INDONESIAN MINING JOURNAL Vol. 28, No. 1, April 2025 : 53 - 72

TECHNICAL AND ECONOMIC ASSESSMENT ON ENVIRONMENTAL QUALITY MANAGEMENT OF COAL STOCKPILE FOR ENVIRONMENTAL SUSTAINABILITY

PENILAIAN TEKNIS DAN EKONOMIS KUALITAS PENGELOLAAN LINGKUNGAN STOCKPILE *BATUBARA UNTUK LINGKUNGAN BERKELANJUTAN*

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ABSTRACT

Coal mining has positive impacts in the form of increasing the national economy and people's income. However, it also has negative impacts, including the decrease of environmental quality such as air, soil, and noise, as well as the potential for spontaneous combustion. The research was conducted to assess the technical and economic aspects of environmental management at coal stockpiles in the Tarahan Port Unit of PT Bukit Asam Tbk to support environmental sustainability. The technical assessment of stockpile environmental management was carried out by comparing observation results with the Environmental Management and Monitoring Plan Document (RKL/RPL) and Indonesia’s applicable Environmental Quality Standards. The economic assessment focused on the cost of environmental monitoring and management by observing the discrepancies between the planned and realization in the first and second quarters. The technical assessment results show that environmental management at the stockpile has been implemented effectively. Air quality parameters and noise levels remain below the established standards, soil quality is classified good as indicated by vegetation growth, and no spontaneous combustion occurred during the observation period. The economic assessment revealed a discrepancy of 2.02% between the planned cost of IDR 121,183,548 to the actual realization of IDR 123,641,668. This increase was attributed to the construction of a dust reduction system and an operational chimney for the 2X8 MW Steam Power Plant, through the use of Electrostatic Precipitators. The study recommends a detailed inventory of environmental cost plans and potential cost escalation to anticipate risk factors. It also highlights the need for regular maintenance of machines that are known to frequently produce emissions. These efforts are expected to reduce the emissions and lower the costs of environmental management and monitoring.

Keywords: assessment, technical, economic, environmental management, stockpile.

ABSTRAK

Pertambangan batubara memberikan dampak positif dalam meningkatkan perekonomian negara dan pendapatan masyarakat. Di sisi lain juga memberikan dampak negatif berupa menurunnya kualitas lingkungan hidup, seperti kualitas udara, tanah, kebisingan, dan potensi swabakar. Penelitian ini bertujuan untuk menilai kualitas pengelolan lingkungan stockpile *batubara Unit Pelabuhan Tarahan PT Bukit Asam Tbk secara teknis dan ekonomis untuk lingkungan berkelanjutan. Penilaian teknik pengelolaan lingkungan* stockpile *dilakukan dengan melihat kesesuaian hasil observasi dengan dokumen rencana pengelolaan/pemantauan lingkungan (RKL/RPL), dan Standar Mutu Lingkungan yang berlaku di wilayah Indonesia. Penilaian ekonomi dilakukan pada biaya pemantauan dan pengelolaan lingkungan dengan mengamati ketidaksesuaian antara rencana dan realisasi dengan Kuartal I dan II. Hasil penilaian teknis menunjukkan bahwa pengelolaan lingkungan hidup di* stockpile *sudah dilaksanakan dengan baik, terlihat dari parameter kualitas udara dan tingkat kebisingan masih di bawah*

Received: 20-07-2024, first revision: 15-12-2024, second revision: 20-02-2025, accepted: 13-03-2025.
DOI: 10.30556/imj.Vol28.No1.2025.1595

baku mutu lingkungan yang ditetapkan, kualitas tanah tergolong baik, terbukti dengan tumbuhan yang tumbuh, dan untuk swabakar tidak pernah terjadi selama masa pengamatan. Penilaian ekonomi pengelolaan lingkungan yang direncanakan dengan realisasi terdapat ketidaksesuaian sebesar 2,02% dari rencana semula sebesar Rp 121.183.548 menjadi Rp 123.641.668. Peningkatan ini disebabkan oleh pembangunan sistem peredam debu dan cerobong operasional Pembangkit Listrik Tenaga Uap 2X8 MW, melalui penggunaan Electrostatic Precipitator*. Penelitian ini merekomendasikan inventarisasi rinci rencana biaya lingkungan dan eskalasinya guna mengantisipasi faktor risiko dan juga melakukan perawatan mesin yang diketahui sering menghasilkan emisi. Dengan demikian emisi yang dihasilkan terpantau menurun, dan dana pengelolaan dan pemantauan lingkungan juga berkurang.*

