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Introduction: Coal consumption for electrical energy at Steam Power Plant increase often with economic and population growth. Burning coal produces harmful pollutants such as PM$_{2.5}$ and SO$_2$ affecting public health problems and decline in social and economic conditions. Therefore, implement the strategies are needed to reduce risks and long-term impacts on the environment. The research aimed to analyze the risk and impact of air pollutants exposure and develop control strategies.

Methods: This study used the methods of environmental health risk analysis, analysis of the level of understanding and perception, cost of illness analysis, and Strength, Weakness, Opportunities, and Threats analysis. Data obtained by survey, interviews using questionnaire instrument to 293 respondents, five experts to determine risk control strategies and the secondary data from Environmental Agency of Bekasi Regency.

Results and Discussion: The result showed that most risk is 13-55 years old, and people who live less than two square kilometres from the power plant. The level of public understanding and perception resulted in moderate criteria. The average cost of illness is 14.51% of the average monthly income of each person. The recommendation strategies are implemented regulations of power plant location, providing guidelines for environmental controlling, air quality control regularly, tightening air quality standards, prioritizing air pollution control budgets, providing green space, implementing clean energy and renewable energy, and building capacity air quality control.

Conclusion: The production of electrical energy on Steam Power Plant had an air pollution impact such as health problems, decreased income, and social disruption. Air pollution control includes structural and nonstructural strategies from internal and external Steam Power Plant to provide environmentally friendly energy production for the communities.
INTRODUCTION

Population growth and economic development are among the factors that influence the increase in demand for electrical energy. The use of electricity in Indonesia increased approximately 26%, from 812 kWh per capita in 2014 to 1,021 kWh per capita in 2017 (1). Coal demand until 2025 is one of the primary fuels for electrical energy production at Steam Power Plant with a target of 30%, followed by fuel oil 25%, new renewable energy 23%, and natural gas 22%.

Moreover, the existence of Steam Power Plant brings a positive influence on the state and society in general. It opens up employment opportunities, develops technology fields, and impacts on economic, political, and social growth (2). However, the existence of Steam Power Plant also has negative impacts on environmental pollution and can lead to changes in the social, economic, and cultural conditions of the surrounding community (3). The burning of fossil fuels can release pollutants such as particulate matter (PM), CO\textsubscript{2}, NO\textsubscript{x}, and SO\textsubscript{2} that contaminate the environment (4).

In 2017, Steam Power Plant Babelan was built by a private company to support the shortage in electricity supply in several areas of Java island. The company uses fossil fuels that have the potential to emit dangerous pollutants such as PM\textsubscript{2.5}, and SO\textsubscript{2}. Particulate matter (PM) is a pollutant consisting of particles such as dust, dirt, soot, smoke, and liquid droplets found in the air with a fairly small size (5). Meanwhile, PM\textsubscript{2.5} refers to particles with a diameter of less than 2.5 micrometres. By this size, PM\textsubscript{2.5} can penetrate the lungs (6). Various complex elements contained in PM\textsubscript{2.5} are Pb, Al, Na, Fe, K, Cl, Mg, Si, S, Ca, Sc, Ti, V, Cr, Mn, Co, Cu, Ni, Zn, As, Se, Br, Ba, P, and Hg (7). It can cause various respiratory disorders such as acute respiratory infections (ARI), lung cancer, cardiovascular, chronic bronchitis, asthma, abnormal heartbeat, reduced pulmonary function, and even death (8). Meanwhile, the environmental damage due to particulate dust emissions in the air is an increase in lake and river water acidity, damage to forests and ecosystems, reduction in visibility, and changes in nutrient balance in water sources and rivers (9).

A study shows that workers exposed to respiratory dust (PM\textsubscript{2.5} dust) have more lung function disorders (>50%) (10). Like PM\textsubscript{2.5}, Sulfur dioxide (SO\textsubscript{2}) also has a dangerous effect on human health. Not only can SO\textsubscript{2} cause bronchitis and emphysema, but it also worsens the condition of people with chronic respiratory diseases (11). Besides, high exposure to SO\textsubscript{2} can increase the acidity of rainwater (12) which causes a decrease in soil nutrients and corrosion of metals and other building materials (13). The risks and impacts of air pollution affect community health and cause economic losses (14), and other activities to bother (15). Furthermore, meteorological factors such as wind, air temperature, and rainfall also affect the increase in the concentration and distribution of pollutants in the air (16). Based on the Regulation of the Indonesian Ministry of Industry Number 35 of 2010 concerning Technical Guidelines for Industrial Estates, the minimum distance between industrial estates and community settlements is at least two kilometres. However, the distance between Steam Power Plant Babelan and the current community settlements does not comply with this regulation.

The health impacts of PM\textsubscript{2.5} on the national economy and provinces of China can be estimated using a general equilibrium model and the new non-linear exposure-response function. The result suggested that the health and economic impacts are significant in areas with high PM\textsubscript{2.5} concentrations. In a scenario without a pollution control policy, health and economic impact estimated that China is likely to lose 2.00% GDP and USD 32 billion in health expenditures by 2030 due to high exposure to PM\textsubscript{2.5} (17). PM\textsubscript{2.5} and SO\textsubscript{2} are potential pollutants released from Steam Power Plant activities. Since they are considered a threat to human health, the aim of this study, therefore, is to determine the level of pollutant concentration, analyze the environmental, social, economic, and health risks for the community, and suggest strategies for controlling risks and impacts of exposure to air pollutants from the Steam Power Plant to the community.

