million Vietnam Dong (10,000 USD). At present, all coal mining companies have screening systems to treat ROM coal for the coal preparation companies. Therefore, the coal mining companies could reduce the total number of the ROM coal pre-treatment screening system if they can transport ROM coal directly to the coal preparation companies after exploiting. Moreover, it could result to the reducing environmental treatment for the screening systems in the coal mining companies.

- Establish environmental management system (EMS):

EMS is the component of the overall management system that includes organizational procedures, environmental responsibilities, and processes. The system has been introduced by many industries in the last few decades. These systems help an organization to control the impacts of its activities, products, and services on the environment by offering a structured approach to dealing with environmental issues [6].

Since 1995, Vinacoal established environmental fund from 1% of its total revenue each year (about 3 million USD).

By this fund, Vinacoal has been implementing many environmental projects in coal mining, coal preparation, and related activities. However, Vinacoal has still not established EMS. All coal mining companies and coal preparation companies (except Cua Ong Coal Preparation Company) do not have department of environment. The environmental problems are managed by one person of technology department. With the large scope of Vincoal, it is necessary to establish EMS.

- Better process control

- The standard for the coal preparation industry: Recently, Vinacoal issued standards for the industry on the products, material and energy consumption, and quality of ROM coal. However, some standards were set a long time ago. Therefore, they are not currently suitable for practice. For example, the standard of ROM coal supporting to coal preparation companies stipulates ratio of fine coal (<1 mm) in ROM coal at 28.4%. However, the ratio is actually 30% - 34% [7]. Similarly, the electricity consumption in coal preparation industry is higher than the standard. It is suggested that Vincoal should evaluate and adjust the standards in line with the current practices.

- Adjust working schedule: Since the year 2004 until now, Cua Ong Coal Preparation Company have been adjusting the working schedule by taking turns having relax times (for

having dinner or lunch), and having 2 free days each week. By this way, the company reduced the non-operating times in each shift, and can operate 24 hours per day and 7 days per week. This method contributed to the increasing of the productivity (from 3.2 million tons of ROM coal in 2004 to 5.2 million ton of ROM coal in 2004) [7]. Hopefully, this method could help the coal preparation industry to increase the productivity and efficiency.

- By-product management:

The coal preparation industry of Vietnam produces ~5.4 million tons of by-product each year. The by-product includes some amount of clean coal (more details in Table 2). However, it is stored and managed by coal mining companies because there is now no technology to reclaim clean coal from the by-product. Therefore, it is difficult for Vinacoal to manage the total by-product before finding technology to reclaim clean coal. At present, Vincoal has 3 regions of coal mining (Uong Bi, Hon Gai, and Cam Pha regions). So Vinacoal can manage the by-product according to the region by buying by-product from coal mining companies in each region. By this method, hopefully, Vinacoal can gather the product in each region to reclaim clean coal in future.

3.3.2 Policy changes

Policy is to ensure the environmental decision-making for all operations of any industry. Some examples are the corporate environmental policies, voluntary impact assessments, environ--mental audits, and reviews. The policy makers can issue environmental rules for all activities of one industry. Many companies have their own environmental policy. For example, WMC Ltd., Australia's third biggest gold mining company, issued an environmental policy that stipulates and guides its branch companies to establish environmental targets on corporate commitment, prevention, review and education, improvement, education and training [6].

In Vietnam, some ministries such as Ministry of Construction (2003) and Ministry of Industry (2004) have issued the environmental policies. Vinacoal is one of the biggest companies in Vietnam with many activities affecting the environment; especially, Vinacoal still has not got EMS. Therefore, the policy can stipulate and guide the branch companies of Vinacoal (including coal preparation activities) to implement environmental protection, including CP.

