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RISK AND IMPACT CONTROL OF $PM_{2.5}$ AND SO_2 EXPOSURE OF POWER PLANT TO COMMUNITIES (A CASE STUDY IN THE STEAM POWER PLANT BABELAN BEKASI)

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Abstract

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_2, NOx, and SO_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 $PM_{2.5}$ and SO_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, $PM_{2.5}$ refers to particles with a diameter of less than 2.5 micrometres. By this size, $PM_{2.5}$ can penetrate the lungs (6). Various complex elements contained in $PM_{2.5}$ 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 evenly 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 ($PM_{2.5}$ dust) have more lung function disorders (>50%) (10). Like $PM_{2.5}$, Sulfur dioxide (SO_2) also has a dangerous effect on human health. Not only can SO_2 cause bronchitis and emphysema, but it also worsens the condition of people with chronic respiratory diseases (11). Besides, high exposure to SO_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 $PM_{2.5}$ 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 $PM_{2.5}$ 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 $PM_{2.5}$ (17). $PM_{2.5}$ and SO_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 $PM_{2.5}$ and SO_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 $PM_{2.5}$ and SO_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 km^2 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 km^2 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_{reall}) (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):

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

∑ = 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.

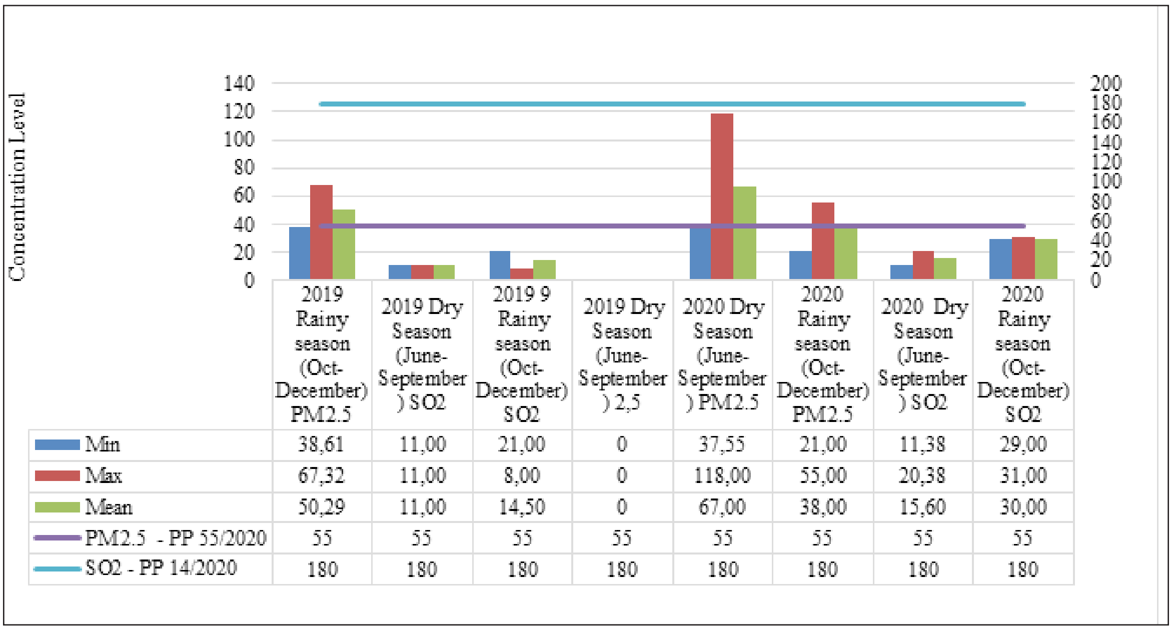

Figure 1. Value of $PM_{2.5}$ and SO_2 Concentrations in the 2019-2020 Dry and Rainy Season

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	53.664/52	9.35
Daily Exposure (hours/day)	(te)	2	12	6.684/7.20	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 irelatively 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						
PM 2.5	0.003	0.01	0.01	0.34	0.57	1.12
SO_2	0.001	0.001	0.003	0.03	0.05	0.10
Wet						
PM 2.5	0.002	0.003	0.006	0.19	0.32	0.64
SO_2	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	Not Risky	%
Dry						
<=12 years old	0	8		0	12	0%
13-55 years old	30	220	10.24	0	250	0%
>55 years old	21	14	7.20	0	35	0%
Wet						
<=12 years old	0	8	0	0	13	0%
13-55 years old	1	249	0,34	0	250	0%
>55 years old	7	28	2,39%	0	36	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			
Outpatient care	1	6	0
Insurance fee	58,396	2,600,000	0
Administration fee	38,089	100,000,00	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	100,0000	0
Other fees	2,389.10	500,000	0
Inpatient			
Total days of inpatient	0.10	7	0
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	5,137.21	50,000	0
Parking fee	2,034.01	55,000	0
Transportation fees of Inpatient			
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	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	1.00	7	0
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)	**373,879.00**	**44,310,012**	**0**
Average population income (IDR)	**2,576,792.00**	**10,000,000**	**0**
Percentage of total charges for health burden/average income	**14,51%**		

