

REPORT

Analysis of Environmental Health Risks Due to Exposure to PM_{10} , $PM_{2.5}$, and SO_2 in Fatufia, Bahomakmur, and Labota Village Communities



Analysis of Environmental Health Risks Due to Exposure to PM₉, PM_{2.5}, and SO₂ in Fatufia, Bahomakmur, and Labota Village Communities

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FOREWORD: Executive Director of TuK INDONESIA

The rapid development of the nickel mining industry in Indonesia, particularly in Morowali Regency, poses serious challenges to environmental quality and public health. TuK INDONESIA (Transformation for Justice Indonesia) as an institution committed to social and environmental justice, views this issue as one of its main focuses. Therefore, our support for the study "Environmental Health Risk Analysis Due to Exposure to PM₁₀, PM_{2.5}, and SO₂ in the Communities of Fatufia, Bahomakmur, and Labota" becomes very relevant and important for various stakeholders to pay attention, especially those involved in the mining sector and environmental protection.

Nickel mining activities can potentially reduce environmental quality, one of which is increasing the concentration of particulates and sulfur dioxide (SO₂) in the air. Particulates (PM₁₀, PM_{2.5}) and SO₂ are direct emissions from various nickel mining activities and have been shown to have a significant impact on public health around the mining operation area. Based on the research results presented in this book, the average concentration of PM₁₀, PM_{2.5}, and SO₂ in Fatufia, Bahomakmur, and Labota Villages has exceeded the quality standards set by the government, reflecting serious health risks for local residents.

This research uses environmental health risk analysis methods to assess the impact of long-term exposure to PM₁₀, PM_{2.5}, and SO₂ on public health. One key finding is that the projected pollutant intake indicates that the average respondents have exceeded the recommended RfC (Reference Concentration) value after 10 years of exposure, suggesting a high potential health risk. In addition, the maximum intake of PM₁₀ and SO₂ reaches 0.023212 mg/kg/day and 0.061579 mg/kg/day, which significantly exceeds the safe limits, underscoring the urgent need for air pollution control policies in the region.

Furthermore, the risk characterization shows that there are several respondents with an RQ (Risk Quotient) value greater than 1, indicating the presence of real and significant health risks that cannot be overlooked. The most common impact is respiratory disorders such as acute respiratory infections, asthma, and even the potential for chronic obstructive pulmonary disease. (PPOK). This situation is exacerbated by the finding that local healthcare facilities, such as community health centers, are inadequate to handle the increase in these cases, highlighting a serious gap in health infrastructure in the affected areas.

This book also underlines the importance of consistent monitoring and evaluation of pollutant emissions from mining activities. The finding that monitoring is often not carried out regularly, but rather only occasionally, indicates a weakness in the enforcement of regulations. This leads to the need for reforms in environmental oversight, particularly in monitoring air quality and enforcing penalties for violations.

TuK INDONESIA recognizes that research and publications are not sufficient to protect health and the environment; it also requires concrete actions from the government, industry, and the wider community. We emphasize that mining activities must be accompanied by strong environmental responsibility and the implementation of effective policies to protect public health and environmental quality.

TuK INDONESIA would like to express our appreciation and gratitude to all participants. A huge thank you to the author and support team, the Faculty of Public Health, University of Tadulako, and Celebes Bergerac for their perseverance in collecting and processing the data. With the publication of this book, TuK INDONESIA is committed to continue advocating for sustainable and fair policies in the mining sector, especially to curb the health impacts of air pollution. We call on all elements of society, academia and government to join us in this advocacy for a healthier future and a safer environment.

17 August 2024

Linda Rosalina
Executive Director of TuK INDONESIA

FOREWORD: Dean of the Faculty of Public Health, University of Tadulako

In the name of Allah SWT, the Most Merciful, the Most Merciful, we offer all praise and gratitude before Him for His abundant grace and blessings, that the research report titled: Analysis of Environmental Health Risks Due to Exposure to PM₁₀, PM_{2.5}, and SO₂ in Fatufia, Bahomakmur, and Labota Village Communities have been completed and published. **PM₁₀, PM_{2.5}, and SO₂** are air pollutants that are highly dangerous to human health. These particles are so small that they can be easily inhaled and enter the airways and lungs.

This research report is undoubtedly the result of dedicated research by the author's team of highly qualified faculty and graduates in the field of environmental health. This research report is undoubtedly a comprehensive understanding of the impacts of these three pollutants, making it highly relevant and important report to read for various stakeholders, especially those working in the mining and environmental protection sectors. The information gained from this study also serves as a warning to local governments to always encourage companies to involve universities in regularly monitoring the quality of the environment (air). Mining may be made sustainable, while keeping it environmentally sensitive.

On behalf of the Faculty of Public Health, University of Tadulako, I welcome and thank the editorial team for the publication of this report book. This report book is intended to be the main reference material for students taking environmental chemistry courses and also serves as a reference for teachers and researchers in the same field.

Finally, I hope that this report will bring maximum benefit to the further development of environmental education in Indonesia.

17 August 2024

Prof. Dr. Nurdin Rahman, M.Si, M.Kes
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GLOSARIUM

- AMDAL/ Environmental Impact Analysis** : A study on the significant and important impacts of decision-making and/or planned activities on the environment that is necessary for the decision-making process regarding the organization of business and/or activities.
- Carcinogenic Materials** : Substances that can trigger the growth of cancer cells.
- Concentration** : The amount of a substance per specific volume.
- Corporate Social Responsibility** : The form of social responsibility the corporations shows to the community and surrounding environment.
- Corrosive** : Materials that can stimulate rust on metallic materials.
- Environmental Health Risk Analysis** : A process intended to calculate or estimate risks to human health, including identification of uncertain factors, tracking of specific exposures, taking into account the inherent characteristics of the agent of concern and the characteristics of the specific target.
- Exposure** : The process in which an organism comes into contact with a danger.
- Intake** : The amount of risk agent concentration (mg) entering the human body with a specific body weight (kg) every 24 hours (mg/kg/day).
- Inhalation Pathway** : The entry pathway of particulates through the respiratory system.
- ISPA/Acute Respiratory Tract Infection (ARI)** : An acute infection that attacks the respiratory tract, from the nose and throat to the lungs.