3.3.3. Physical changes

- Input substitution solution

To treat slurry coal in the subsequent product treatment process, the coal preparation industry uses coagulant in thickener tanks. At present, the industry uses VFA 1099 and VFO 1088 as coagulants [7]. They are imported from Australia and France. In 2004, the industry used 100,000 kg of the coagulants [7]. Vinacoal spends 36,337 billion Vietnam Dong (VND) (about 2 million USD) on coagulants each year. To solve this problem, Vinacoal can find other coagulants produced domestically. Similarly, in 1996, Vinacoal produced magnetite that helps it to save money from not importing magnetite. Hopefully, the domestic coagulant can help Vinacoal to reduce cost for clean coal production.

- Tailing coal:

Tailing coal is the unexpected product of coal preparation process. In Vietnam, the coal preparation industry produces more than 1 million tons of tailing coal each year. However, it is consumed mainly domestically with low demand [7]. Therefore, the industry still meets problems of the tailing coal.

In many countries, tailing coal is used to feed power plants. For example, Wllerawang, a mining company of Australia, solved problems resulting from 300,000 m^3 of coal tailing by reusing it in one power plant. The coal tailings are compressed into 50 mm dried briquettes which are then fed to the power plant at 20 tons per day. It is expected that all the

tailing coal would be consumed when the power plant will consume 100 tons of the briquettes in near future [9]. In the period of 2005 – 2010, Vietnam will increase the number of power plants with a total capacity of 3,025 MW [4]. Therefore, the coal preparation industry should set up plan for using tailing coal in power plants.

- Improve subsequent product treatment:

Recently, all coal preparation plants of Vietnam still meet problems of the subsequent product treatment. The subsequent product treatment is to treat fine coal product from jig system. However, the ratio of fine coal in feed ROM coal of jig is higher than the design [7]. This results in a high ratio of fine coal in the subsequent product treatment. All equipments of the process operation with overload capacity and low efficiency. The fine product has low quality (ash content is in range of 24% - 30%) [7]. Therefore, it is necessary to improve this process.

In the world, froth flotation method has been used to clean fine coal for over 50 years. In general, the carbonaceous mineral constituents of coal can be made to preferentially attach to fine bubbles and float to the surface of dilute slurry, where they can be removed, while in contrast the low carbonaceous inert minerals of the raw coal do not attach to the bubbles. This is because the carbonaceous particles are

generally naturally hydrophobic whereas the inert minerals are not. Now, the fine coal in feed ROM coal is about 2 times than the design. Therefore, the coal preparation industry can apply the froth flotation method to wash fine coal [10].

For other solution, all the coal preparation plants use spiral cyclones to improve quality of fine coal [7]. However, the cyclones operate with low efficiency (in Hon Gai Coal Preparation Company) or are not used any more (in Cua Ong Coal Preparation Company). Therefore, the fine coal product has low quality. Therefore, it is necessary to recover operation of the spiral cyclones.

- Reducing magnetite loss:

A high volume of magnetite is lost in the coal preparation process. Records of coal preparation companies show that the total magnetite loss is 1.5 - 2.0 times higher than the standard. To find reasons for the problem, it is necessary to access more detail in each process of the coal preparation plants. However, some possible reasons are as follows:

- The quality of magnetite: The magnetite solution depends on magnetic factor and size of magnetite. Therefore, the coal preparation plants should use suitable magnetite for different ROM coal sources;

- The magnetite solution making process: At present, the coal preparation plants have grinding machines to grind magnetite before making magnetite solution. However, some plants do not use these machines any more. Therefore, there are still some magnetic lumps that do not dissolve during magnetite solution preparation. Therefore, it is necessary to ensure the magnetite can be dissolved completely in the solution;
- Reducing and using effectively the water flow in the process of cleaning magnetite from products of DM cyclone.
- Operation of the magnetite preparation machines.
- Ensuring DM cyclones operate at their production capacity.