METHODS

This study used a mixed-method, a combination of quantitative and qualitative methods for data collection and data analysis (18). The data were in the form of measured variable values. The data were collected through direct observation at the research location and questionnaire to the community living around the Steam Power Plant. Meanwhile, the analyses of the risk and impact of exposure to pollutants were done using the SWOT method (19). The primary data of this study were data on PM\textsubscript{2.5} and SO\textsubscript{2} concentration values, meteorological parameter values, community anthropometric characteristics, and the level of community understanding of the relationship between Steam Power Plant and air quality. The secondary data of this study were concentration values of the PM\textsubscript{2.5} and SO\textsubscript{2} in 2019 and 2020 from the Bekasi District Government.
Environmental Service and Green Peace Organization. This study was conducted around the Steam Power Plant Babelan settlement from October to December.

The population in this study were people aged 6 - 70 years and living within a radius of 5 km² from the Steam Power Plant Babelan area. To this criteria, a total of 293 people were obtained as the samples. Measurement of PM$_{2.5}$ and SO$_2$ was carried out twice by field survey using HVAS tool according to SNI 7119.14-2016 procedure within a radius of 5 km² from Steam Power Plant Babelan. The pollutant concentration value is employed to perform an Environmental Health Risk Analysis or Analisis Risiko Kesehatan Lingkungan (ARKL). In this case, ARKL is useful to identify the danger and analysed dose-response (RfC), exposure (intake), and risk characteristics (RQ) (20).

The reference concentration (RfC) estimates of the daily exposure dose that does not cause health effects during a lifetime. The RfC value for PM$_{2.5}$ was 0.01 mg/kg/day (21) while the RfC value for non-carcinogenic SO$_2$ was 0.026 mg/kg/day (22). Anthropometric data and activity patterns were collected from the community using a questionnaire. Anthropometric data and activity patterns taken for ARKL were body weight (W), length of daily exposure (tE), frequency of exposure in a year (fE), and duration of exposure that individuals have received during their lifetime in the research location ($D_{real}$) (23). Anthropometric values were employed to analyze the exposure to risk agents received by individuals. This analysis was done to determine the level of health risk (RQ) of individuals by comparing the intake value (I) with the reference concentration (RfC) value. This analysis uses the following formula (24):

$$\text{Intake (I)} = \frac{C \times R \times tE \times fE \times DT}{Wb \times tavg}$$

If RQ is <1, it means that the health risks are considered low. While if RQ is >1, it means that the health risks are high and require a control action (20).

The analysis on community understanding was carried out with the questionnaire and calculated using descriptive technique (25):

$$\text{Percentage (%) } = \frac{\sum \text{Answer} \times \text{Weight for each option}}{\sum \text{highest weight}} \times 100\%$$

$\sum =$ Total

n = Total number of questionnaire items

The conclusion was drawn from the average percentage level of the understanding category, which was obtained from comparing the total score and the items. This study did not use the pass limit or the minimum limit value to make sure that the assessment was based on interval.

Analysis of Cost of Illness

Cost of Illness (COI) analysis was employed to determine estimated health costs by analyzing the direct and indirect variables (26). The direct variables included costs incurred to pay services such as outpatient, inpatient, examination, doctor consultation, laboratory, medical procedures, medicine, administrative costs (27), and transportation fees for outpatient and care fees for inpatient including the person who looks after the patient.

The indirect variable calculated in this study was the loss of productive days of the patient and its caretakers. Meanwhile, the loss of productivity referred to in this study is the reduction in the patient’s income and its caretakers (28) during the period of treatment and recovery (27). The estimated health costs were calculated using descriptive statistical methods.

Analysis of Risk and Impact Control Strategies

SWOT analysis was employed to determine the control strategies for risks and impacts of exposure to pollutants on health. First, the internal and external factors were identified in the questionnaire. Then, in-depth interviews were conducted with 5 experts including the Head of Environmental Pollution Control from the Bekasi Environmental Office, Head of Public Health from the Bekasi Health Office, environmental health expert, and environmental public policy expert, and socio-economic expert from the Government of DKI Jakarta. Based on the questionnaire, the score and total weight were collected. Then, the total score was determined by its value, and thus points (x, y) were obtained (29).

RESULTS

The data were processed to understand the minimum, maximum, and mean (average) PM$_{2.5}$ and SO$_2$. Figure 1 showed that the concentration values of PM$_{2.5}$ and SO$_2$ were fluctuating in both dry and wet seasons. According to the mean value, SO$_2$ tends to have a higher value in the wet season than in the dry season from year to year. This study found the highest concentration value of SO$_2$ in the wet season of 2020 with a daily average of 30 ug/m³. On the other hand, the highest average value of PM$_{2.5}$ concentration was seen in the dry season of 2020. The higher concentration of PM$_{2.5}$ in the dry season could result from increased temperature, wind speed, and low humidity levels during the dry season.
The ARKL method requires concentration values of both types of pollutants and anthropometric characteristics of the 293 respondents. In Table 1, people aged 12 - 55 years were the dominant group in the sample study. The ARKL only used data from direct interviews in 2020. The variables used for the next analysis are the average value of each measured variable, as shown in Table 2.

