Assessment on Environmental Quality Management of Coal Stockpile for Environmental Sustainability

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Abstract

The positive impact of coal mining has been reported to increase the country's economy and community income. However, the negative impact is found to be reducing the physical and chemical parameters of air, noise, soil and spontaneous combustion quality, therefore, having the potential to decrease environmental quality. Environmental management is often carried out to improve the physical and chemical parameters of societal quality, in order to match the required standards, therefore, resulting in sustainable coal mining. The management has also created environmental costs, as an externality of coal mining activities. Based on the technical assessment conducted, the results showed that environmental management at Tarahan Port Unit of PT BUKIT ASAM Persero Tbk, has been implemented in accordance with the Environmental Management/Monitoring Plan (RKL/RPL) documents, as well as the prevailing Indonesian laws and regulations. The physical and chemical parameters were observed to have met the standards of environmental quality, for a sustainable community. However, the economical assessment showed a mismatch between planned and realized environmental management costs. The funds used in the second quarter increased by IDR. 121,183,548 or 102.02%, compared to the realization program in that of the first. This increase was due to the construction of a dust suppression system and an operational chimney for the 2X8 MW Steam Power Plant, via the use of Electrostatic Precipitators. This research recommended a detailed inventory of environmental cost plans and escalation, in order to anticipate risk factors. And also help in carrying out machine maintenances, which are known to produce emissions on a regular basis. Therefore the emission produced were observed to be decreased, with the funds for managing and monitoring the environment also reduced.

Introduction

Environmental-friendly development has been reported to be important for nations, which are oriented to natural resources and societal preservations [1], as the mining industry is observed to be similar to two sides of a coin. On one side, it has an important role in improving the country and community's economy [2–10]. The mining contribution to other industrial sectors is also very important in maintaining the function of the global economy, as well as the community's welfare. Furthermore, it provides large amounts of energy, raw materials for industries and building infrastructure, producing goods and services, improving the life quality in the community, etc [11–13].

On the opposite side of the coin, mining is one of the potential sectors for environmental degradation. It has the ability in making the society unfriendly, due to pollutants produced by industries [2,4, 14–16].

Examples are related to a decrease in air quality, which occurred in previous studies carried out by [17–22]. Also, examples of air pollution originating from SO₂ emissions in Kankoyo Township, Zambia, are entirely considered by the community, as a result of mining operations. Air pollution is also one of the most significant environmental problems, which are encountered by communities living in and around mining areas [23]. Similarly, the impact of CO₂ emissions as air pollutants from coal-fired power plants, contributed to environmental problems [21,24–26]. Meanwhile, other potential impact emerged from the use of fossil fuels in large quantities, which is likely to result in health deterioration of living things [18,19,27–29], such as noise kebisingan [2,30], spontaneous combustion [9,10,31–34] and a decrease in soil quality [35–40]. These impacts

occurred in an attempt to secure more energy, food, and infrastructure. In addition, there are traces of environmental contamination and human health hazards [41].

Furthermore, coal loading activities from the stockpile to barge at Tarahan Port Unit of PT. Bukit Asam, have potentials in causing negative impacts on the environment, such as decreased air & soil qualities, as well as spontaneous combustion. The environmental quality management towards the impact of the coal loading process is also very important, as the air and soil qualities that are discharged into the environment does not exceed the applicable standards. Environmental management and monitoring activities on a regular basis are also very important, in order to overcome these impacts [42]

Therefore, natural resource management policy is compulsory and important for the utilization of raw materials, in the coal mining sector. However, the environment remains sustainable, through the monitoring and management of environmental quality [43].

Environmental management activities on coal stockpiles have also been found to incur operational costs [13,44]. External costs are known to reflect the money value of damages, which are caused by the life cycle of coal mining, transportation, and burning, on the functions of human health, the environment, streams, forests, as well as the ecosystems [44]. This cost is, ecologically, and socially observed to be a form of protection for the environment [13,45–48]. Due to the environment and natural resources having no money value, protection by providing an economical assessment is required [1,13,49].

Therefore, as an effective and efficient environmental protection effort in the mining sector, it is important to carry out technical and economical assessments on the implementation of societal quality management and costs, as stated in the RKL-RPL report of PT Bukit Asam Persero Tbk, at Tarahan Port Unit. This societal implementation of PT Bukit Asam Persero Tbk at Tarahan Unit in 2020, refers to the Environmental Management and Monitoring Plans (RKL & RPL), based on the Governor of Lampung Decree No: G/149/II.05/HK/2015, concerning Permits Environment of Tarahan Port Development Activity Plan.

Material And Methods

Research location

Tarahan Port Unit of PT. Bukit Asam Persero Tbk is located ± 18 km from Bandar Lampung City, and ± 6 km to the south of Panjang Port, Lampung Province. These locations are illustrated in Fig. 1.