Kata kunci: penilaian, teknis, ekonomi, pengelolaan lingkungan, stockpile*.*

INTRODUCTION

Environmental-friendly development has been reported to be important for nations, which are oriented to natural resources and societal preservations (Juniah, 2014), 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 (Kioe-A-Sen *et al.*, 2016; Ribeiro *et al.*, 2016; Ribeiro, Suárez-Ruiz and Flores, 2016; Batsaikhan *et al.*, 2017; Juniah, 2017; Kodir *et al.*, 2017; Mishra and Das, 2017; Ping *et al.*, 2017; Rela *et al.*, 2020). 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. (Carvalho, 2017; Juniah *et al.*, 2017; Agboola *et al.*, 2020).

Real steps taken in environmental management and monitoring planning could prevent and reduce environmental impacts caused by mining activities (Kun, 2019). Ecological, environmental and social problems as the negative impact of mining result in a significant decrease in the groundwater table, which results in the lack of water supply needed by humans, animals and the reduction and death of surface plants (Jin *et al.*, 2021; Juniah *et al.*, 2023). An important issue in water management is ensuring that the supply area for drinking water sources consumed by people living around coal mining is safe. This is very important because the quality of drinking water sources is closely related to public health. (Ding *et al.*, 2017). A major role in the Human Health, social stability and, sustainable economic development is played by safe drinking water. Therefore, the safety of water quality must be maintained from water pollution (Dong *et al.*, 2019; Guo and Cheng, 2019).

Pollution emission is one of the serious environmental problems as a result of mining activities (Xu, Ma and Xie, 2017). The impact of coal mining on air pollution occurs when coal is burned. As a result of combustion, CO_2, NO_x, SO_2 gases and Hg, As, Se and will be emitted into the air as hazardous materials which are released into the air (Setiawan *et al.*, 2018). Air pollution causes premature birth, weakens the performance of the heart, respiratory system and lungs (Trianisa, Purnomo and Kasiwi, 2020).

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 (Wantzen and Mol, 2013; Kodir *et al.*, 2017; Mishra and Das, 2017; Juniah, 2018; Juniah, Susetyo and Rahmi, 2019; Yovanda *et al.*, 2023). Examples are related to a decrease in air quality, which occurred in previous studies carried out by (Schwegler, 2006; Pandey, Agrawal and Singh, 2014; Pokorná, Hovorka and Brejcha, 2016; Boyles *et al.*, 2017; Greene and McGinley, 2019; Myllyvirta and Suarez, 2020). Also, examples of air pollution originating from SO_2 emissions in Kankoyo Township, Zambia, were 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 (Araya *et al.*, 2020). Similarly, the impact of CO_2 emissions as air pollutants from coal-fired power plants, contributed to environmental problems (Bian *et al.*, 2009; Pandey, Agrawal and Singh, 2014; Andika and Valentina, 2016; Nádudvari *et al.*, 2020). 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 (Boyles *et al.*, 2017; Emmanuel, Jerry and Dzigbodi, 2018; Greene and McGinley, 2019; Muslim and Helmy, 2020; Satriawan *et al.*, 2021), such as noise (Mishra and Das, 2017; Lilic *et al.*, 2018), spontaneous combustion (Ribeiro *et al.*, 2016; Ribeiro, Suárez-Ruiz and Flores, 2016, 2020; Saffari, Sereshki and Ataei, 2019; Gogola *et al.*, 2020; Onifade and Genc, 2020) and a decrease in soil quality (Rai and Paul, 2011; Masto *et al.*, 2015; Dejun, Zhengfu and Shaogang, 2016; Mushia, Ramoelo and Ayisi, 2016; Guo *et al.*, 2018; Park *et al.*, 2020). These impacts occurred in an attempt to secure more energy, food, and infrastructure. In addition, there were traces of environmental contamination and human health hazards (Gasparotto and Martinello, 2021).

Furthermore, coal loading activities from the stockpiles to barges such as at Tarahan Port Unit of PT. Bukit Asam, have the potential to negatively impacts the environment, such as reduced air and 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 (PT Bukit Asam, 2021).