- ISPU/Air Pollutant Standard Index** : A number without a specific unit that is used to describe the air quality conditions at a particular location.
- Nickel** : A type of silvery-white metal found naturally in the earth's crust
- Particulate Matter** : Small-sized pollutants that are made up of solids or liquids in the air.
- Pneumonia** : An infection that causes inflammation of the air sacs in one or both lungs.
- Pollutant** : Pollution-causing materials.
- Quality Standards** : The reference level of living creatures, substances, energy or components that must be present and/or pollutant elements that can be tolerated in a particular resource as an environmental element.
- Reference Dose/ Concentration** : The dose/concentration of daily exposure to non-carcinogenic risk agents is estimated not to cause disruptive effects, even in a lifetime exposure.
- Response Dose** : The total amount of an agent that is given, received, or absorbed by an organism, system, or sub/population compared with the changes in an organism, system, or sub/population.
- Risk** : The likelihood or chance of a negative impact on an organism, system, or sub/population arising from exposure to an agent under certain conditions.
- Risk Quotient** : The magnitude of the risk expressed in numbers without units, which is a comparative calculation between intake and the reference dose/concentration of a non-carcinogenic risk agent, can also be interpreted as the safety or lack of safety of a risk agent towards an organism, system, or sub/population.

- RKL/ Environmental Management Plan** : Efforts to address the environmental impacts arising from business plans and/or activities.
- RPL/ Environmental Monitoring Plan** : Efforts to monitor environmental components affected by business and/or activity plans.
- Slag** : Rocky waste material separated from metal during ore smelting or refining.
- Sulfate Aerosol** : Small particles that reflect sunlight, the spraying of which are expected to increase the amount of sunlight that is reflected into space and thus lower global temperatures.
- Sulfur Dioxide/ SO₂** : A colorless toxic gas compound, with a pungent smell.
- Toxic and Hazardous Waste** : Residual activities or activities that contain substances or components that can directly or indirectly pollute, damage, or endanger the environment, health, and survival of humans and other living beings.

RESEARCH FINDINGS

The Health Aspect

- 1 | Based on risk characterization (**determining the risk level/risk to health**), there are 5 respondents (5.43%) with an $RQ > 1$ for $PM_{2.5}$ exposure, which means that there are 5 respondents at health risk from $PM_{2.5}$ mining activities.
- 2 | Based on the risk characterization (**Determination of risk level/risk to health**), 5 respondents (5.43%) had an $RQ > 1$ for PM_{10} exposure, which means that there are 5 respondents at health risk from mining activities due to PM_{10} exposure.
- 3 | Based on the risk characterization (**Determination of risk level/risk to health**), 6 respondents (6.52%) have an $RQ > 1$ for SO_2 exposure, which means that there are 6 respondents at health risk from mining activities due to SO_2 exposure.
- 4 | The average results of the projections for the intake and maximum RQ of PM_{10} , $PM_{2.5}$, and SO_2 pose risks over a 10-year exposure. The longer the exposure, the higher the intake values of pollutants received by individuals, which can increase the health risk.
- 5 | The community is upset by the dust generated from mining activities and complains about the noise, especially during the high-demand season for nickel, causing the machines to operate 24/7.
- 6 | The data on the number of cases of Acute Respiratory Infections (ISPA) in 2023 shows a total of 55,527 cases, based on reports from the Bahodopi Community Health Center. The data shows that there are 372 cases of adult pneumonia, while there are 438 cases in toddlers.
- 7 | Some symptoms experienced by the respondents include coughing (70%), sneezing (65%), runny nose (53%), headache (50%), and sore throat (37%).

The Aspect of Health Care Facilities

- 1 | The high number of patients visiting the company clinic for health examinations.
- 2 | Regarding the infrastructure and healthcare personnel, the clinics and community health centers are still inadequate, resulting in suboptimal services being provided.
- 3 | The availability of medications is more comprehensive at the company's large clinic. In addition, many pharmacies have also been established at several locations. Meanwhile, the community health centers only provide generic types of medication.
- 4 | People face several challenges in accessing healthcare services, such as poor accessibility and road capacity.

The Environmental Aspect

- 1 | The pollutants released from nickel industrial activities can cause the community's zinc-based infrastructure to be prone to corrosion.
- 2 | The local community experiences changes in weather patterns after the mining activities commence and the decline in aquatic life that serves as a source of livelihood for some members of the community.
- 3 | Some of the leftover materials from the excavations or mining activities are processed, utilized as raw materials for roads, or mixed into concrete bricks; while the mountain of debris that has been dug up is simply discarded.
- 4 | The condition of the main road, which is often damaged due to the traffic of heavy transport vehicles, causes difficulties in accessibility to healthcare facilities. Additionally, this condition leads to the accumulation of dust particles, especially during the dry seasons.

The Social Aspect

- 1 | Based on the interviews, the forms of criminal activities in the industrial area include murder, robbery, infidelity, rape, gambling, and drug trafficking.
- 2 | The establishment of the mining industry has garnered both support and opposition from the community. Those who oppose are generally the residents living close to the industrial areas, as they are directly affected by mining activities.
- 3 | The local indigenous community receives an annual corporate social responsibility (CSR) fund of one million from the company.

The Economic Aspect

- 1 | One of the positive impacts of nickel mining activities is the economic improvement enjoyed by the community, as well as the availability of a significant number of job opportunities.

The Aspects of Governmental and Company Policies

- 1 | The company's policy regarding mining activities includes empowering local communities, preventing pollution through dust suppression tools, environmental impact assessment documents (AMDAL), Corporate Social Responsibility (CSR), and replacing roofs of homes that have corroded due to carbon compounds.
- 2 | The implementation of monitoring and evaluation is not carried out regularly, but several agencies such as the Department of Mining, the Department of Environment, and occasionally the Ministry have conducted in-situ visits.

RECOMMENDATIONS

The Health Aspect

- 1 | improvement of the quality and quantity of healthcare personnel and local healthcare facilities to ensure optimal health services.
- 2 | Enhancement of early diagnosis and health education, particularly in disease prevention related to respiratory issues in communities around mining areas.
- 3 | Collaboration between the Health Office of the Local Government and the Company in conducting regular health checks for workers and the surrounding community near the mines.
- 4 | Transparency in the comprehensive health examination reports from the company to the workers and relevant government authorities.
- 5 | Community settlements should be relocated in accordance with safe limits for environmental contamination parameters (soil, water, and air) in order to reduce future health concerns.