Methods

The method was carried out via the use of survey and direct observations to the stockpile location of PT Bukit Asam Unit Persero Tbk, Tarahan Port. Also, it was carried out quantitatively, by calculating the environmental costs incurred, which were observed as activity externalities in the coal stockpile. The selection of Tarahan Port Unit as the sample location was carried out by the purposive sampling technique, with the following considerations,

(1) Coal stockpile of PT. Bukit Asam Persero Tbk, Tarahan Port Unit: This is one of the largest stockpiles in Indonesia, which is located in Lampung Province.

(2) The operational activities of PT Bukit Asam Persero Tbk, Tarahan Port Unit: These activities have environmental impacts, which aids in reducing air, noise and soil qualities, as well as the potential for coal spontaneous combustion.

Also, primary data were obtained by,

- (1) Observing the implementation and success rate of environmental management, in the coal stockpile of PT Bukit Asam Persero Tbk, at Tarahan Port Unit,
- (2) Conducting sampling and measurement of air, noise, soil, and spontaneous combustion,
- (3) The quality test results of the physical and chemical parameters, which are related to environmental management, on the coal stockpile of PT Bukit Asam Persero Tbk, at Tarahan Port Unit

Moreover, secondary data were obtained by conducting literature and institutional studies. Literature study was carried out through the tracing of previous results, national and international journal publications, as well as other sources related to the research problems. Furthermore, the institutional study was obtained from various educational documents of the mining company at Tarahan Port Unit of PT. Bukit Asam Persero Tbk, and other related agencies. Data processing was also carried out, by comparing the quality standards between the study location's environmental management with the prevailing laws and regulations in Indonesia. Also, data analysis was descriptively conducted, in order to technically and economically explain the implementation and success of environmental quality management, in the coal stockpile of PT Bukit Asam Persero Tbk, Tarahan Port Unit.

Environmental Monitoring and Management Procedure

Quality of Ambient Air Emissions and Noise

Monitoring the quality of ambient air and noise was intended, in order to observe the extent by which they were to be carried out in PT Bukit Asam Persero Tbk, Tarahan Port Unit. This was in accordance with the Environmental Quality Standards, which had been stipulated by a Government Regulation Decree, and/or the Indonesian Minister of Environment.

The monitoring periods of the air and noise quality were carried out once every month. Therefore, the procedures for the monitoring and management of ambient air and noise quality emissions are as follows,

a. Monitored Impact and Parameter Indicators

The monitored environmental impact and parameter indicators were in accordance with Government Regulation no. 41 of 1999, concerning Air Pollution Control, as well as Minister of the Environment Decree No. Kep-48/MENLH/XI/1996, on Noise Level Standards.

b. Source of Impact

Sources of impact from the operational activities of Tarahan Port, includes coal shipping and transportation activities.

c. Monitoring Location

The monitoring locations where the ambient air and noise qualities were carried out, included the coal stockpile of PT. Bukit Asam Persero Tbk at Tarahan Port Unit, and the surrounding residential areas of neighbourhood 22 and 23, Batu Serampok.

Monitoring Points:

- U1 = The Corner of Stockpile 3
- U2 = Near the Water Tank
- U3 = Yard of the State Electricity Company (PLN) Boarding House
- U4 = Yard of the Begandang IV Restaurant
- U5 = Yard of the Batu Serampok Village Residents

The quality of the coal stockpile spontaneous combustion

When the spontaneous combustion of the stockpile occurs on a large scale, it causes air pollution, and reduces the quality and amount of coal that should be sold. In order to prevent this case, PT Bukit Asam Persero Tbk at Tarahan Port Unit, conducted spontaneous combustion monitoring at the coal stockpile location.

This monitoring period was carried out at any time, via direct observation in the field. The procedures for monitoring and managing coal pile spontaneous combustion are as follows,

a. Monitored Impact and Parameter Indicators

The indicators monitored were the occurrence of spontaneous combustion, at the front location and coal stockpiling.

b. Source of Impact

Sources of impact were observed from coal stockpiling activities.

c. Monitoring Location

The 4 locations where coal pile spontaneous combustion was carried out, includes,

- Stockpile 1
- Stockpile 2
- Stockpile 3
- Stockpile 4

Soil Quality Monitoring and Management

Soil quality monitoring and management in PT. Bukit Asam Persero Tbk at Tarahan Port Unit, was carried out through reforestation, which involved the planting of trees. Moreover, plant management was carried out using compost. Before moving to the soil, the trees were initially planted in polybags, as there was no soil physical chemistry test during its management. This was due to the existing soil being heaped and rocky.