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 (Zakir and Juniah, 2015). This is in line with sustainable mining management, as stated in Article 33 paragraph (3) of the 1945 Constitution, covering social, economic, and environmental aspects. The social aspect is related to the welfare of the community around the mining area, the economic aspect is related to increasing state and community income, and the environmental aspect focuses on environmental preservation and damage prevention (Gumanti, Juniah and Taqwa, 2016).

Environmental management activities on coal stockpiles have also been found to incur operational costs (Juniah *et al.*, 2017; Yu *et al.*, 2020). 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 (Yu *et al.*, 2020). This cost is, ecologically, and socially observed to be a form of protection for the environment (Moersidik *et al.*, 2014; Krawczyk, Majer and Krzemień, 2016; Juniah *et al.*, 2017; Castillo-Eguskitza *et al.*, 2019; Gunton *et al.*, 2020). Due to the environment and natural resources having no money value, protection by providing an economical assessment is required (Damigos, 2006; Juniah, 2014; Juniah *et al.*, 2017).

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 the USA (Alabama, Kentucky, Marland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia) and Brazil, Spain (Kioe-A-Sen *et al.*, 2016; Ribeiro *et al.*, 2016; Ribeiro, Suárez-Ruiz and Flores, 2016; Batsaikhan *et al.*, 2017; Juniah, 2017; Kodir *et al.*, 2017; Mishra and Das, 2017; Ping *et al.*, 2017; Rela *et al.*, 2020). For example, mining was found to be an important industrial sector, in Indonesia (Rela *et al.*, 2020). In 2013, the country's foreign exchange, which amounted to USD 28,434,240,130, was generated from the mining sector (Kodir *et al.*, 2017). Data from the Ministry of Energy and Mineral Resources showed that, from the Non-Tax State Revenue, the contribution of the mining sector continued to indicate an increasing trend. This can be seen from the Non-Tax State Revenue of the mineral and coal sector in 2021 of IDR 75.5 trillion, in 2022 of IDR 183.4 trillion which exceeded the target of IDR 101.8 trillion, and in 2023 IDR 173.0 trillion, or 58% of the total Non-Tax State Revenue. 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 Colombia's GDP, with coal, metals, and other minerals at 68%, 18%, and 13%, respectively (Méndez and Rodríguez, 2016). Also, the South African economy was heavily dependent on fossil fuels, with about 91% of the main source on electricity being coal (Mushia, Ramoelo and Ayisi, 2016).

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 Tbk (PTBA), at Tarahan Port Unit. This societal implementation of PTBA 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.

METHODOLOGY

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 Figure 1.

Methods

This method is done as follows:

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 (Agboola *et al.*, 2020). The first step of a technical assessment towards the implementation of environmental management in the coal stockpile of PTBA 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.

Figure 1. Research location map of PTBA

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 PTBA Tarahan Port Unit: This is one of the largest stockpiles in Indonesia, which is located in Lampung Province.
(2) The operational activities of PTBA 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 PTBA, 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 the environmental management, on the coal stockpile of PTBA 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 PTBA 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 PTBA Tarahan Port Unit.

A. Environmental monitoring and management procedure

1. Quality of Ambient Air Emissions and Noise

   Monitoring the quality of ambient air and noise was conducted to observe the extent by which they were to be carried out in PTBA 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 (Figure 2). 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 the Government Regulation no. 41 of 1999, concerning Air Pollution Control, as well as the 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 PTBA at Tarahan Port Unit, and the surrounding residential areas of neighbourhood 22 and 23, Batu Serampok.

(a) (b)

Figure 2. (a) monitoring air emissions, (b) monitoring noise

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

2. 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, PTBA 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
      Monitoring of spontaneous combustion was carried out at 4 locations, namely:
      - Stockpile 1
      - Stockpile 2
      - Stockpile 3
      - Stockpile 4

3. Soil Quality Monitoring and Management
   Soil quality monitoring and management in PTBA at Tarahan Port Unit, was carried out through reforestation, which involved the planting of trees (Figure 3). 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.

Economic valuation

Economic valuation was carried out quantitatively, by calculating the environmental costs incurred, which were observed as activity externalities in the coal stockpile.