The Environmental Aspect

- 1 | The utilization of technology for controlling air pollution from industries that is to be applied by companies and the Environmental Agency.
- 2 | A review of the RKL (Environmental Management Plan) and RPL (Environmental Monitoring Plan) documents by the relevant authorities, as well as the implementation of regular monitoring and evaluation efforts.
- 3 | The development of real-time air quality monitoring systems to support business and government policy-making and serve as alerts for impacted areas. For instance, the adoption of the Air Pollution Standard Index (ISPU) board to help limit air pollution.
- 4 | The management of mining waste before disposal in the environment or conducting a double check on the hazardous waste content in mining waste.
- 5 | Conducting dissemination to ensure the transparency and accountability of emission data in nickel industrial areas as a consideration for the government in their environmental management efforts.

- 6 | Establish stringent and rigid emission regulations for manufacturing facilities and businesses. Moreover, the federal and municipal governments should conduct frequent audits and inspections.
- 7 | Stricter licensing requirements and guidelines for building residential complexes and public works projects adjacent to industrial zones. Observations indicate that there may be a risk of direct exposure to air pollutants due to the proximity of the smelter to residential areas and public facilities.
- 8 | The implementation of repairs to damaged roads and preventive efforts by the relevant parties.
- 9 | The provision of waste processing facilities and infrastructure, as well as the improvement of waste management through the PPP (Public-Private Partnership) scheme.

The Social Aspect

- 1 | Support and facilitate the active involvement of local communities, government, NGOs (Non-Governmental Organizations), and companies through regular public discussions.
- 2 | Increased monitoring by authorities in preventing the proliferation of drug users, sexual harassment, robbery, and murder.
- 3 | Enforcement of strict implementation of laws and sanctions for companies that violate the rules.
- 4 | Increased implementation of evaluations and provision of social protection and empowerment for workers and communities around mining areas.

The Economic Aspect

- 1 | Increasing community welfare by opening as many job opportunities as possible, especially for communities around mining areas.
- 2 | Establish a proper management of resources to increase regional income and continue to prioritize environmental sustainability.

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INTRODUCTION

1. Background

It's always interesting to talk about the issue of environmental contamination, which is also becoming a more serious one. Not just focusing on the environmental quality but also taking into account how the community's health is affected by the exposure to the numerous detrimental effects of environmental pollution. In parallel to the annual industrial growth, the actors in this area continue to siphon off earth's valuables, which could be used to build the infrastructure that the community needs. One of the main participants in the international commerce in mining materials, particularly nickel, is Indonesia. Indonesia holds the top spot in the world's nickel-producing index with a nickel mining area of 520.877,07 hectares (ha) (ESDM, 2022). Regarding trade, in the last five years, Nickel exports have experienced quite rapid growth. It was 2.44 million tons in 2019 and increased to 3.61 million tons in 2023 (Statista, 2022).

Nickel (Ni) is one of the most sought-after natural resources. Numerous nickel mining operations are conducted to satisfy the growing demands of industrial firms and the expanding needs of the community. Naturally occurring in the earth's crust, nickel (Ni) is dispersed throughout the surroundings. In addition to arsenic and antimony (Sb), nickel can also be found in various compositions of garnierite, a magnesium-nickel silicate, and in oxides, silicates, sulfides, and arsenides like millerite (NiS). Conversely, nickel is a necessary mineral for the body as well, but overexposure to it can be harmful. Eating polluted food, smoking, drinking water tainted with excess nickel concentrations, and inhaling contaminated air can all cause human infection. Excessive Nickel consumption can cause lung cancer, nasal cancer, laryngeal cancer, and prostate cancer.

The nickel industry uses a lot of land in terms of land use. People may be exposed to hazardous materials from nickel mining operations due to its close proximity to the residential areas. Particulate matter and sulfur dioxide concentrations are two ways that nickel mining operations may potentially lead to a deterioration in the quality of the surrounding environment. Nickel mining has an effect on the aquatic environment in terms of the deterioration of soil and water quality, the possibility of aquatic biota poisoning, and harm to aquatic life's habitat (Saputro et al., 2024). Sulfur dioxide and particulates are emitted during nickel mining operations. In order to provide policy recommendations for controlling pollution, particularly air quality in nickel mining, it is necessary to conduct an environmental health risk analysis study on particulates and sulfur dioxide (SO₂) to see the impacts and health risks to communities around mining areas.

It should be noted that some of the health impacts caused by nickel mining include silicosis, asthma, and lung cancer (Yudo & Hernaningsih, 2021). These health problems are caused by particulate mining dust containing toxic metals and emission gases from combustion engine activities. In addition, nickel mining waste has a fairly high degree of acidity so it has the potential to contaminate surrounding water bodies. Acid mine waste is created due to the process of mining minerals in water and air which has the potential to cause damage to the environment. Nickel mining activities produce various types of particles. The types of dust particles are generally divided into two types, namely PM_{2.5} and PM₁₀. The PM produced can affect the health of the community and workers.

Sulfates, nitrates, organic chemicals, ammonium compounds, metals, acidic materials, and other contaminants that may be harmful to human health are the components that makeup PM_{2.5}. The primary causes of PM_{2.5} and PM₁₀ are burning biomass, (industrial) materials vehicles, secondary aerosols, and urban anthropogenic sources (Wardoyo, 2024). The degree of exposure is mostly determined by the size and makeup of the particles. Due to its small size, PM_{2.5} can enter the deepest parts of the lungs. Thus, PM_{2.5} has been linked to a number of acute respiratory conditions, including lung cancer, cardiovascular illness, acute respiratory tract infections (ARI), and chronic obstructive pulmonary disease. It can also cause premature death. In the meantime, a number of studies have connected exposure to PM₁₀ pollutants with a number of illnesses, including heightened respiratory symptoms, reduced lung function, exacerbation of asthma, development of chronic bronchitis, mild heart attacks, and early mortality in patients with lung and heart disease.

The quality standards for PM_{2.5} set by the Environmental Protection Agency (EPA) in 2006 are 35 µg /m³ (24-hour average) and 15 µg /m³ (annual average). The WHO also sets the quality standards for PM_{2.5} at 10 µg/m³ (annual average) and 25 µg/m³ (24-hour average) (WHO, 2005). Meanwhile, the PM_{2.5} ambient air quality standards set by the Government Regulation of the Republic of Indonesia No. 22 of 2021 are 55 µg /m³ (24-hour average) and 15 µg /m³ (annual average). The main sources of dust in the air are soil, droplets, seawater, forest fires, domestic fires, and organic dust from vehicles, industrial processes, and plant materials. Dust is generated when solids are processed in industry. The particles are between 1 and 10 micrometers in diameter and are typically combustion products from soil and local industry.