Results And Discussion

Positive and negative impacts of coal mining

The utilization of mining natural resources has been observed to play an important role in generating foreign exchange, increasing the economy, as well as improving major industries in developing (Suriname, Mongolia, India, Pakistan, Indonesia, Nigeria), and developed countries, such as Alabama, Kentucky, Marland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia and Brazil, Spain [2–10]. For example, mining was found to be an important industrial sector, in Indonesia [3]. In 2013, the country's foreign exchange, which amounted to USD 28,434,240,130, was generated from the mining sector [4]. Data from the Ministry of Energy and Mineral Resources showed that, from the Non-Tax State Revenue (PNBP), the contribution of the mining sector continued to indicate an increasing trend. This was observed in the increasing revenues from 2015–2017, at IDR 29.6, 27.2, 40.6 trillions, until November 2018 when it reached IDR. 41.02 trillion. This indicated that the mining sector (PNBP) in 2018 had exceeded the government's target. Similarly in Colombia, there was no doubt about the importance of the mining and energy sectors. In 2011, the mining sector contributed 2.3% to GDP, with coal, metals, and other minerals at 68%, 18%, and 13%, respectively [50]. Also, the South African economy was heavily dependent on fossil fuels, with about 91% of the main source on coal electricity [38].

Even though the mining contribution to other industrial sectors was very important in maintaining the community welfare and global economy function, it is also observed to have an impact on the environment, which was likely to disrupt public acceptance towards this sector, especially when the effect management was not properly carried out [51].

Environmental Issues on coal stockpile

A coal stockpile should be stored for a certain time, before being transported and utilized. Environmental issues in the management of coal stockpiles, includes,

- (1) Dust, toxic fumes, heavy metals, and radiation spills of chemicals, which are poison miners, have caused health problems throughout their existence.
- (2) An increase in waste of toxic and hazardous materials or B3, which requires special handling.
- (3) The smoke from coal piles, which are observed to reduce air quality.

Environmental problem have also occurred in coal stockpiles through the following,

- (1) As a result of leaching process that occurs by rainwater against the coal surface or forming acidic leachates, which are known to pollute the waters,
- (2) Most of Indonesia's coal includes lignite to bituminous types, which are spontaneous-combustible, as a result of oxidation that increases temperature.

These aforementioned issues were found to have eliminated environmental functions as carbon assimilators, in order to provide clean energy, which were needed by humans and other living things. Therefore, the use of coal should always maintain the sustainability of environmental functions [15,52].

In order to minimize environmental impacts, irregular landscaping, mine pits, high erosion and sedimentation, low soil fertility, as well as the production of acid mine drainage were observed to have lasted for hundreds of years, which in turn kills biota in public waters. These also required planning, implementation, supervision, as well as an assessment of good mining activities.

Technical Assessment of Environmental Quality Management Implementation in stockpile

Law No. 32 of 2009 concerning Environmental Protection and Management, regulated the existence of planning, utilization, control, maintenance, supervision, and regulation enforcement activities. However, the control aspect was divided into prevention, counter-measures, and recovery. Prevention was carried out by issuing environmental quality standards, such as air, water, and soil quality principles. The implementation of environmental impact activities was also regulated in a management and monitoring system, as well as required aspects of compliance with permits, regulations, and standards. Assessment on the implementation of environmental monitoring and management activities was also carried out, based on the prevailing laws and regulations in Indonesia. However, the assessment used in this research was the visual observation method, as it had also been adopted by previous studies [11]. The first step in conducting a technical assessment towards the implementation of environmental management in the coal stockpile of PT Bukit Asam Persero Tbk at Tarahan Port Unit, was observation. Based on the visual results, an analysis of the quality test was carried out on the chemical physics parameters of ambient air, noise, soil, non-hazardous waste (fly ash and bottom ash), and spontaneous combustion. Furthermore, it was compared to environmental quality standards, as stipulated in Government and Minister of Environment Regulations.

Ambient Air and Noise Quality Management

This research also conducted a technical assessment on the implementation of environmental management, at PT Bukit Asam in Tarahan Port Unit, which was related to the ambient air and noise qualities. Therefore, analysis was conducted, in order to determine whether the implementation of ambient air management was in accordance with the Environmental Quality Standards (BML), which had been stipulated in the Government Regulation No. 41 of 1999, concerning Air Pollution Control. Moreover, the noise was in accordance with the Minister of the Environment Decree Number. 48/MENLH/XI/ 1996, concerning Noise Level Standards.

1. Ambient Air Quality

Coal as the main energy source, was a basic requirement for fulfilling the energy needs of a country [5]. However, its use had been observed to produce carbon dioxide emissions, which also contributes to air pollution [26]. Air pollution causes a decrease in atmospheric quality, due to the release of dust and gaseous pollutants, such as sulphur & nitrogen dioxide (SO_2 & NO_2), as well as particulate matter [53]. A decrease in air quality is found to have an impact on coal dust dispersion, due to wind assistance (blows on the coal pile), as well as when unloading and loading of charcoal into transport vehicles. The most important parameters for air quality within the active surface mine area, were the total suspended particles (TSP) and residues with an aerodynamic diameter smaller than $10\text{ }\mu\text{m}$ (PM10) [54].