### Table 1. Community Understanding Criteria Interval

| Interval       | Criteria       |
|----------------|----------------|
| 0%<%<20%       | Very low       |
| 20%<%<40%      | Low            |
| 40%<%<60%      | Moderate       |
| 60%<%<80%      | High           |
| 80%<%<100%     | Very high      |

### Table 2. Anthropometry Characteristics Based on Age Group in 2020

| Element                  | Min  | Max  | Mean/ Median | SD   |
|--------------------------|------|------|--------------|------|
| **Age<12 years old**     |      |      |              |      |
| Weight (kg) (Wb)         | 15   | 40   | 27.75 / 30.00 | 8.41 |
| Daily use (hour/day) (te)| 4    | 8    | 6.00 / 6.00  | 1.07 |
| Exposure Frequency (day/ year) (Fe)| | | | |
| Exposure Duration (year) (Dt)| 4    | 12   | 8.5/10.00  | 3.16 |
| **Age >12-55 years old** |      |      |              |      |
| Weight (Wb)              | 30   | 80   | 53.66/52     | 9.35 |
| Daily Exposure (hours/day) (te)| 2    | 12   | 6.68/7.20   | 2.69 |
| Exposure Frequency (day/ year) (Fe)| | | | |
| Exposure Duration (year) (Dt)| 0    | 55   | 24.73/24.00 | 14.70 |
| **Age >55 years old**    |      |      |              |      |
| Weight (Wb)              | 40   | 80   | 58.37 / 60.00 | 9.53 |
| Daily Exposure (hours/day) (te)| 2    | 12   | 7.20 / 8.00  | 3.14 |
| Exposure Frequency (day/ year) (Fe)| | | | |
| Exposure Duration (year) (Dt)| 2    | 12   | 7.20 / 8.00  | 3.14 |

In Table 3, the highest intake value of PM$_{2.5}$ exposure (0.01) was found in the elderly (>55 years) in the dry season of 2020. Meanwhile, the highest intake value of SO$_2$ exposure was found in the same group but in the wet season. The highest average of RQ in PM$_{2.5}$ was found in the elderly (>55 years) in the dry season (1.12) and wet season (0.64) of 2020. The RQ of >1 indicates that the season was relatively unclean, and the age group was at high risk, while the RQ of <1 indicates that the season was relatively clean and the age group was at low risk. On the other hand, the highest average value SO$_2$ (0.20) was found in the same group in both dry and wet seasons of 2020. The RQ of <1 shows that both dry and wet seasons in 2020 were relatively clean from SO$_2$.

### Table 3. Calculation on Intake and Risk Characteristics of PM$_{2.5}$ and SO$_2$ based on Age Group in the Dry and Wet Seasons of 2020

| Parameters | Average intakes | Average rates of risk characteristics (RQ) |
|------------|-----------------|------------------------------------------|
|            | <12 years old   | <12 – 55 years old | >55 years old | <12 years old | <12 – 55 years old | >55 years old |
| Dry        | 0.003 | 0.01 | 0.01 | 0.34 | 0.57 | 1.12 | 0.001 | 0.001 | 0.003 | 0.03 | 0.05 | 0.10 |
| Wet        | 0.002 | 0.003 | 0.006 | 0.19 | 0.32 | 0.64 | 0.002 | 0.003 | 0.005 | 0.06 | 0.1 | 0.20 |

**Environmental Health Risk Characteristics**

Based on the calculation of the risk characteristic (RQ), the population aged 13 - 55 years was the dominant group (30 people), followed by people aged 55 years and above (21 people). In the wet season, seven people from the elderly group (>55 years) were affected...
by PM$_{2.5}$. Meanwhile, none of them was affected by SO$_2$ in both dry and wet seasons.

**Table 4. Total Risk of PM$_{2.5}$ and SO$_2$ based on Age Group in the Dry and Wet Seasons of 2020**

| Age          | Category of PM$_{2.5}$ | Category of SO$_2$ |
|--------------|------------------------|-------------------|
|              | Risky | Not Risky | % Risky | Risky | Not Risky | % |
| Dry          |       |           |         |       |           |   |
| <=12 years old | 0     | 8         | 0 12 0% | 0     | 0         | 0% |
| 13-55 years old | 30    | 220       | 10.24 250 0% | 0     | 0         | 0% |
| >55 years old | 21    | 14        | 7.20 35 0% | 0     | 0         | 0% |
| Wet          |       |           |         |       |           |   |
| <=12 years old | 0     | 8         | 0 13 0% | 0     | 0         | 0% |
| 13-55 years old | 1     | 249       | 0.34 250 0% | 0     | 0         | 0% |
| >55 years old | 7     | 28        | 2.39 36 0% | 0     | 0         | 0% |

**Table 5. Overall Risks based on Settlements in the Dry and Wet Seasons of 2020**

| Age | Category of PM$_{2.5}$ | Category of SO$_2$ |
|-----|------------------------|-------------------|
|     | Risky | Not Risky | Risky | Not Risky |
| Dry |       |           |       |           |
| <2 km | 47     | 208       | 0     | 255       |
| <5 km | 3      | 25        | 0     | 28        |
| <10 km | 1      | 9         | 0     | 10        |
| Wet |       |           |       |           |
| <2 km | 7      | 248       | 0     | 10        |
| <5 km | 1      | 27        | 0     | 255       |
| <10 km | 0     | 10        | 0     | 28        |

Table 5 showed the number of people at risk that exposure to PM$_{2.5}$ and SO$_2$ based on the distance from where they lived. The highest number of people at risk due to exposure to PM$_{2.5}$ comes from those who lived less than 2 km$^2$. In the dry season, the number of affected people was 47. In the wet season, meanwhile, there was a decrease with only seven people were affected. On the other hand, none of them was at risk of exposure to SO$_2$ in both dry and wet seasons.