The nickel mining industry may also produce SO₂ emissions from nickel smelters. Sulfur dioxide is a gas that is highly soluble in water and is odorous but colorless. SO₂ is produced by the combustion of sulfur-containing fossil fuels such as feedstocks (crude oil and coal). One activity that produces SO₂ is industrial or mining activities that use coal or diesel as fuel. Workers in the nickel industry production and processing can be exposed to low levels through inhalation or skin contact. The nervous system is one of the target organs of nickel toxicity, which may eventually accumulate in the brain (Genchi et al., 2020). The quality standard for SO₂ air pollutants according to Government Regulation of the Republic of Indonesia No. 21 of 2022 is 150 µg/m³ for 24-h measurements.

SO₂ gasses can irritate the airways, including the mucous membranes of the nose, throat, and lungs. These health effects are exacerbated in asthmatics. In addition, airborne SO₂ can be converted into secondary pollutants, such as sulfate aerosols.

Aerosols produced as secondary pollutants are generally very fine and can be inhaled into the lower respiratory tract. Sulfate aerosols that enter the respiratory tract can have more serious health effects than other particles because they are corrosive and carcinogenic. Because SO₂ gas can produce sulfate aerosols as a secondary pollutant, increased mortality from respiratory failure, especially in the elderly and children, is often associated with the simultaneous concentration of SO₂ and particulate matter. SO₂ can also react with other compounds to form sulfate particles. When inhaled, sulfate particles can accumulate in the lungs and cause breathing difficulties, respiratory diseases, and even death.

One of the provinces with large nickel deposits is Central Sulawesi, more precisely in Morowali Regency, Bahodopi District. Nickel is one of the basic ingredients in the production of batteries, electronics, medical devices, and various other metal equipment mixtures. One of the largest nickel-based industrial companies in Morowali is PT. Indonesia Morowali Industrial Park (PT. IMIP). PT. IMIP was established in 2013. Since its establishment, several communities have voiced opposition to the company's presence due to its impacts on the environment and the health of the surrounding communities.

The Bahodopi area is the center of the mining development of PT. IMIP, which operates nickel mines. The number of workers and immigrants also continues to grow, making the area more crowded with activities over time. This will encourage the development of the Bahodopi area, which is densely populated with housing, shopping centers, and other buildings. The Bahodopi area, which is the focus of this study, includes the villages of Bahomakmur, Fatufia, and Labota. Based on the measurement results of concentration parameters of air pollutants, it is found that the average concentrations of particulate matter and SO₂ in the study area exceed the quality standards, which encourages researchers to carry out further studies related to the study of environmental health risks to the population and workers in the region.

2. Problem Identification

Mining activities are one of the causes of air pollution. Mining is the activity of extracting deposits of mined material from the earth's crust mechanically or manually on the earth's surface, below the earth's surface, and below the water surface. Stone mining activities are carried out in several stages, starting with clearing, surface excavation, drilling, or blasting. Quarried stone is transported to sawmills and processed to the required size. Nickel processing processes can be carried out using pyrometallurgical and hydrometallurgical extraction methods. Pyrometallurgical processes (smelting) are mineral processing processes that use high temperatures. The heat obtained comes from coal-fired ovens (coking). Burning coal produces particulates and gases that can increase the risk of exposure to air pollution, especially $PM_{2.5}$ and SO_2 . Additionally, $PM_{2.5}$, PM_{10} , and SO_2 can also be generated during transportation processes, with emissions from transportation equipment and wind-borne raw materials.

Various substances contained in $PM_{2.5}$ can cause various respiratory diseases such as acute respiratory infections (ARIs), lung cancer, cardiovascular diseases, premature death, and chronic obstructive pulmonary disease. $PM_{2.5}$ can breach the defenses of the human airways and combine with human blood through air exchange at the alveoli. Particles can be deposited within the airways through various physical mechanisms such as settling, impaction, diffusion, interception, and electro-precipitation. Outdoor air pollution in urban and rural areas is estimated to have caused 4.2 million premature deaths worldwide in 2019.