4. Conclusion

The coal preparation industry has been playing a key role in the coal mining industry of Vietnam contributing also to the energy security. The clean coal production process in Vietnam can be divided into two processes that are classifying in coal mining companies and cleaning up in coal preparation plants. In the coal mining companies, ROM coal is classified by screening, grinding and blending systems. In the coal preparation plants, ROM coal is washed by good technology (Jigs, DM cyclone, spiral separators, etc.). However, these processes are meeting some problems of production and environment. At present,

most of the screening systems in the coal mining companies were designed and constructed about 30 years ago. This has resulted in low efficiency, high amount of by-products and reject, and high environmental treatment cost. Similarly, the coal preparation plants have some problems of low efficiency of operation, high magnetite consumption, high amount of waste, coal slurry consumption, and environmental treatment cost. Additionally, the coal preparation industry will meet some other problems in near future (high fresh water demand, waste treatment) when they increase their production capacity. This paper points out the opportunities to solve the problems in the coal preparation industry using CP techniques. Hopefully, Vinacoal can get comprehensive target of economy and environment from the CP application. However, to get successful results, it is necessary to assess and evaluate more details about each situation.

References

[1] MIP, UNEP, CEERD (2001) *CP3 Pilot Course.*

[2] Bent, H., 2001. *Promising CP Demonstration Projects in Vietnam*, Vietnam Cleaner Production Centre, Hi-tech Building, Hanoi University of Technology.

[3] Mining & Industrial Consultant and Investment Company (2003) *Tong So Do Phat Trien Nganh Than (Vietnam Coal Sector Strategy toward 2010 and oriented to 2020).*

[4] Mining & Industrial Consultant and Investment Company (2003) *Dieu Chinh Quy Hoach Phat Trien Nganh Than Vietnam Giai Doan 2005-2010 Co Xet Trien Vong Den Nam 2020 (Adjusting Vietnam Coal Sector Strategy toward 2010 and oriented to 2020)*.

[5] Hoang, M.H. (2003) *Nghien Cuu Cong Nghe Thu Hoi Than Tu Bai Thai Ba Sang Tai Cac Mo Than Vung Quang Ninh (Researching the Coal Reclaiming Technology from by-product in Mining Coal Companies in Quang Ninh area)*, IMSAT.

[6] Hilson, G. (2003) Defining "cleaner production" and "pollution prevention" in the mining context, *Minerals engineering*, **16**, pp. 305-321.

[7] Nguyen, T.H.H. (2004) *Nghien cuu anh huong cua cong nghe tuyen than toi moi truong (studying effects of coal preparation technologies in environment)*, IMSAT.

[8] Luong, N.L and Bach, L.B.V. (2003) *Xu ly bui tai xuong sang khu vuc 36 - Cong ty than Duong Huy (Dust treatment at screen system in the 36 area - Duong Huy Coal Mining Company)*, IMSAT.

[8] Nguyen, V.C. (2004) Bao cao tham luan tai hoi nghi tong ket 10 nam thuc hien cong tac bao ve moi truong cua Tong cong ty than Vietnam (Environmental report of Cua Ong Coal Preparation Company at meeting of environmental protection holding by Vinacoal).

[9] Bradley, R., Marc, K., and Russell, A. (2004) Wallerawang Colliery Rehabilitation: The Coal Tailings Briquetting Process, *Minerals Engi-neering*, **17**, pp. 153 – 157.

[10] Budge, G., Brough, J., Knight, J., Woodruff, D. and McNamara, L. 2000) *Review of the worldwide status of coal preparation technology*.

[11] Ralph, A.L. and Jaroslave, N. (2004) A Programmatic Review of UNIDO/UNEP National Cleaner Production Centres, *Journal of Cleaner Production*, **12**, pp. 195-205.

[12] Dharmappa, H.B., Wingrove, K., Sivakumar, M., and Singh, R., (2000) Wastewater and Stormwater Minimization in A Coal Mine, *Journal of Cleaner Production*, **8**, pp. 23 - 34.

[13] IMSAT. (2003) *Environmental Monitoring Report in 2003*. IMSAT.

[14] Hilson., G. (2000) Pollution prevention and cleaner production in the mining industry: an analysis of current issues, *Journal of Cleaner Production*, **8**(2), pp. 119 – 126.