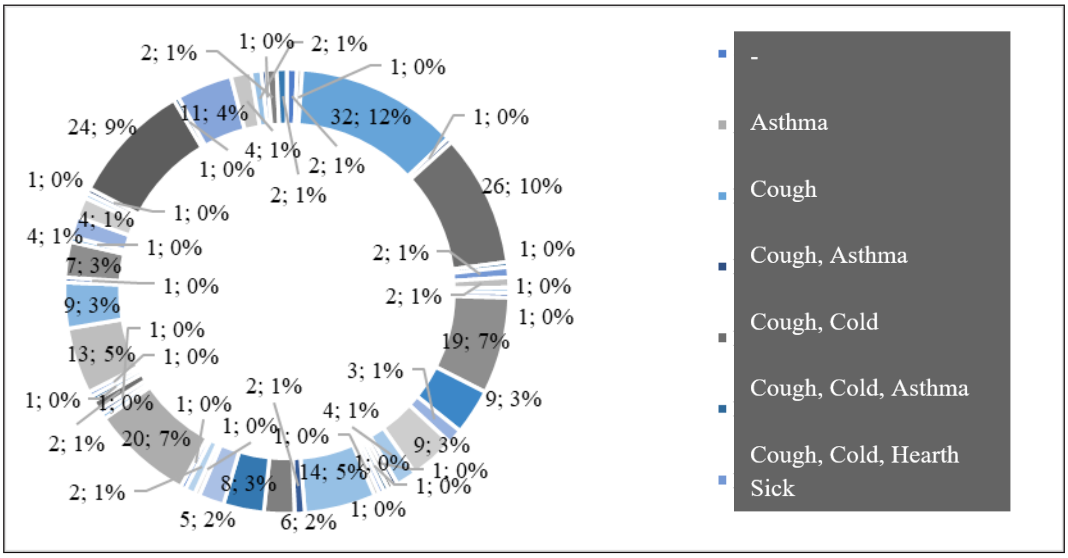

Figure 2. Types of Health Problems on the Community around the Steam Power Plant

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 km^2 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 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.