(a) (b)

Figure 3. (a) monitoring in the SBS area, (b) planting in the weighing area

RESULTS AND DISCUSSION

Positive and Negative Impacts of Coal Mining

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 (Mancini and Sala, 2018).

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 (Juniah and Sastradinata, 2017; Juniah, 2018).

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

1. Ambient Air Quality
   Coal as the main energy source, was a basic requirement for fulfilling the energy needs of a country (Ping *et al.*, 2017). However, its use had been observed to produce carbon dioxide emissions, which also contributes to air pollution (Andika and Valentina, 2016). Air pollution causes a decrease in atmospheric quality, due to the release of dust and gaseous pollutants, such as sulphur and nitrogen dioxide (SO_2 and NO_2), as well as particulate matter (Ghose and Majee, 2000). 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 µm (PM10) (Weng *et al.*, 2012).

   Also, another impact was on the living things' health, which emerged from air pollution, due to the large use of coal fossil fuels (Boyles *et al.*, 2017; Emmanuel, Jerry and Dzigbodi, 2018; Greene and McGinley, 2019; Satriawan *et al.*, 2021). This impact was as a result of dust, sulphur and nitrogen dioxide (SO_2 and NO_2), as well as particulate matter (Pandey, Agrawal and Singh, 2014). Coal mining contributes to air pollution. The results of research by Heydrix Michael et.al 2020 on Australian coal mines during the 2008-2018 showed that coal mines emitted 42.1% of national PM10 air emissions from NPI sites. Pure PM2.5 is 19.5% of the national total, metals are 12.1%, and nitrogen oxides are 10.1%. Air exposed to coal dust is inhaled by miners during working hours. 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 (Swain, Goswami and Das, 2011), ARI (acute respiratory infection), coughs, colds, and asthma (Muslim and Helmy, 2020). Additionally, health impacts were observed to often occur in mining workers, as well as the surrounding community. Beside the negative impacts on the human health. 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 (Myllyvirta and Suarez, 2020).

   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 are inhaled 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% to 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 (Rusdianasari, 2015). However, PM10 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 (Pandey, Agrawal and Singh, 2014).

Apart from human health, dust from mining waste disposal also polluted the soil (Bian *et al.*, 2009; Swain, Goswami and Das, 2011), 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_2, SO_2, SO_3, HCl, and NH_4, which were concentrated in the atmosphere, absorbed by trees (flora), and inhaled by fauna (Agboola *et al.*, 2020).

Environmental monitoring and management at Tarahan Port Unit of PTBA, 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 (Manwar, Mandal and Pal, 2016; Lilic *et al.*, 2018).

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 PTBA at Tarahan Port Unit, 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 Figure 4, respectively.

Table 1 and Figure 4 show 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, SO_2, NO_2, O_3, HC, Pb, and PM10 at 159.6, 12.01, 28.8, 26.2, 16.88, 6.6, < 0.01, and 56.64 (μg/Nm^3), respectively. These results indicated that the ambient air level in Tarahan Port Unit of PTBA 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 (Muslim and Helmy, 2020) reported different observations, where the dust parameters in the research area was above standards, with indication of an average value of 224 μg/Nm^3 for the 7 monitoring location points. These results indicated that the current management of dust parameters (159.6 224 μg/Nm^3) in Tarahan Port Unit of PTBA, 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 conveyor. Therefore, the coal dust was sucked into this equipment, resulting in less concentrated potential in the air.

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	(μg/Nm^3)	159.6	230
CO	(μg/Nm^3)	1201	10000
SO_2	(μg/Nm^3)	28.8	365
NO_2	(μg/Nm^3)	26.2	150
O_3	(μg/Nm^3)	16.88	235
HC	(μg/Nm^3)	6.6	160
Pb	(μg/Nm^3)	< 0.01	2
PM_{10}	(μg/Nm^3)	56.64	150