Also, another impact was on the living things' health, which emerged from air pollution, due to the large use of coal fossil fuels [18,19,27,29]. This impact was as a result of dust, sulphur and nitrogen dioxide (SO_2 & NO_2), as well as particulate matter [21]. These parameters were observed to increase significantly in areas with coal mining, compared to regions without the activity. For example, in New South Wales, there has been a significant increase in areas with coal mining, compared to other states without the activity. Moreover, it also had an impact on health, resulting in the occurrence of diseases such as an increased risk of cancer, cardiovascular and respiratory disorders, pneumoconiosis, chronic bronchitis, silicosis, tuberculosis [55], ARI (acute respiratory infection), coughs, colds, and asthma [28]. Additionally, health impacts were observed to often occur in mining workers, as well as the surrounding community. Also, air pollution was observed to cause inflation. As in the Philippines, air pollution incurred an economical cost of around IDR 2 billion (PHP 103 billion), due to lower life quality and increased health care values. Therefore, air pollution was conclusively the biggest environmental risk factor for human health and the environment, in the Philippines [17].

Generally, the dust particulates' size in the air also has an impact on health, with the most dangerous ones ranging from 0.1 to 10 micron. Airborne particulates enters directly into the lungs and settle in the alveoli, on a size of about 5 microns. However, this does not mean that particulate sizes larger than 5 microns were harmless. Larger particulates are observed to disturb the upper respiratory tract, which in turn causes irritation. When there is a synergistic reaction with SO_2 gas present in the air from the coal crusher, as well as loading and unloading activities, this situation tends to become worse. Also, irritation to the eyes have been reported to block visibility, due to dust particles floating and flying in the wind. Furthermore, the greatest danger to human health is the presence of toxic metals in the dust particles floating in the air. However, the polluted air only contains hazardous metals, which are about 0.01–3% of all dust particulates. The metals contained in the inhaled air have greater effects, compared to similar doses emerging from food or drinking water. This is because metals are accumulative, with high possibilities of synergistic reactions occurring in the body tissues [56]. However, PM_{10} was formed due to mechanical disturbances (crushing, grinding and surface abrasion), spray evaporation, and dust re-suspension. The oxidation of SO_2 in the atmosphere were observed to occur homogeneously in the gas and water phases (rain drop), as well as heterogeneously on the particle's surface or a combination of the three [21].

Apart from human health, dust from mining waste disposal also polluted the soil [25,55], and biodiversity, because during the combustion process, greenhouse emissions were formed with several other gases, such as H_2O , CO_2 , CO , CH_4 , H_2S , H , SO_2 , SO_3 , HCl , & NH_4 , which were concentrated in the atmosphere, absorbed by trees (flora), and inhaled by fauna [11].

Environmental monitoring and management at Tarahan Port Unit of PT Bukit Asam Persero Tbk, which were related to the chemical physics parameters of ambient air, were carried out by identifying, assessing, and controlling the dust impacts, as well as the type of sources. Moreover, this method was previously used for dust impact management in Serbian mines. This was observed to be efficient, in order to reduce dust below the permitted standard [30,57].

Based on the assessment carried out on the quality test results of chemical physics parameters, monitoring and management of ambient air and noise qualities in the coal stockpile of PT Bukit Asam Persero Tbk at Tarahan

Port Uni, were in accordance with the quality standards, which were set by the two regulations applied in Indonesia. The results are presented in Table 1 and Fig. 4, respectively.

Table 1
Test results of Physical and Chemical Parameters Quality for Monitoring Ambient Air Quality

Parameter	Unit	Sampling	Government Regulation No. 41 of 1999 Minister of the Environment Decree No. Lep-48/MENLH/ XI/1996
Dust	($\mu\text{g}/\text{Nm}^3$)	159.6	230
CO	($\mu\text{g}/\text{Nm}^3$)	1201	10000
SO ₂	($\mu\text{g}/\text{Nm}^3$)	28.8	365
NO ₂	($\mu\text{g}/\text{Nm}^3$)	26.2	150
O ₃	($\mu\text{g}/\text{Nm}^3$)	16.88	235
HC	($\mu\text{g}/\text{Nm}^3$)	6.6	160
Pb	($\mu\text{g}/\text{Nm}^3$)	< 0.01	2
PM ₁₀	($\mu\text{g}/\text{Nm}^3$)	56.64	150
Source: Author, 2021			

Table 1 and Fig. 4 showed that the quality of the air physics and chemical parameters of Tarahan Port Unit, was below the standard required by Government Regulation No. 41 of 1999, with values of Dust, CO, SO₂, NO₂, O₃, HC, Pb, and PM₁₀ at 159.6, 12.01, 28.8, 26.2, 16.88, 6.6, < 0.01, and 56.64 ($\mu\text{g}/\text{Nm}^3$), respectively. These results indicated that the ambient air level in Tarahan Port Unit of PT Bukit Asam Persero Tbk was stable and normal, as it was safe to be released into the atmosphere, in order to minimize the impact that was to emerge on the health of mining workers and community living around the stockpile.

However, a previous study by [28] reported different observations, where the dust parameters in the research area was above standards, with indication of an average value of 224 $\mu\text{g}/\text{Nm}^3$ for the 7 monitoring point locations. These results indicated that the current management of dust parameters (159.6 224 $\mu\text{g}/\text{Nm}^3$) in Tarahan Port Unit of PT Bukit Asam Persero Tbk, was better than before. This research also found that the reduction in dust was caused by the use of a suppression system in each dropping zone, transfer chute, feeding hopper, and belt convenience. Therefore, the coal dust was sucked into this equipment, resulting in less concentrated potential in the air.