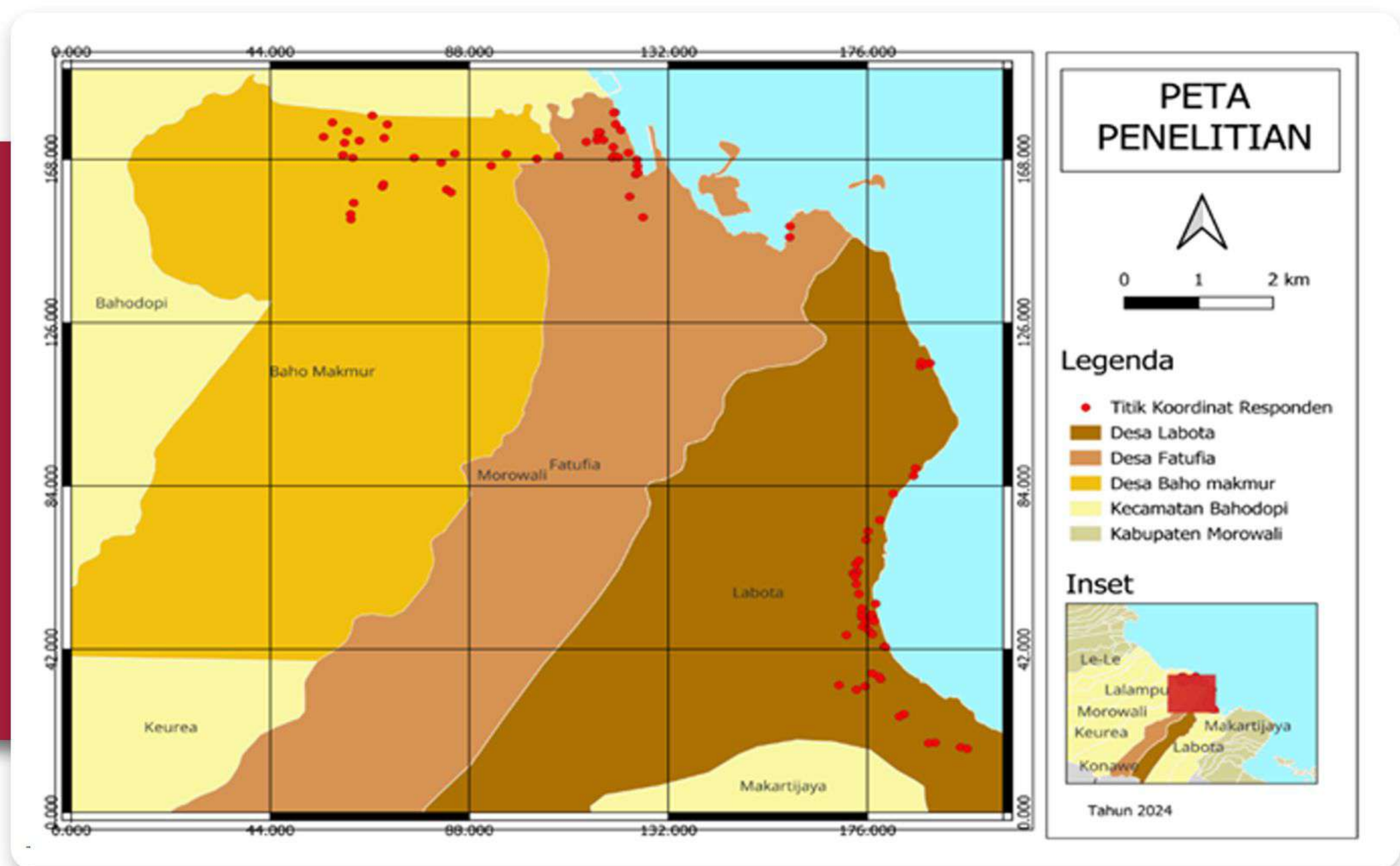
These deaths are caused by exposure to particulate matter, which causes cardiovascular diseases, respiratory diseases, and even cancer. Sulfur dioxide can irritate the lungs and cause breathing difficulties, especially in sensitive groups such as asthmatics, children, and the elderly. SO_2 can also react with other compounds to form sulfate particles, which when inhaled can accumulate in the lungs and cause breathing difficulties, respiratory diseases, and even death. The aim of this study is to analyze the environmental health risks to residents and workers and to determine the projected health risks posed by exposure to $PM_{2.5}$ and SO_2 to residents over a period of 5 to 30 years.

3. Environmental Health Risk Analysis

Environmental Health Risk Analysis (EAHR) is an approach that delves into the conditions and characteristics of the environment that may pose health risks in order to identify, understand, and predict health risks. It addresses changes in environmental media, exposed communities, and sources of new health impacts. According to Joseph F. Louvar and B. Diane Louvar (1998), EAHR is a scientific framework for solving environmental and health problems.

4. Research Location

Figure 1 Research Location and Sample Coordinates



Source: Primary Data, 2024

The research locations are spread across three villages in Bahodopi District, Morowali Regency, the villages are:

1. Fatufia
2. Labota
3. Bahomakmur

5. Sampling Technique

This study uses a mixed-method research method. The population of this study consists of general residents and miners from the villages of Fatufia, Labota, and Bahomakmur. The population was drawn from the total population of Fatufia with a population of 3,548, Labota with a population of 6,510, and Bahomakmur with a population of 3,731. The total population of the three villages is 13,789. The sample size is determined using the Slovin formula with a sample size of 92 people.

In qualitative research, the so-called "purposive sampling" is used to determine the sample of respondents/informants. It is based on the criteria and characteristics established by the researcher. The criteria for the main/permanent respondents/reference persons to be surveyed are:

Table 1 Inclusion and Exclusion Criteria for Respondent and Informant Samples

No.	Inclusion Criteria	Exclusion Criteria
1.	Informants working in mining	Informants not working in mining
2.	Informants living in the villages of Fatufia, Labota, and Bahomakmur	Informants not living in the villages of Fatufia, Labota and Bahomakmur
3.	Informants who have worked in mining for ≥ 5 years	Informants who have worked in mining or residing in the villages of Fatufia, Labota, and Bahomakmur for ≥ 5 years
4.	Informants who give consent for an interview	

The informants in this study are divided into two groups: key informants and main/regular informants. Key informants are people who know and have the basic information required for this study. The key informants for this study are the village heads and the director of Bahodopi Community Health Center. The main/regular informants for this study are people from each village who meet the inclusion criteria. There are a total of 10 informants.

6. Data Collection

1. Primary Data

The primary data used in this study were weight data (the measuring device was a digital scale), age, time of exposure, frequency of exposure, and duration of exposure. Primary data was collected by ten investigators using in-depth interviews using the questionnaire and interview guide in the KoboToolbox application.

2. Secondary Data

Secondary data was obtained from the results of previous research on PM_{2.5}, PM₁₀, and SO₂ measurements, temperature, and humidity (2023) conducted by TuK INDONESIA.

7. EAHR Steps

Environmental Health Risk Analysis (ARKL) consists of several steps, including:

a. Hazard Identification

Hazard identification is the first stage of ARKL and involves the detailed identification of risk factors that may cause health problems if they come into contact with the body. Hazard identification may include adding symptoms of health problems closely related to the risk factor being analyzed. This stage requires answering the questions: which specific risk factor is dangerous, in which environmental medium does that risk factor occur, how high the concentration of the risk factor in the environmental medium is, and what potential health symptoms will occur?

b. Response Dose Analysis

After identifying the hazards (risk agents, concentration, and environmental medium), the next step is to perform a response dose analysis. This step is the focus of ARKL to determine the RfD and/or RfC and/or SF values for the risk agents and understand how the risk agents may affect the human body.