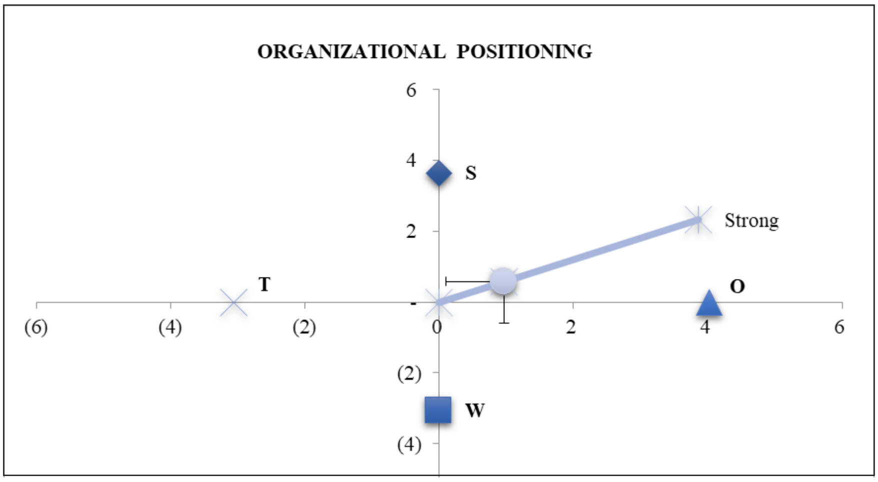

Figure 3. Position of Strengths of Control Strategy

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

Internal Factor	
Strengths	**Weaknesses**
a. The location of the steam power plant does not comply with the spatial and zoning provisions b. Environmental impact analysis documents c. Passive report on industrial activity d. Limitation on the operational time of the steam power plant e. Production process time that applies the principle of environmental control f. Prioritization of the budget for controlling the risks and impacts of air pollution from the steam power plant industrial exhaust g. Implementing corporate social responsibility or CSR programs to improve the environment, social, and economy of the community around the steam power plant h. Installation of dust filters in the steam power plant zone i. Perform routine dusting j. Switching to euro 4 gas k. Availability of coal resources l. Availability of occupational health and safety documents m. Leader's understanding of the risks and impacts of air pollution on the work environment and society. n. Obligation to use PPE in the steam power plant work environment o. Increasing the capacity of employees regarding the efficiency and effectiveness of electrical energy production p. Dissemination of risks and impacts of air pollution on the work environment and society q. Good cooperation with the government as well as satate electricity company	a. Implementing corporate responsibility or CSR programs to improve the environment, social, and economy of the community around the steam power plant b. High cost of pollution control equipment c. The risk of reducing company revenue d. The risk of reducing the number of employees e. Guarantee of the ability to supply demand for electrical energy needs f. Increased demand for electricity g. Increase in electricity bills
External Factor	
Opportunities (O)	**Threat (T)**
a. Regulations on conditions for the location of industrial activities including steam power plant b. Regulations concerning provisions for air quality control c. Measurement and regular monitoring of air quality per 6 months at the steam power plant d. Budgets for air pollution control e. Budgets for quality improvement of community health (National Health Insurance (JKS), health services, food), f. Provision of free/subsidized public health insurance by the government g. Tightening the quality standard values from immovable sources h. Provision of air quality measuring instruments i. Regulations on the use of renewable energy resources/environmentally friendly fuels to fuel electrical energy sources. j. Rules regarding labor protection k. Availability of Green Space and Pollutant-Absorbing Plants l. Provision of euro 4. m. Increase in the price of coal fuel n. Availability of alternative fuels from renewable energy sources (EBT) o. Socialization on how to use electrical energy wisely p. Socialization on how to reduce the risk of getting contaminated by pollutants produced by steam power plant q. Community participation to maintain the quality of environmental health r. The level of community understanding of air pollution s. Positive response to the existence of steam power plant to employment t. Community income level u. Availability of green space and pollutant-absorbing plants v. Geopolitical Conditions and Environmental Issues. w. The increasing issue of global warming, Paris Agreement - commitment to reduce GHG emissions	a. Settlements close to the steam power plant b. Health and medical expenses c. Primary Needs of Electrical Energy d. Demand for electrical energy e. Availability of coal resources f. Energy policy which still affects fossil resources g. Non-competitive EBT policies\ h. Health and medical expenses i. Non-competitive EBT policies j. Increase in electricity charges

Combination of Strength-Opportunities (SO)	Combination of Weakness - Opportunities (WO)
a. Implementing regulations regarding the location of industrial activities and zoning (steam power plant) concerning its risks and impacts on community settlements b. Implementing the provisions of air quality control regulations by taking the regular preventive measurement to evaluate the risk and impact of steam power plant waste activities per 6 months through the availability of Environmental Impact Management Analysis documents, routine reports on steam power plant activities, and time limits for electrical energy production c. Priority budget allocation from the company for air pollution control to minimize the risks and impacts of air pollution d. Budget allocation for health quality improvement of steam power plant employees and nearby community through the provision of subsidized health insurance by the government or the use of corporate social responsibility budget allocations e. Efforts by the government to tighten the quality standards of immovable sources to ensure that dust build-up does not exceed the standards of ambient air by installing air quality and dust filtering equipment around the steam power plant zone f. Encouraging the use of Euro 4 fuels, gas, and renewable energy as primary materials in the production of electrical energy g. Implementing the mandatory provisions of manpower protection for steam power plant employees through the availability of Occupational Health and Safety documents and the obligation to use PPE when doing activities in the steam power plant environment h. Encouraging the implementation of leadership responsibilities in controlling the risks and impacts of air pollution to the steam power plant. i. Implementing effective use of electrical energy through the use of coal for electrical energy, as well as the socialization on how to use electrical wisely j. Conducting public discussion on clean air and the impact of air pollution to increase community awareness and community engagement in supporting clean air for the environment. k. Encouraging the production of eco-friendly electrical energy and providing job opportunities to improve the life of the surrounding community through the cooperation between the government, state electricity company, and private companies	a. Allocating a corporate responsibility budget for the implementation of risk and impact control based on the regulations for the location of industrial activities b. Providing support in terms of equipment regulations and budget for air quality control equipment c. Providing a budget for risk control and minimizing impact control costs d. Providing subsidies for workers' health costs e. Switching to alternative renewable energy sources to fill electrical energy needs f. Increasing community understanding of the efficient use of electrical energy and the impact of using electrical energy on air pollutant levels g. Increasing the standard living of the community by opening new job opportunities to support the daily needs of the surrounding community including electricity.
Combination of Strength-Threat (ST)	**Combination of Weakness-Threat (WT)**
a. Evaluating the results of the Environmental Impact Management Analysis documents, periodic passive reports on PLTU activities, and time limits on pollutant emissions b. Providing insurance or health assistance subsidies to employees and affected communities c. Implementing policies to limit the use of energy that is not environmentally friendly and encouraging a switch to renewable or more environmentally friendly energy d. Increasing community awareness regarding the role of the community in saving the use of electrical energy e. Increasing community awareness regarding the role of individuals in maintaining air quality and community health f. Conducting further studies in the application of electricity charge policies based on the production of eco-friendly electrical energy	a. Providing assistance related to risk control and impact from corporate responsibility funds or CSR to surrounding communities b. Increasing public awareness and steam power plant employees on the efficient use of electrical energy and encouraging a switch to renewable energy c. Subsidies or incentive scheme absorption for individuals that have switched to renewable energy.

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 km2. 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 mínimum 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.

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