2. Noise Quality

Noise at the stockpile location was caused by sounds, which were emitted by heavy equipments, when loading and unloading coal into/from transport vehicles [56]. Apart from dust, noise was also recognized as a major pollutant for the mining environment, as it posed a high risk to health when its permitted level had been exceeded. Accordingly, noise should be prevented via the use of mapping. Besides being very efficient, this

method is also cheap in solving environmental noise problems [30,57]. In India, the noise mapping method was mandatory for use in coal mining, as recommended by the Tenth Conference on Safety in Mining [57]. This method should be carried out by using efficient and accurate computer modeling software. This should also be strategized at the mine planning stage [58]. The noise test results and quality standards are presented in Table 2.

Table 2
The Results of Noise Test and Noise Quality Standards

Location	Parameter	Unit	Sampling	Minister of the Environment Decree. No.Kep-48/MENLH/XI/1996
U1. The corner of <i>stockpile</i> 3	noise	dBA	62.3	70
U2. Near the Water Tank	noise	dBA	62.7	65
U3. PLN boarding house yard	noise	dBA	54.2	65
U4. Begadang IV Restaurant yard	noise	dBA	52.4	65
U5. Residents Yards at Batu Serampok Village	noise	dBA	51.6	55

Table 2 and Fig. 6 showed the noise level in the coal stockpile, at Tarahan Port Unit of PTBA Persero Tbk. Generally, the condition was below the quality standard required by the Minister of Environment Decree No. Kep-48 / MENLH / X1 / 1996, concerning Noise Level Standard.

U1 = The noise value at the monitoring point location corner of Stockpile 3 at 62.3 dBA.

U2 = The water tank at 62.7 dBA.

U3 = The PLN boarding house yard at 54.2 dBA.

U4 = The Begadang 4 Restaurant yard at 52.4 dBA.

U5 = The residential yards of Batu Serampok Village at 51.6 dBA.

The parameters above are very important as benchmarks for noise quality standards. Mostly, the noise level at Tarahan Port Unit of PT Bukit Asam, was in stable and normal conditions, as the potential to have an impact on the community health around the coal stockpile, was small.

Furthermore, these results indicated that the implementation of noise management at Tarahan Port Unit of PT Bukit Asam Persero Tbk, was in accordance with the Indonesian Minister of Environment Decree.

Spontaneous Combustion Management of Coal Stockpiles

Coal has been observed to have a tendency to carry out self-combustion or Spontaneous Coal Combustion, which is likely to cause uncontrolled fires when exposed to air [59]. Spontaneous Coal Combustion is a phenomenon that starts with self-heating on the coal surface, without any additional externalities. The existence of SCC in coal mining also posed a high risk to the workers and environment, because of its potential

to trigger fires. Self-heating is observed to occur when insufficient heat generated by coal oxidation, is dissipated into the surrounding environment. This heat accumulation causes a slow temperature increase, at the beginning of the coal oxidation stage. Once the temperature attains a critical point of 60–120°C, thermal runaway occurs, and the self-heating rate of coal is likely to take off in a relatively short period of time. The phenomenon of this spontaneous combustion was observed to always be a big challenge in the coal industry, which is also affected by many parameters, such as pyrite and moisture content. These fires aids the ignitions in coal waste piles, stockpiles, transits, as well as surface and underground mines [59]. However, large-scale spontaneous combustion causes air pollution, and reduces the quality and amount of coal that should be sold. Therefore, the Tarahan Port Unit of PT Bukit Asam had to conduct monitoring, in order to prevent the emergence of the spontaneous coal combustion danger at the stockpile location [60].

Based on the assessment conducted on the management of SCC at Tarahan Port Unit of PT. Bukit Asam Persero Tbk, there was no occurrence of spontaneous coal combustion. Therefore, it was concluded that the management of spontaneous coal combustion had been implemented properly and correctly. The monitoring activities on spontaneous coal combustion at the Tarahan port unit of PT Bukit Asam for the August 2020 period, are shown in Table 3.