This response dose analysis does not have to be performed by in-house experimental research; it is sufficient to refer to the available literature. This response dose analysis step is intended to:

- a) Knowledge of the pathways of absorption of hazardous substances into the human body.
- b) Understand the change in symptoms or health impacts with increasing concentration or dose of a risk substance in the body.
- c) Knowledge of the Reference Dose (RfD), Reference Concentration (RfC), or Slope Factor (SF) of a risk agent.

c. Exposure Analysis

Once the first and second phases are completed, the next step is the exposure analysis by calculating the intake value of risk agents. The calculation/measurement of intake values is carried out using various formulas and equations. The data used for the calculation can be primary data from the results of independently carried out measurements of the concentration of risk agents in environmental media, or secondary data in the form of measurements of the concentration of risk substances in environmental media carried out by other reliable parties, such as BLH, health offices, NGOs, etc., and opinions based on logical reasoning or opinions using available default values/constants.

d. Risk Quotient

The final stage of ARKL is the risk characterization. This is performed to determine the risk level of the risk substance at the specific concentration analyzed in ARKL. This identifies the risk of causing health problems in the community due to several characteristics (weight, inhalation, or consumption). The risk is characterized by dividing the intake by the tolerable dose/concentration of the risk substance. The variables used to calculate the risk level are the intake determined from the exposure analysis and the reference dose (RfD)/reference concentration (RfC) taken from existing literature. The risk level is expressed as a unitless number or a decimal. The risk level at the time of recording is considered to be safe if intake < RfD/RfC or RQ.

e. Risk Management

Risk management is not included in the ARKL step, but is a subsequent step when the risk characterization results indicate a level of uncertainty ($RQ \geq 1$). With regard to risk management, a distinction must be made between risk management strategies and risk management methods. Risk management strategies include determining safe boundaries such as:

a) Determination of Safe Threshold

- 1) Determination of safe concentration (C) to calculate safe non-carcinogenic inhalation concentration, namely:

$$C_{nk} = \frac{RfC \times W_b \times t_{avg}}{R \times t_E \times f_E \times D_t}$$

2) Determination of exposure time (tE)

When exposure occurs to individuals in non-permanent work or education environments, safe exposure time can be managed. Time management can be accomplished by reducing the duration of exposure per day. To calculate safe exposure time for inhalation of non-carcinogens:

$$t_{nk} = \frac{RfC \times W \times t}{C \times R \times f \times D_t}$$

3) Determination of safe exposure frequency (fe) To calculate the safe exposure frequency for non-carcinogenic inhalation:

$$f_{nk} = \frac{RfC \times W_b \times t_{avg}}{C \times R \times t_E \times D_t}$$

4) Determining safe exposure duration (Dt)

For inhalation exposure in permanent environments such as residential (settlement) environments, the safe duration of exposure is controlled. The duration of exposure is controlled by limiting the duration of stay (in years) of people in a residence, with relocation if the safe duration is exceeded. To calculate the safe duration of non-carcinogenic inhalation exposure, use:

$$D_{nk} = \frac{RfC \times W_b \times t_{avg}}{C \times R \times t_E \times f_e}$$

b) Risk Management

If the RQ value of PM_{2.5} > 1, then risk management to reduce the impact of PM_{2.5} on human health is necessary.

Results and Discussion

1. General Description of the Research Location

The study was carried out in the villages of Fatufia, Bahomakmur, and Labota in Bahodopi District, Morowali Regency, Central Sulawesi. There are industrial zones along the coast of Fatufia and Labota villages. The industrial zone has three clusters arranged according to production type. Cluster 1 produces stainless steel with a capacity of 3 million tons per year; Cluster 2 produces carbon steel with a capacity of 3.5 million tons per year; and Cluster 3 produces nickel-cobalt (NiCo) and nickel sulfide (NiSx) as raw materials. The energy required for these production activities is provided by coal-fired power plants (PLTU), one of which is located just behind the primary and secondary school in Labota village. The coal deposits (stocks) are located in two docks built on undeveloped land on the coast near residential areas.

The expansion of the industrial zone in Labota village may exacerbate the existing situation in the villages of Fatufia and Bahomakmur. This expansion has apparently led to a decrease in the forest area that forms the habitat of the primate *Macaca tonkeana*, which is endemic to Central Sulawesi. Residues from the HPAL (High-Pressure Acid Leaching) smelter may also contaminate the soil, groundwater, and surface water around Labota village, including increasing the concentration of Cr(VI) (hexavalent chromium) in the aquatic environment. PLTU's use of coal will also continue to increase carbon dioxide emissions in the atmosphere, contributing to rising global temperatures and, in the short term, increasing the number of cases of respiratory diseases, especially among school-age children (AEER, 2023).