Based on the data of health problems, 271 out of 293 people (92.49%) reported that they had experienced health problems while living around the Steam Power Plant Babelan. They suggested that common types of health problems include coughs, colds, and headaches. Figure 2 shows other health problems experienced by the community living around the Steam Power Plant Babelan.

Based on the survey analysis, common health problems associated with PM$_{2.5}$ and SO$_2$ are coughing, eye irritation, acute respiratory infections, dizziness, asthma, and runny nose (30). Consequently, these health problems resulted in health burdens in terms of costs for treatment and recovery. The components and details of the maximum, minimum, and (mean) average costs incurred by each individual shown in Table 6.

**Table 6. Analysis of Cost of Illness**

| Average Direct Costs Per Person in a Month | Average | Max | Min |
|-------------------------------------------|---------|-----|-----|
| Outpatient care                           |         |     |     |
| Insurance fee                             | 58,396  | 2,600,000 | 0 |
| Administration fee                        | 38,089  | 100,000,000 | 0 |
| Medication fee                            | 30,683  | 1,000,000  | 0 |
| Laboratory check fee                      | 3,322   | 500,000   | 0 |
| Roengent fee                              | 1,365.20| 200,000   | 0 |
| Additional care fee                       | 4,794.50| 100,000,000| 0 |
| Other fees                                | 2,389.10| 500,000   | 0 |

**Table 6. Analysis of Cost of Illness (Continued)**

| Average Direct Costs Per Person in a Month | Average | Max | Min |
|-------------------------------------------|---------|-----|-----|
| Total days of inpatient                   |         |     |     |
| Administration fee                        | 46,147.30| 3,400,000 | 0 |
| Room fee                                  | 52054.80| 3,000,000 | 0 |
| Doctor fee                                | 11,160.41| 500,000  | 0 |
| Medication fee                            | 11,774.74| 500,000  | 0 |
| ICU fee                                   | 2,405.50| 400,000   | 0 |
| Other fees                                | 3,664.38| 500,000   | 0 |

**Transportation fees of Outpatient**

| Transportation fee/month | Average | Max | Min |
|--------------------------|---------|-----|-----|
| Transportation fee/month  | 5,137.21| 50,000 | 0 |
| Parking fee              | 2,034.01| 55,000 | 0 |

**Transportation fees of Inpatient**

| Transportation fee/month | Average | Max | Min |
|--------------------------|---------|-----|-----|
| Transportation fee/month  | 1,836.74| 50,000 | 0 |
| Parking fee              | 2,034.01| 55,000 | 0 |
| Total fee (IDR)          | 277,288.00| 24,310,012 | 0 |

**Assistant fee**

| Sustenance fee | Average | Max | Min |
|----------------|---------|-----|-----|
|                | 13,924.92| 3,000,000 | 0 |
| Transportation fee | 9,743.15| 1,500,000 | 0 |
| Other fees | 4,931.97| 1,000,000 | 0 |
| Total fees | 28,600.00| 5,500,000 | 0 |
| Total cash (IDR) | 305,888.00|  |  |

**Other fees**

| Patient’s work absence | Average | Max | Min |
|------------------------|---------|-----|-----|
| Assistant’s work absence | 0.22 | 6 | 0 |
| Patient’s loss income (IDR) | 40,273.00| 10,000,000 | 0 |
| Assistant’s loss income (IDR) | 56,317.00| 10,000,000 | 0 |
| Other fees (IDR) | 96,590.62| 20,000,000 | 0 |

**Average charges for health burden/person/month (IDR)**

| Average | Min |
|---------|-----|
| 373,397.00 | 0 |

**Average population income (IDR)**

| Average | Min |
|---------|-----|
| 2,576,792.00 | 0 |

**Percentage of total charges for health burden/average income**

14.51%
Table 7. Understanding the Risks and Impacts of Pollutant Exposure from PLTU

| Components                                                                 | n   | N   | (%)  |
|---------------------------------------------------------------------------|-----|-----|------|
| Opinion about the establishment of steam power plant                      | 332 | 586 | 56.65|
| The minimum distance of 2 km² from community settlements                  | 383 | 586 | 65.36|
| Understanding of steam power plant which release harmful pollutants through fossil fuels | 357 | 586 | 61.00|
| Understanding the impact of exposure to air pollutants on long-term health| 459 | 1,172| 39.16|
| Understanding the right to air quality at any time                         | 371 | 1,172| 31.70|
| Understanding the company obligation to control the output of the steam power plant industrial chimney | 452 | 1,172| 38.60|
| Understanding that all parties must have an obligation to preserve clean and healthy air | 501 | 1,172| 42.75|
| Perceptions of the smoke disruption caused by the steam power plant        | 483 | 879 | 54.95|
| Total                                                                     | 3,775| 7,911| 46.00|

While direct cost refers to the cost incurred to health services such as outpatient care, inpatient care, and patient transportation, indirect cost refers to a sum of money incurred due to loss of productive days. In a month, the affected individual could cost up to IDR 277,288.00 and additional fees up to IDR 28,600.00 for the caretaker (IDR 305,888.00 in total). For the indirect cost, a total time loss of the patient was 24 hours (1 day) which was equal to IDR 40,273.00/month, while a total time loss of the caretaker was 5.3 hours which was equal to IDR 56,317.00/month. Therefore, the total indirect cost incurred was IDR 96,590.62. To conclude, affected individuals spent up to 14.51% of their income. This amount was relatively high considering their low income which was only IDR 2,576,792.00/month.