Table 3
Monitoring Activities on Spontaneous Coal Combustion at Tarahan Port Unit of PT Bukit Asam for
the August 2020 Period

Monitoring date	Monitoring Points (Stockpile)				Descriptions
	1	2	3	4	
1-Aug-20	NO SPONTANEOUS COAL COMBUSTION				
2-Aug-20					
3-Aug-20					
4-Aug-20					
5-Aug-20					
6-Aug-20					
7-Aug-20					
8-Aug-20					
9-Aug-20					
10-Aug-20					
11-Aug-20					
12-Aug-20					
13-Aug-20					
14-Aug-20					
15-Aug-20					
16-Aug-20					
17-Aug-20					
18-Aug-20					
19-Aug-20					
20-Aug-20					
21-Aug-20					

Source: Author, 2021

Descriptions:

Extinguishing action was carried out

Actions were in accordance with the Management Procedure of Spontaneous Coal Combustion

The Executive of Operational Support Division

22-Aug-20
23-Aug-20
24-Aug-20
25-Aug-20
26-Aug-20
27-Aug-20
28-Aug-20
29-Aug-20
30-Aug-20
31-Aug-20
Source: Author, 2021
Descriptions:
Extinguishing action was carried out
Actions were in accordance with the Management Procedure of Spontaneous Coal Combustion
The Executive of Operational Support Division

Soil Management

The soil in ex-mining land is often characterized by low organic matter (SOM) content, due to the significant loss of nutrition associated with SOM. This loss of nutrition includes nitrogen (N), phosphorus (P), potassium, Iron (Fe), Copper (Cu), reduced fertility, as well as decreased physical, chemical, and biological properties of soil quality (Fig. 7) [38,40,55]. These malnutrition changes includes compression, decreased soil resistance to erosion, reduced soil productivity, infiltration rates affecting groundwater, as well a less soil pH and microbial population [61]. Moreover, low nutrient elements were caused by soil acidity, due to intensive leaching [55,62]. Soils with high acidity are found to reduce bacterial activity, which in turn leads to permanent sterility (reduces soil productivity and tends to inhibit formation and plant growth), due to very low amounts of nitrogen, phosphorus, and potassium. Soil in the ex-mining land were observed to contain low chemical properties, such as cation exchange capacity (CEC), organic matter (OM), and ppm base saturation [63].

However, soil quality assessment is one of the key parameters for evaluating a contaminated mining environment [39]. This is because plants needs to assimilate nutrients from quality soil, in order to complete their vegetative and reproductive life cycle. Other important elements, such as carbon, hydrogen, and oxygen, which are available to plants, are obtained freely from CO₂ and water. These are then converted into carbohydrates, during the process of photosynthesis [64].

Besides nutrients, other impacts on soil quality include a decrease in the average value of SWC (soil water content), cohesion, organic matter, as well as an increase in the mean rate of the inner fraction angle. However,

it does not significantly affect soil and dry densities, as well as porosity. The decline in the surface of the coal mining were also observed to have an impact on soil quality [36,37].

The management used in improving the quality of degraded soil was performed by planting trees. The choice of tree species greatly influenced the increase, for example, long-rooted plants help in restoring fertility [55]. Furthermore, a mixture of desulphurized coal waste with rice husk ash, steel slag, and sludge disposal as a technosol constituent, were observed to produce soil that helps in promoting plant growth [65].

The soil management carried out by PT. Bukit Asam, Tbk at Tarahan Port Unit, was reforestation by planting of trees. However, plant management was carried out by using compost. Also, before moving to the ground, the plants species were planted in polybags. In the soil management at Tarahan Port Unit of PT Bukit Asam Persero Tbk, there was no occurrence of physical chemistry test. This was mainly because of the heaped and rocky nature of the existing soil. The management efforts being carried out were,

- (1) Planting green plants around the Tarahan Port area, as a medium for rainwater absorption.
- (2) Providing Green Open Space.
- (3) Performing reforestation in operational road areas, as well as locations that have the potential for more dust.

The species of plant seeds managed by PT. Bukit Asam, Tbk at Tarahan Port Unit, and its benefits for the environment (air, land, and water), are presented in Table 4.

Table 4

Species of plant seeds managed by PT. Bukit Asam, Tbk at Tarahan Port Unit and its benefits for the environment (air, land, and water) [66]

Species of Seeds	Seed Stock per July 2020	Planting in August 2020	The rest of the seeds per August 2020	Benefits of these plants for the environment
Buddha's Belly Bamboo (<i>bambusa tuldoidea ventricosa</i>)	121	0	121	Erosion barrier to prevent flood hazards.
Haur Geulis bamboo (<i>Bambusa vulgaris var vitata</i>)	116	0	116	Handling toxic waste due to mercury poisoning
Petung Bamboo (<i>dendrocalamus asper</i>)	535	25	510	Source of well water supply
Latin African Bamboo (<i>oxytenathera abyssinica</i>)	108	0	108	
Chinese yellow fence bamboo (<i>bambusa multiplex alphonse karr</i>)	161	10	151	
Agarwood	388	0	338	Erosion barrier
Eucalyptus wood	332	0	332	As a biofilter for heavy metal pollution
Mahogany	17	0	17	Absorb air pollution O ₂ generator
Pulai	5	0	5	O ₂ generator Water infiltration guard Storing groundwater reserves
Sandalwood	261	0	261	Erosion barrier Water infiltration guard
Ironwood	48	0	48	Maintain soil fertility O ₂ generator CO ₂ absorber
Cinnamon	284	0	284	Removes fungus Soil fertilizers
Ketapang kencana	254	0	254	Absorb air pollution