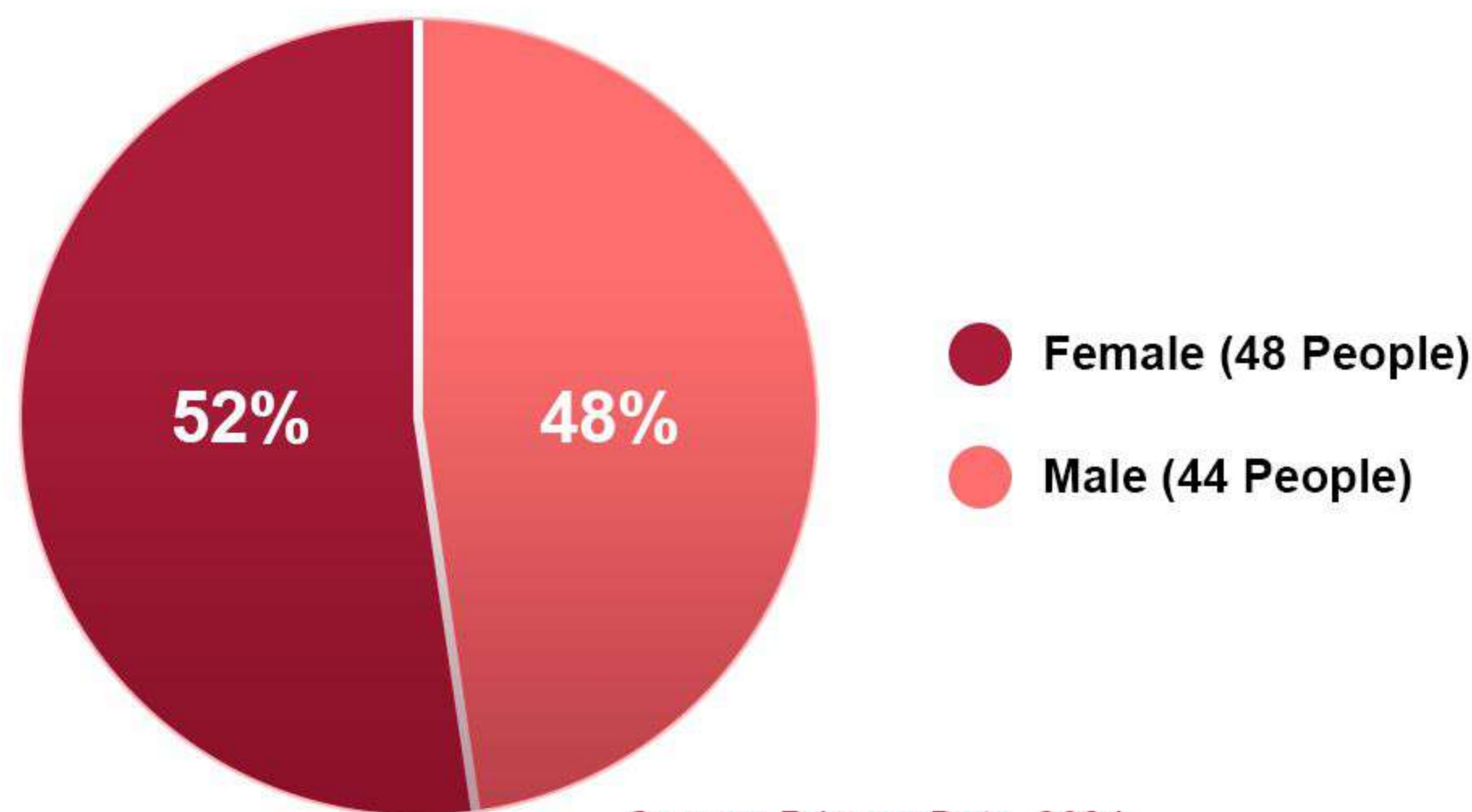
2. Result

The study was conducted on March 27-April 1, 2024. Respondent interviews used the KoboToolbox application, respondents' weight measurements used digital scales and house area and ventilation measurements used a rolling meter.

A. Respondents Characteristics

Respondent characteristics are the criteria established by the researcher and communicated to the study subjects so that the information within the study meets expectations. The characteristics of the respondents in this study were categorized by gender, age, education level, occupation, exercise habits, PPE (mask and/or dust goggles) use habits, type of mask used in the workplace, smoking habits, tobacco exposure, smoking, vitamin C intake habits, and milk intake habits. The distribution of respondents by gender is shown in Figure 2 below.

Figure 2 Distribution of Respondents by Gender in Fatufia, Bahomakmur, and Labota Villages



Source: Primary Data, 2024

Figure 2 shows the gender distribution of the respondents, out of 92 respondents, 48 (52%) were female and 44 (48%) were male. The distribution of the respondents by age, education level, and occupation is shown in Table 2 below.

Table 2 Distribution of Respondents Based on Age, Education, and Occupation in Fatufia, Bahomakmur and Labota Villages

	Respondents' Characteristics	Frequency (n)	Percentage (%)
Age	22 – 29 y.o	21	23
	30 – 37 y.o	36	39
	38 – 45 y.o	17	18
	46 – 53 y.o	5	5
	54 – 61 y.o	7	8
	62 – 69 y.o	3	3
	70 – 77 y.o	1	1
	78 – 85 y.o	2	2
Education	High School graduate/equivalent	43	47
	Primary School graduate	18	20
	Middle School graduate/equivalent	13	14
	Undergraduate (S1/D4)	7	8
	Unschooling	5	5
	Academy (D1/D2/D3)	3	3
	Primary School (not graduate)	3	3
Pekerjaan	Worker/Miner	28	31
	Trading/Self-employed	20	22
	Private Company Employee	1	1
	Farming/Gardening	1	1
	Mason	1	1
	Fisherfolk	1	1
	Stay Home Mother/Housewife	30	33
	Nurse	1	1
	Domestic Assistant	1	1
	Cook	2	2
	Hamlet Chief/Head of neighbourhood/citizen association (RT/RW)	3	3
	Unemployed/Not in labour force	2	2
	Driver	1	1
Total		92	100