Analysis of Community Understanding

Nine questions were posed in the questionnaire to check community understanding and perception of Steam Power Plant Babelan and its effect on the air quality. The result suggested that the level of community understanding and perception was in moderate criteria (40% < % <60%). The highest value (65.36%) was regarding the minimum distance between Steam Power Plant and community settlement. Meanwhile, questions with low values concerned the long-term impact of pollution on health, the right to good quality air, and Steam Power Plant’s obligation to control industrial wastes.

Determining Risk and Impact Control Strategies Using the SWOT Analysis

Based on the analysis of the risk and impact of PM$_{2.5}$ exposure, it can be understood that 51 respondents in the dry season and 8 in the wet season experienced health problems. According to the interviews with the community, several types of health problems were mostly related to respiratory disorders, which consequently required direct and indirect health costs for treatment and recovery. Besides, community understanding regarding social risks of low-quality air was still in the moderate category. Therefore, serious efforts to reduce the risks and improve the air quality are highly required. Based on the SWOT analysis, it can be seen that the value of the external factor matrix point was 2.32, while the internal factor matrix point was 3.868. After plotting the matrix points of both factors into the SWOT diagram, it can be seen that the SO (Strength and Opportunities) strategy was the most appropriate marketing strategy for controlling the risks and impacts of exposure to PM$_{2.5}$ and SO$_2$. Steam Power Plant Babelan and all of the stakeholders in air pollution control can work together to minimize the risks and impacts of PM$_{2.5}$ and SO$_2$ by considering the internal and external factors mentioned.

Figure 2. Types of Health Problems on the Community around the Steam Power Plant
in this study. The SWOT analysis, moreover, shows the air pollution control strategy plan was in Quaternary I. It means that the planned strategy can have a beneficial impact and support aggressive growth policies. Priority strategy for controlling the risks and impacts of the pollutants is further detailed in Table 8.

Figure 3. Position of Strengths of Control Strategy

Table 8. SWOT Matrix for Control Strategy of Risk and Exposure Impact of PLTU Babelan

| Internal Factor | Strengths | Weaknesses |
|----------------|-----------|------------|
| a. The location | b. The location | Strong |
| of the steam   | does not comply | b. Implementing | |
| power plant   | with the spatial | corporate | |
| does not comply | zoning provisions | responsibility | |
| c. Environmental impact analysis documents | d. Production process | e. Prioritization | |
| d. Limitation on the operational time of the | time that applies | the budget for controlling | |
| steam power plant | the principle of | the risks and impacts | |
| e. Production process time that applies the | of environmental | of air pollution from the | |
| principle of | control | steam power plant | |
| f. Implementing corporate social responsibility | g. Guarantee of the | h. Installation of dust filters | |
| or CSR programs to improve the environment, | ability to supply demand | in the steam power plant | |
| social, and economy of the community around | for electrical energy | zone | |
| the steam power plant | needs | i. Perform routine dusting | |
| j. Switching to euro 4 gas | k. Availability of | l. Availability of | |
| l. Availability of coal resources | occupational health | occupational health and | |
| m. Leader’s understanding of the risks and | and safety documents | and safety documents | |
| impacts of air pollution on the work environment | n. Obligation to use | o. Increasing the | |
| and society | PPE in the steam power plant | capacity of employees | |
| p. Dissemination of risks and impacts of air | q. Good cooperation with the government | r. Rules regarding | |
| pollution on the work environment and society | as well as state electricity company | labor protection | |

| External Factor | Threat (T) |
|-----------------|------------|
| a. Settlements close to the steam power plant | a. High cost of pollution control equipment |
| b. Health and medical expenses | b. The risk of reducing company revenue |
| c. Primary Needs of Electrical Energy | c. The risk of reducing the number of employees |
| d. Demand for electrical energy | d. Guarantee of the ability to supply demand for |
| e. Availability of coal resources | electrical energy needs | |
| f. Energy policy which still affects fossil resources | f. Increased demand for electricity | |
| g. Non-competitive EBT policies | g. Increase in electricity bills | |
| h. Health and medical expenses | i. Non-competitive EBT policies | |
| i. Socialization on to how use electrical energy wisely | j. Increase in electricity charges | |
DISCUSSION

While concentration levels of PM$_{2.5}$ and SO$_2$ constantly fluctuate, the highest concentration of PM$_{2.5}$ in 2020 was found in the dry season. For SO$_2$, its lowest concentration value was found in the wet season. Wind speed and humidity in the wet season influence the condition of SO$_2$ which leads to its low concentration. The higher the wind speed and humidity, the lower the SO$_2$ concentration. Meanwhile, the temperature variable is directly proportional to the SO$_2$ concentration (31).