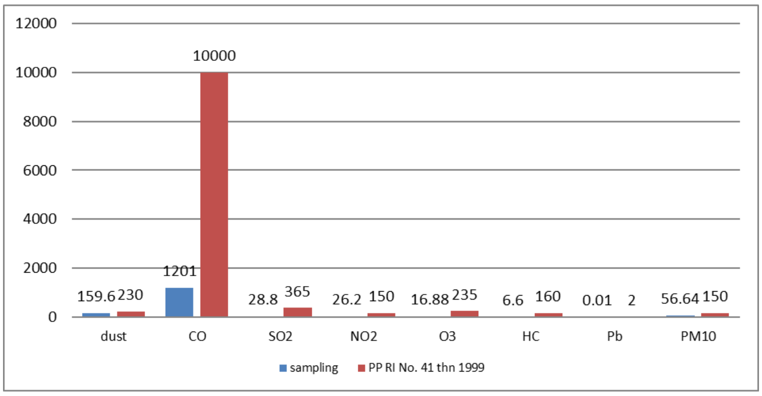


Figure 4. Comparison of quality for Physical and Chemical Parameters in Monitoring Ambient Air Quality with the quality standard aacroding to Indonesian Government Regulation No. 41/1999

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 (Rusdianasari, 2015). 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 (Manwar, Mandal and Pal, 2016; Lilic *et al.*, 2018). In India, the noise mapping method was mandatory for use in coal mining, as recommended by the Tenth Conference on Safety in Mining (Manwar, Mandal and Pal, 2016). This method should be carried out by using efficient and accurate computer modeling software. This should also be strategized at the mine planning stage (Madahana, Nyandoro and Moroe, 2020). The noise test results and quality standards are presented in Table 2.

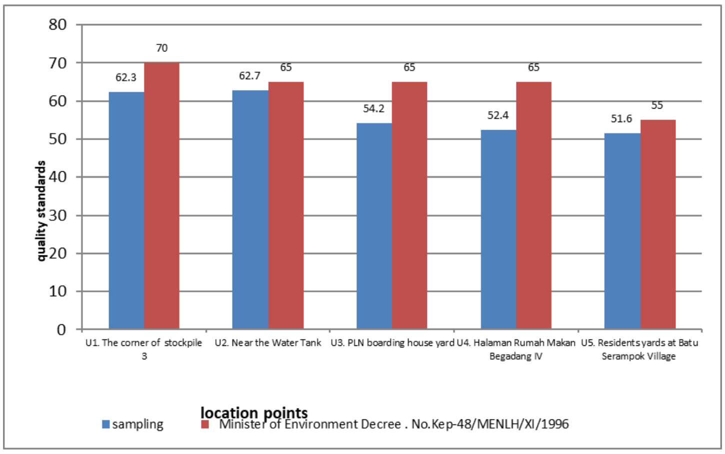
   Table 2 and Figure 5 show the noise level in the coal stockpile, at Tarahan Port Unit of PTBA. Generally, the condition was below the quality standard required by the Minister of Environment Decree No. Kep-48 / MENLH / X1 / 1996, concerning Noise Level Standard.

   The parameters above are very important as benchmarks for noise quality standards. Mostly, the noise level at Tarahan Port Unit of PTBA, was in stable and normal conditions, and the potency on the community health around the coal stockpile, was relatively small.

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

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 *stockpile* 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



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.

Figure 5. Comparison of quality on Physical and Chemical Parameters for Noise Monitoring with the quality standards of the Indonesian Minister of Environment Decree.

3. Spontaneous Combustion Management of Coal Stockpiles
   Coal has been observed to have a tendency to undergo self-combustion or Spontaneous Coal Combustion (SCC), which is likely to cause uncontrolled fires when exposed to air (Finkelman, Wolfe and Hendryx, 2021). SCC 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 (Finkelman, Wolfe and Hendryx, 2021). 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 PTBA had to conduct monitoring, in order to prevent the emergence of the spontaneous coal combustion danger at the stockpile location (PT Bukit Asam, 2020a).

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

Table 3. Monitoring Activities on SCC at Tarahan Port Unit of PTBA for the August 2020 Period

Monitoring date	Monitoring Point (Stockpile)				Description
	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					

Monitoring date	Monitoring Point (Stockpile)				Description
	1	2	3	4	
14-Aug-20					
15-Aug-20					
16-Aug-20					
17-Aug-20					
18-Aug-20					
19-Aug-20					
20-Aug-20					
21-Aug-20	NO SPONTANEOUS COAL COMBUSTION				
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 SCC
- The Executive of Operational Support Division

4. 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 (Figure 6) (Rai and Paul, 2011; Swain, Goswami and Das, 2011; Mushia, Ramoelo and Ayisi, 2016). 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 (Fitrianti, Nurcholis and Mulyanto, 2018). Moreover, low nutrient elements were caused by soil acidity, due to intensive leaching (Swain, Goswami and Das, 2011; Rahman, Howladar and Faruque, 2017). 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 (Ernawati, 2008).