Species of Seeds	Seed Stock per July 2020	Planting in August 2020	The rest of the seeds per August 2020	Benefits of these plants for the environment
Small mangroves (<i>Rhizophora stylosa</i>)	142	0	142	Storm and flood surge barrier Protecting the shoreline area Slowing erosion
Damar	6	0	6	Erosion barrier Soil fertilizers
Ebony	19	0	19	Soil fertilizers
Total	2797	35	2712	

Table 4 showed the species of plants managed at PT Bukit Asam Persero Tbk, at Tarahan Port Unit. These plants were observed to improve the soil quality and greenness of the surrounding environment, as it is beneficial for a sustainable environment (air, noise, and soil). The bamboo species used in this process were Buddha's Belly (*Bambusa tuldoidea ventricosa*), Haur Geulis (*Bambusa vulgaris var vitata*), Petung (*Dendrocalamus asper*), and Chinese yellow fence (*Bambusa multiplex alphonse karr*). Other species that were also used, includes agarwood, eucalyptus, mahogany, pulai, sandalwood, Ironwood (Ulin), Cinnamon, Ketapang kencana, Small mangroves (*Rhizophora stylosa*), Damar, and Ebony.

In 2020, Tarahan Port Unit of PT Bukit Asam Persero Tbk, won the Gold Proper award at the Company Performance Rating Program (Proper) event, from the Ministry of Environment and Forestry for land management, via the use of greening methods and plantation of plant and tree species, as shown in Table 4 [42]. This award was provided on the innovative basis of PT Bukit Asam Persero Tbk, in the field of CSR (Community Social Responsibility), for the bamboo downstream program, via the plantation of ten thousand seedlings, which were scattered in various locations. The company also made bamboo vinegar available for use in the agricultural sector, as well as a liquid disinfectant products, which are needed in fighting the COVID-19 outbreak. Another award was won from the Indonesian Record Museum (MURI), with the innovation of planting bamboo at 2–5 metres below sea level (masl) on the beach, with the most available species. Gold Proper was the highest award to be won by a company, confirming the organization's sustainable efforts in the environmental sector, innovating in the aspects of resource management, as well as community development and empowerment. Through this achievement, it was observed that the environmental management for land contaminated by coal stockpile at Tarahan Port Unit of PT Bukit Asam Persero Tbk, had been carried out effectively and efficiently.

Technical Assessment on Quality Implementation of Environmental Management Plan (RKL)

The implementation of environmental management was carried out through various efforts, in order to control and improve the environment, which were stated in the RKL-RPL document, as well as other societal activities

that were commitments of PT. Bukit Asam Persero Tbk, at Tarahan Port Unit. Based on the results of the technical assessment, it showed that environmental management of ambient air and noise qualities, spontaneous coal combustion, and soil, had been implemented by PT Bukit Asam Persero Tbk, at Tarahan Port Unit. This was also observed to be in accordance with the RKL-RPL document, and the Environmental Quality Standards, which were applicable in the territory of Indonesia. The results of the technical assessment on the implementation of environmental quality management on coal stockpile at Tarahan Unit of Pt Bukit Asam Persero Tbk Bandar Lampung City, Lampung Province, are presented in Table 5.

Table 5

Result of Technical Assessment on the Implementation of Environmental Quality Management on Coal Stockpile at Tarahan Unit of PT Bukit Asam Persero Tbk in Bandar Lampung City, Lampung Province

No.	Stockpile Environmental Management Activities	Implementation		The Management Appropriateness
		Yes	No	
1.	Ambient air and noise management			
	- Spraying with water mist on the surface of the coal stockpile.		✓	Management is according to the applicable quality standards
	- Planting tall protective trees on the coast and in office areas		✓	
2.	Management of Spontaneous Coal Combustion StockPiles			
	- Monitoring the stockpile location		✓	Management is according to the applicable quality standards.
3.	Soil Management			
	- Doing reforestation by planting trees.		✓	Management is according to the applicable quality standards.

Economic Assessment on the Implementation of Environmental Quality (RKL) Management Costs at Tarahan Port Unit of PT Bukit Asam Persero Tbk

Environmental management activities on the coal stockpiles were observed to have incurred societal costs [13,44]. Similar to that of quality, environmental costs occurred due to the activities of the company, which is affecting the societal value [67]. Moreover, environmental costs are basically related to the prices of products, processes, systems, or facilities, which are important for better management decision-making. This is because the environment quality is likely to be disturbed, when the resulting industrial waste, such as ash or dust containing chemical compounds, is not monitored and managed, therefore, incurring environmental costs. Also, environmental costs are industrial efforts, which are involved in taking steps, in order to fulfill social responsibilities to the community [68]. Economically, ecologically, and socially, this cost is also observed to be a form of protection for the environment [13,45–48]. These environmental costs reflected the monetary value of damages, which were caused by the life cycle of coal mining, transportation, and burning, to the human health,

environment, streams, forests, and ecosystems ekosistem [44]. Due to the non-monetary value of the environment and natural resources, the protection provided by an economical assessment is observed to require environmental costs [1,13,49].