Analysis on environmental health risks from exposure to PM$_{2.5}$ suggested that the number of respondents with risk of getting infected by pollutant in the dry season was higher than in the wet season. This condition can be caused by several meteorological factors such as an increase in outdoor temperature, higher humidity, wind direction, speed, and seasonal changes (32). Based on the intake calculation, the differences in the concentration value of each pollutant, body weight, rate of inhalation, and frequency of exposure influence the intake of polluting agents. The longer the exposure, the higher the value of intake received.

Of 293 respondents in the sample, 51 were infected in the dry season and 8 in the wet season by PM$_{2.5}$. Meanwhile, none of the respondents was found infected by SO$_2$. This study suggested that the average concentration value of PM$_{2.5}$ in the rainy season exceeded the national quality standard. Based on Presidential Regulation Number 41 of 1999, the daily standard value of PM$_{2.5}$ is 65 ug/Nm$^3$, and the annual standard value of PM$_{2.5}$ is 15 ug/m$^3$. Meanwhile, a low value of SO$_2$ can affect the results of the intake value and the level of environmental health risks (33).

From the total of 293 respondents, it was found that 92.49 respondents experienced various types of health problems such as coughs, colds, headaches, shortness of breath, and asthma. Some of these health problems are found related to exposure to PM$_{2.5}$. In a worse condition, the accumulation of PM$_{2.5}$ can cause deep breathing (34). Indoor exposure to PM$_{2.5}$ can increase respiratory symptoms in smokers, women, and children in low-income households (35). The low concentration of SO$_2$ can influence this.

The criteria of areas with a higher risk of pollutants were those located less than 2 km$^2$. Within this distance, densely-populated settlements and active...
economic activities were found. Based on the Regulation of the Indonesian Ministry of Industry Number 35 of 2020, the minimum distance between Steam Power Plant and community settlements is 2 kilometers. Based on the interviews done in this study, it was understood that a lot of residents had already settled for more than ten years around the area where Steam Power Plant Babelan has been standing. On the other hand, Steam Power Plant Babelan had just been established in 2015. Therefore, it concluded that Steam Power Plant Babelan should be responsible for environmental, social, and health problems but not the residences or the other way around.

Based on the age group, the highest number of people at risk was those in productive years (13 - 55). This condition can be influenced by the accumulated exposure time to pollutants when working, going to school, and doing other outdoor activities. The impact experienced by the community due to exposure to the two pollutants was respiratory health problems. Moreover, these health problems also bring another problem such as the cost of health burdens that exceed the community’s average income (IDR 2,576,792.00). This number is still below the minimum wage or Upah Minimal Kabupaten (UMK) of Bekasi in 2020 (IDR 4,498,961.00). Therefore, it is necessary to control risk and impact by optimizing the internal and external factors of Steam Power Plant Babelan. It is recommended that control on the risk and impact of PM$_{2.5}$ and SO$_2$ can be carried out through the implementation of official regulations. Based on the Regulation of Ministry of Industry of Republic Indonesia No. 35 Year 2010 about Industrial Estate Technical Guidelines, the minimum distance between Steam Power Plant and the community settlements is at least 2 km$^2$. Also, the risk and impact of electrical energy production from Steam Power Plant must be prevented through regular activity reports, proper management of work safety, environmental health, and the availability of Environmental Impact Management Analysis (AMDAL) documents.

Serious efforts must also be made to allocate a priority budget for air pollution control, use corporate social responsibility funds to support the recovery of the communities affected by exposure to the pollutant. The government is also responsible to ensure that the dust build-up does not exceed the ambient air standard by tightening the quality standards from immovable sources. Moreover, the company must install air quality equipment and dust filters around the Steam Power Plant zone, use eco-friendly fuels for electrical energy production, conduct socialization regarding clean air and the impact of air pollution, and establish good cooperation with the government and the State Electricity Company (PLN) to open more job opportunities for the surrounding community to support their social and economic conditions.

**CONCLUSION**

This study suggested that PM$_{2.5}$ and SO$_2$ released from Steam Power Plant Babelan have decreased the environmental, social, and economic quality of the surrounding community. Therefore, serious and joint efforts are required to reduce the risk and impact of air pollution. Steam Power Plant and State Electricity Company need to synergize to implement the regulations for air quality control, optimize eco-friendly electricity production, allocate budgets for risk and impact control, use corporate social responsibility funds to support the environmental and social recovery of affected communities, promote the use of euro 4 quality fuels, gas and renewable energy. Moreover, they also need to open more job opportunities and implement the provisions of the manpower protection for employees through the availability of occupational health and safety documents, mandatory use of Personal Protective Equipment (PPE), and socialization regarding energy saving to reduce the risk and impacts of air pollution.