Figure 6. Degradation of the soil quality at coal mining area in Jharia, Jharkhand

However, soil quality assessment is one of the key parameters for evaluating a contaminated mining environment (Masto *et al.*, 2015). This is because plants need 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 CO_2 and water. These are then converted into carbohydrates, during the process of photosynthesis (Unanaonwi and Amonum, 2017).

Besides nutrients, other impacts on soil quality include a decrease in the average value of soil water content (SWC), 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 (Dejun, Zhengfu and Shaogang, 2016; Guo *et al.*, 2018).

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 (Swain, Goswami and

Das, 2011). 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 (Firpo, Weiler and Schneider, 2021).

The soil management carried out by PTBA at Tarahan Port Unit, was reforestation by planting of trees. In addition, 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 PTBA, 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 PTBA~~,~~ 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 PTBA at Tarahan Port Unit and its benefits for the environment (air, land, and water)

Species of Seed	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 (*Bambusa tuldoides 'Ventricosa'*)	121	0	121	
Haur Geulis Bamboo (*Bambusa vulgaris var vitata*)	116	0	116	Erosion barrier to prevent flood hazards.
Petung Bamboo *(Dendrocalamus asper)*	535	25	510	Handling toxic waste due to mercury poisoning
Latin African Bamboo (*Oxytenathera abyssinica*)	108	0	108	Source of well water supply
Chinese Yellow Fence Bamboo (*Bambusa multiplex 'Alphonse Karr'*)	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
Small Mangroves (*Rhizopora stylosa*)	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	

Source: (PT Bukit Asam, 2020b)

Table 4 shows the species of plants managed at PTBA, 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 tuldoides 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 (Rhizopora stylosa), Damar, and Ebony.

In 2020, Tarahan Port Unit of PTBA~~,~~ 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 (PT Bukit Asam, 2021). This award was provided on the innovative basis of PTBA in the field of Community Social Responsibility (CSR), 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 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 meters 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 PTBA 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 PTBA at Tarahan Port Unit. Based on the results of the technical assessment, it showed that environmental management of ambient air and noise qualities, SCC, and soil, had been implemented by PTBA 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 PTBA 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 PTBA 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 SCC Stockpile	✓		
	- 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 PTBA

Environmental management activities on the coal stockpiles were observed to have incurred societal costs (Juniah *et al.*, 2017; Yu *et al.*, 2020). Similar to that of quality, environmental costs occurred due to the activities of the company, which is affecting the societal value (Bangun and Sunarni, 2014). 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 (Rohelmy, ZA and Hidayat, 2015). Economically, ecologically, and socially, this cost is also observed to be a form of protection for the environment (Moersidik *et al.*, 2014; Krawczyk, Majer and Krzemień, 2016; Juniah *et al.*, 2017; Castillo-Eguskitza *et al.*, 2019; Gunton *et al.*, 2020). 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 (Yu *et al.*, 2020). 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 (Damigos, 2006; Juniah, 2014; Juniah *et al.*, 2017).

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

Table 6. Details of environmental management and monitoring costs at Tarahan port unit of PTBA

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 *dust surpression system*	-	-	15,987,668	15,875,543		
3) The *construction* of 2 X 8 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)

Description of Environmental Management and Monitoring Costs	Plan and Realization					
	Q.I		Q.II		Total	
	Plan	Realization	Plan	Realization	Plan	Realization
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 (carried out by a 3rd party)	17,000,000 (carried out by a 3rd party)	20,000,000 (carried out by a 3rd party)	20,000,000 (carried out by a 3rd party)	20,000,000 (carried out by a 3rd party)	20,000,000 (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

Source: Financial Statement in Environmental Document of PTBA at Tarahan Port Unit, Lampung

Based on Table 6, the total costs required to implement environmental quality monitoring and management, in the coal stockpile of PTBA, 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 PTBA, 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 was 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 PTBA 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.

CONCLUSIONS AND SUGGESTION

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 economic 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 recommends that the Tarahan Port Unit of PTBA 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 to anticipate external risk factors.

ACKNOWLEDGEMENT

The authors are grateful to Sriwijaya University and PTBA for supporting this research.

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