The implementation of the management carried out through various efforts, for control and improvement of activities by PT Bukit Asam Persero Tbk, at Tarahan Port Unit, raised environmental costs. Details of the management and environmental monitoring costs of PT Bukit Asam Persero Tbk, at Tarahan Port Unit, are presented in Table 6.

Table 6

Details of Environmental Management and Monitoring Costs at Tarahan Port Unit of PT Bukit Asam (Persero) Tbk [66]

Description of Environmental Management and Monitoring Costs	Plan and Realization					
	Q.I		Q.II		Total	
	Plan	Realization	Plan	Realization	Plan	Realization
a. Air and Noise Emission Management						
1) Storage of the stockpile area	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)
2) The installation of <i>dust suppression system</i>	-	-	15,987,668	15,875,543		
3) The construction of 2X8 MW operational chimney of steam power plant (PLTU) and using an electrostatic precipitator	-	-	45,000,000	46,986,987	45,000,000	46,986,987
4) Test on the Emissions of Chimney Generator and vehicle exhaust	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)
b. Land Management / Reforestation						
1) Planting	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)
2) Rearing (Fertilization, weeding, etc.)	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)	(according to the needs)
c. Environmental Monitoring Costs	17,000,000	17,000,000	20,000,000	20,000,000	20,000,000	20,000,000
	(carried out by a 3rd party)	(carried out by a 3rd party)	(carried out by a 3rd party)	(carried out by a 3rd party)	(carried out by a 3rd party)	(carried out by a 3rd party)
TOTAL ENVIRONMENTAL MANAGEMENT AND MONITORING COSTS	36,111,000	34,421,543	87,530,668	88,762,005	123,641,668	121,183,548

Based on Table 6, the total costs required to implement environmental quality monitoring and management, in the coal stockpile of PT Bukit Asam Persero Tbk, at Tarahan Port Unit, were IDR 123,641,668 (102.02%) of the

originally planned IDR 121,183,548.

The results of above indicated that Tarahan Port Unit of PT Bukit Asam Persero Tbk had included costs, in order to manage the environmental impact of coal stockpiles, in the company's financial budget. This was in accordance with the company's mission to become an environmentally sound industry (Go Green), with goals set on minimizing environmental impacts.

Also, the assessments carried out on the monitoring and environmental management costs, observed a mismatch between plan and realization with Quarter I and II, due to the following,

(1) Installation of a dust suppression system in each dropping zone, transfer chute, as well as hopper feeding and conveyor belts, which were completed in September. The actual use of funds was IDR 15,875,543 (99.97%) of the planned amount of IDR 15,987,668.

(2) Construction of 2X8 MW operational chimney of steam power plant (PLTU), via the use of an electrostatic precipitator. The actual use of funds were IDR 46,689,987 (100.09%) of the planned amount at IDR 45,000,000.

Technically, in order to overcome this aforementioned mismatch, Tarahan Port Unit of PT Bukit Asam Persero Tbk needs to carry out regular maintenance on the emission-producing machines, which in turn leads to the reduction of the resulting emissions and funds used in managing and monitoring the environment.

Economically, it is also necessary to carry out a detailed inventory of environmental cost plans and escalation, in order to anticipate external risk factors.

Conclusion

The results of the technical assessment on the implementation of monitoring and management, showed that the environmental quality had attained the standards being stipulated by the Regulations of the Government and Minister of Environment. The economical assessment that was carried on the mismatch between planned and realized environmental costs, was due to the installation of a dust suppression system and construction of a 2X8 MW operational chimney of the steam power plant (PLTU). Moreover, this research recommended that Tarahan Port Unit of PT Bukit Asam Persero Tbk needs to carry out regular maintenance of emission-producing machines, which in turn leads to the reduction of resulting emissions and funds used in managing and monitoring the environment. However, a detailed inventory of cost plans and escalation needs to be performed, in order to anticipate external risk factors.

Declarations

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Authors' contributions

NA prepared draft manuscripts, formal analysis, and presentation of data. RJ revised the draft manuscript, and was involved in the development of the methodology, formal analysis and presentation of the data. S contributed to mining analysis. SZ contributes to socio-economic analysis. HR contributed to the presentation of the manuscript data. All authors reviewed and approved the final manuscript.

Availability of data and materials

The data used to support the findings of this study are available from the corresponding author upon request.

Competing interests

The authors declare they have no competing interests.

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Figures

Figure 1

Research Location Map of PT. Bukit Asam (Persero) Tbk Source: Author et.al, 2021 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

(a) monitoring air emissions, (b) monitoring noise.

(a)

(b)

Figure 3

(a) monitoring in the SBS area, (b) planting in the weighing area

Image not available with this version

Figure 4

Image not available with this version

Figure 5

Comparison of quality standards for Physical and Chemical Parameters in Monitoring Ambient Air Quality with Indonesian Government Regulation No. 41/1999

Figure 6

Figure 7

Degradation of the soil quality at coal mining area in Jharia, Jharkhand