**REFERENCES**

1. Arinaldo D, Adiatame JC. Rangkuman untuk Pengambil Kebijakan: Dinamika Batubara Indonesia Menuju Transisi Energi yang Adil. Geneva: Institute For Essential Services Reform; 2019. http://iesr.or.id/wp-content/uploads/2019/04/SPM-bahasa-lowers.pdf
2. Prakoso BA, Roslyaningisih D, Marom A. Evaluasi Dampak Pembangunan Pembangkit Listrik Tenaga Uap (PLTU) Tanjung Jati B Di Desa. *Journal of Public Policy and Management Review*. 2016;5(2):208-222. https://doi.org/10.14710/jppmr.v5i2.10986
3. Nooraliza A, Salam R. Dampak Pembangunan Pembangkit Listrik Tenaga Uap Pencaharian dan Tingkat Pendapatan (Desa Tubanan Kecamatan Kembang Kabupaten Jepara). *Journal Unnes Harmony*. 2020;5(2):155–164. https://doi.org/10.15294/HARMONY.V5I2.43670
4. Munawer ME. Human Health and Environmental Impacts of Coal Combustion and Post-Combustion Wastes. *Journal of Sustainable Mining*. 2018;17(2):87–96. https://doi.org/10.1016/j.jsm.2017.12.007
5. Indiana Department of Environmental Management. Criteria Pollutants: Particulate Matter (PM$_{2.5}$/PM$_{10}$). *IDEM Fact Sheet*. 2016;317(1):1–2. https://www.in.gov/idem/files/factsheet_oaq_criteria_pm.pdf
6. Xing YF, Xu YH, Shi MH, Lian YX. The Impact of PM$_{10}$ on the Human Respiratory System. *Journal of Thoracic Disease*. 2016;8(1): E69–E74. http://dx.doi.org/10.3978/j.issn.2072-1439.2016.01.19
7. Kusmartini I, Adventini N, Sari DK, Kurniawati S, Lestiani DD, Santoso M. Karakterisasi Unsur PM$_{2.5}$ pada Periode Kebakaran Hutan di Pekanbaru Dengan Teknik Analisis Aktivasi Neutron. JSTNI. 2019;20(1):29-44. http://dx.doi.org/10.17146/jstni.2019.1.14655

8. Laeremans M, Dons E, Avila PI, Carrasco TG, Orjuela JP, Anaya E. Short-Term Effects of Physical Activity, Air Pollution And Their Interaction On The Cardiovascular And Respiratory System. Journal Environment International Elsevier. 2018;(117):1:82–90. https://doi.org/10.1016/j.envint.2018.04.040

9. Kurnia LA, Keman S. Analisis Risiko Paparan Debu PM$_{2.5}$ Terhadap Kejadian Penyakit Paru Obstruktif Kronis Pada Pekerja Bagian Boiler Perusahaan Lem di Probolinggo. Jurnal Kesehatan Lingkungan. 2014;7(2):118-125. http://repository.unair.ac.id/id/eprint/22549

10. Yulaekah S, Adi MS. Pajanan Debu Terhirup dan Gangguan Fungsi Paru Pada Pekerja Industri Batu Kapur (Studi di Desa Misri Kecamatan Tangungharjo Kabupaten Grobogan). Journal Kesehatan Lingkungan Indonesia. 2017;6(1):24–32. https://doi.org/10.14710/jkkl.6.1.2420-9301

11. Prabowo K, Muslim B. Penyehatan Udara. Bahan Ajar Kementerian Kesehatan Republik Indonesia. Jakarta: Ministry of Health of Republic Indonesia; 2018. http://bppsdmk.kemkes.go.id/pusdiksdmk/

12. Mohajan HA. Acid Rain is a Local Environment Pollution but Global Concern Acid Rain is a Local Environment Pollution but Global Concern. Journal of Analytical Chemistry. 2019;3(5):47–55. https://mpra.uni-muenchen.de/91622/

13. Miksusanti, Eviyanti NY. Studi Pengaruh Temperatur, Kelembaban dan Tekanan Udara Terhadap Kadar Polutan SO$_{2}$ di Sepanjang Jalan Palembang-Inderalaya. Journal Penelitian Sains. 2007;10(3):309-316. https://doi.org/10.26554/jps.v10i3.452

14. Shyamsundar P, Springer NP, Tallis H, Polasky S, Jat ML, Sidhu HS, et al. Fields on Fire: Alternatives to Crop Residue Burning in India. Journal Science. 2019;365(6453):536-538. http://dx.doi.org/10.1126/science.aaw4085

15. Mursindo D, Kusumawardani D. Estimasi Dampak Ekonomi dari Pencemaran Udara Terhadap Kesehatan di Indonesia. Journal Kesehatan Masyarakat. 2016;11(2):163-172. https://doi.org/10.15294/kemas.v11i2.3677

16. Liu Y, Zhou Y, Lu J. Exploring The Relationship Between Air Pollution and Meteorological Conditions In China Under Environmental Governance. Scientific Report. 2020;10(1):1-11. https://doi.org/10.1038/s41598-020-71383-7

17. Xie Y, Dai H, Zhang Y, Wu Y, Hanaoka T, Masui T. Comparison of Health and Economic Impacts of PM$_{2.5}$ and Ozone Pollution in China. Journal Environmental. 2019;130(1):104881. https://doi.org/10.1016/j.envint.2019.05.075

18. Askun V, Cizel R. Twenty Years of Research on Mixed Methods. Journal Mix Methods Study. 2020;1(1):1–16. http://dx.doi.org/10.14689/jomes.2020.1.2

19. Sulistiani D. Analisis SWOT Sebagai Strategi Perusahaan dalam Memenangkan Persaingan Bisnis. El-Qudwah. 2014;10(1):1-10. http://ejournal.uin-malang.ac.id/index.php/ejmlt/article/view/2725

20. Siswati, Diyanah KC. Analisis Risiko Pajanan Debu (Total Suspended Particulate) di Unit Packer PT. X. Jurnal Kesehatan Lingkungan. 2017;9(1):100–110. http://dx.doi.org/10.20473/jstn.v9i1.2017.100-101

21. Kasam I. Analisis Risiko Lingkungan pada Tempat Pembuangan Akhir (TPA) Sampah (Studi Kasus: TPA Piyungan Bantul). Journal Sains dan Teknologi Lingkungan. 2011;3(1):19–30. https://doi.org/10.20885/jstl.vol3.iss1.art2

22. Nanda F. Analisis Risiko Pajanan Karbon Monoksida (CO) Pada Pedagang di Jalur Raya Indarung Kawasan Industri PT. Semen Padang. Skripsi. Padang: Universitas Andalas; 2016. http://scholar.unand.ac.id/id/eprint/28506

23. Abbas HH, Lestari A, Bur N, Indonesia UM. Environmental Health Risk Assessment (EHRA) of Ammonia (NH$_{3}$) Exposure to Scavengers at Tamangara Landfill. International Conference on Health Science in Developing Country (I-CHEDEPY). 2019:1–7. http://repository.umi.ac.id/238/2/Environmental%20Health%20Risk%20Assessment.pdf

24. Divayana DGH, Adiarta A, Abadi IBGS. Uji Coba Rancangan Model CSE-UCLA yang dimodifikasi dengan Metode Weighted Product dan Validasi Instrumen Evaluasi Layanan Perpustakaan Digital pada Perguruan Tinggi Komputer di Bali. In Prosiding Seminar Nasional Pendidikan Teknik Informatika (SENAPATI). 2017;7(1):28-34. https://eproceeding.undiksha.ac.id/index.php/senapati/article/view/1169

25. Anugrah F, Sekplin ASS, Edward N, Christoffel MOM, Arthur HPM. Unit Cost Analysis of Tuberculous Meningitis Patients. Journal Sinaps. 2019;2(1):43–56. http://jurnalsinaps.com/index.php/sinaps/article/view/50

26. Aulia D, Ayu SF, Nefonafratilova. Analisis Perbandingan Biaya Langsung (Direct Cost) dan Biaya Tidak Langsung (Indirect Cost) pada Pasien Stroke di Rumah Sakit. Journal Ekonomi Kesehatan Indonesia. 2017;2(2):82–88. http://dx.doi.org/10.7454/eki.v2i2.2143

27. Ingenida H, Tri MA, Dwi ERT. Cost of Illness Pengobatan Meningitis pada Pasien Anak Rawat Inap di Yogyakarta. Journal Farmasi Sains dan Praktik. 2020;6(1):9–18. https://doi.org/10.31603/pharmacy.v6i1.3292

28. Gurel E. SWOT Analysis: A Theoretical Review. Journal of International Social Research. 2017;10(51):994-1006. http://dx.doi.org/10.17719/jisr.2017.1832

29. Aisyah HRPM. Hubungan Antara Kualitas Udara Ambien (O$_{3}$, SO$_{2}$, NO$_{2}$ dan PM$_{10}$) dengan Kejadian ISPA (Infeksi Saluran Pernapasan Akut) di Kota Pekanbaru Tahun 2014-2017. Skripsi. Medan: Universitas Sumatera Utara; 2018.

30. Anshari MMA, Santoso IB. Analisis Pengaruh Faktor Meteorologi dan Unsur Ruang terhadap...
Nilai Reduksi Sulfur Dioksida Udara Ambien di Kota Surabaya. Jurnal Teknik ITS. 2017;6(2): 2337-3520. http://dx.doi.org/10.12962/j23373539.v6i2.24231

31. Turyanti A, Santikayasa IP. Analisis Pola Unsur Meteorologi dan Konsentras Polutan di Udara Ambien Studi Kasus : Jakarta dan Bandung. Journal Agromet. 2006;20(2):25-37. https://doi.org/10.29244/j.agromet.20.2.25-37

32. Government of Republic Indonesia. Government Regulation of Republic Indonesia No. 41 Year 1999 about Air Pollution Control. Jakarta: Ministry of the State Secretariat; 1999

33. Hidayat A, Inaku R, Novianus C. Pengaruh Pencemaran Udara PM_{2.5} dan PM_{10} Terhadap Keluhan Pernapasan Anak di Ruang Terbuka Anak di DKI Jakarta. Arsip Kesehatan Masyarakat. 2020;(5)2:9–16. https://doi.org/10.22236/arkesmas.v5i2.4990

34. Rosalia O, Wispriyono B, Kusnoputran. H. Karakteristik Risiko Kesehatan Non Karsinogen pada Remaja Siswa Akibat Pajanan Inhalasi Debu Particulate Matter < 2,5 (PM_{2.5}). Media Kesehatan Masyarakat Indonesia. 2018;14(1):26-33. http://dx.doi.org/10.30597/mkmi.v14i1.2079

35. Ministry of Industry of Republic Indonesia. Regulation of Ministry of Industry of Republic Indonesia No. 35 Year 2010 about Industrial Estate Technical Guidelines. Jakarta : Ministry of Industry of Republic Indonesia; 2010.