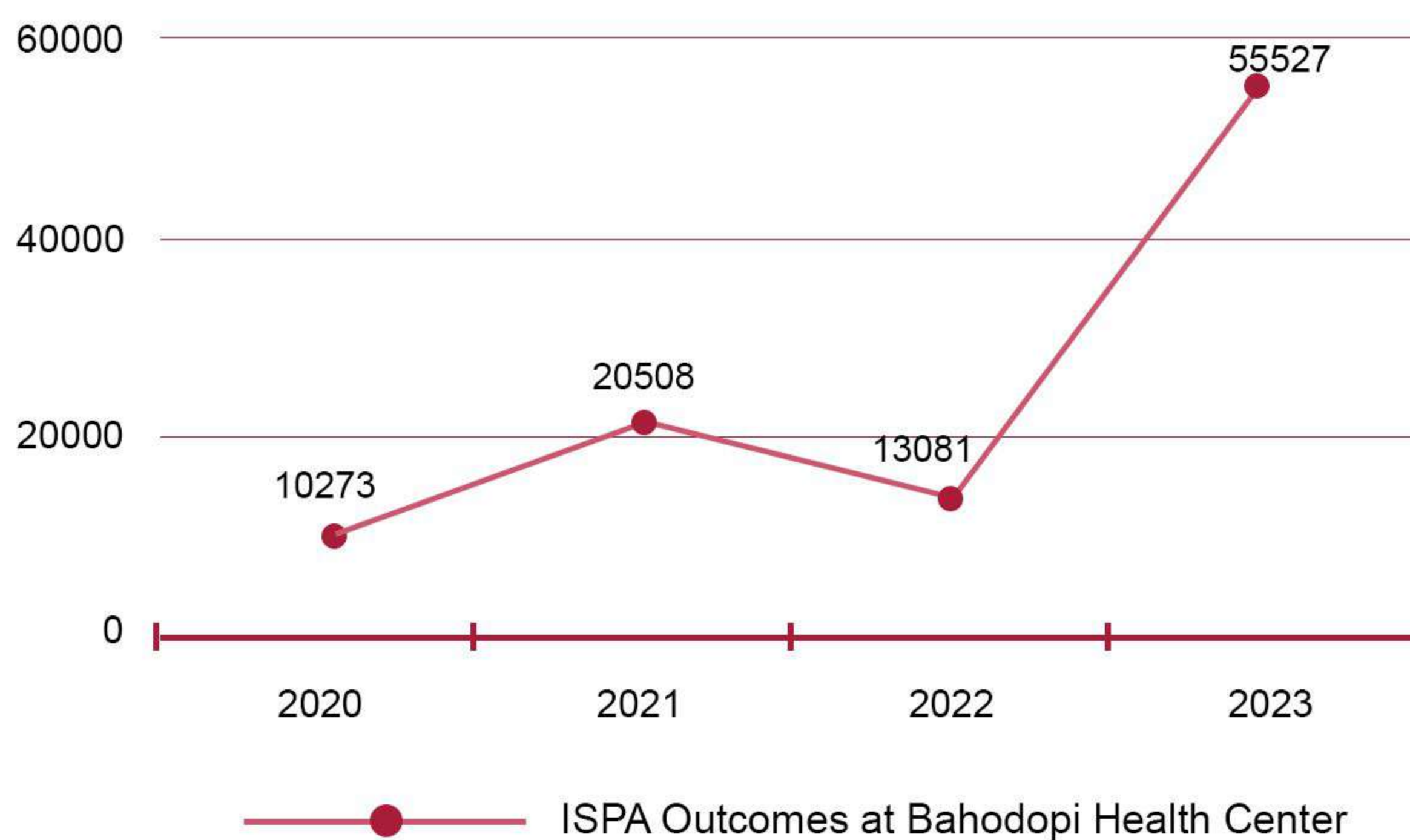
Source: Primary Data, 2024

Table 2 shows the age distribution of the respondents. Among the 92 respondents, the most frequent age group was 30-37 years old with 36 respondents (39%) and the least frequent age group was 70-77 years old with 1 person (1%). Distribution of respondents by education level: Among the 92 respondents, the most frequent education group was High School with 43 respondents (47%) and the least frequent education group was D1/D2/D3 Academy with 0 respondents (3%) and Primary School graduate with 0 respondents (3%). The most frequent occupational distribution of the respondents was housewife with 30 respondents (33%) and the least frequent occupations were private employee, farmer/gardener, mason, fisherfolk, nurse, domestic assistant and driver with 1 person (1%).

B. Number of ISPA Cases

Figure 3 ISPA Cases in Bahodopi Community Health Center Work Area 2020 - 2023

ISPA Outcomes at Bahodopi Health Center



Source: Bahodopi Community Health Center 2020

Figure 3 on the cases of ISPA in the working area of Bahodopi Community Health Center from 2020 to 2023 shows that the number of ISPA cases fluctuated for four years, but in 2023 it jumped to 55,527 cases, with 438 infant cases of pneumonia and 372 adult cases of pneumonia according to pneumonia program indicators; 8,348 cases of non-pneumonia cough in infants and 46,369 cases of non-pneumonia cough in adults.

C. Concentration of PM₁₀, PM_{2.5}, and SO₂

The following are the results of measuring the concentration of PM₁₀, PM_{2.5}, SO₂, in Fatufia, Bahomakmur, and Labota Villages, Bahodopi District, listed in Table 3 below:

Table 3 Concentration of SO₂, PM₁₀, PM_{2.5} in the Villages of Fatufia, Bahomakmur,

Village	PM ₁₀ (µg/m ³)	PM _{2.5} (µg/m ³)	SO ₂ (µg/m ³)
Fatufia	49	46,11	
Bahomakmur	108,75*	23,8	288,497*
Labota	27,2	91,5*	

Source: Tuk INDONESIA (2023) & AEER (2023)

Note:

*Exceeding quality standards

Based on Table 3 on the measurement results of PM₁₀, PM_{2.5} and SO₂ concentrations in Fatufia, Bahomakmur and Labota villages, the highest PM₁₀ concentration was recorded in Bahomakmur village with 108.75 µg/m³, while the highest PM_{2.5} concentration was recorded in Labota village with 91.5 µg/m³.

D. Intake Value of PM₁₀, PM_{2.5}, and SO₂

The intakes of PM₁₀, PM_{2.5}, and SO₂ are the amounts absorbed by the human body per day for a given body weight. The formulas for inhalation (breathing) exposure to non-carcinogenic effects are:

$$I_{nk} = \frac{C \times R \times t_E \times f_e \times D}{W_b \times t_{avg}}$$

Notes:

I : Intake, mg/kg/day

C : Concentration of risk agents

R : Rate of intake or consumption (adult 0,83 m³/day)

t_(E) : Exposure time (hour/day)

f_(E) : Frequency of exposure (day/year)

Dt : Duration of exposure (year)

W_b : Body weight (kg)

t_{avg} : Average duration (30 x 365 days).

Based on the ARKL guidelines established by the Secretary General of P2-PL in 2012, the default value for inhalation dose for adults is 0.83m³/hour, and the average period is 30 x 365 days, which is 10,950 days. Values for exposure time, exposure frequency, exposure duration, and body weight were collected from each respondent in Fatufia, Bahomakmur, and Labota villages.

Table 4 Intake Value of PM₁₀, PM_{2.5}, and SO₂ in the Villages of Fatufia, Bahomakmur, and Labota

Exposure	Village	Mean (mg/kg/hari)	Median (mg/kg/hari)	Minimum (mg/kg/hari)	Maksimum (mg/kg/hari)	SD (mg/kg/hari)
PM ₁₀	Fatufia	0,000984	0,000872	0,000127	0,002868	0,000667
	Bahomakmur	0,005707	0,002965	0,000176	0,023212	0,006719
	Labota	0,000679	0,000526	0,000026	0,004332	0,000785
PM _{2.5}	Fatufia	0,000926	0,000821	0,00012	0,002699	0,000627
	Bahomakmur	0,004801	0,002494	0,000148	0,019530	0,005653
	Labota	0,000594	0,000461	0,000023	0,003790	0,000687
SO ₂	Fatufia	0,005793	0,005135	0,000751	0,016888	0,003928
	Bahomakmur	0,015139	0,007865	0,000468	0,061579	0,017825
	Labota	0,007200	0,005584	0,000277	0,045947	0,008330

Source: Primary Data, 2024

Based on Table 4, we can see that the minimum intake value of PM₁₀ concentration in Labota village is 0.000026 mg/kg/day, and the maximum intake value in Bahomakmur village is 0.023212 mg/kg/day. The maximum intake is proven to exceed the PM₁₀-RfC value of 0.014mg/kg/day. At the same time, the minimum intake value of PM_{2.5} in Labota village is 0.000023 mg/kg/day, and the maximum intake value in Bahomakmur village is 0.023212 mg/kg/day. The maximum intake value of PM_{2.5} also exceeds the RfC of 0.01mg/kg/day. The minimum intake value of SO₂ in Labota village is 0.000277 mg/kg/day, and the maximum intake value in Bahomakmur village is 0.061579 mg/kg/day. The maximum SO₂ intake also exceeded the RfC value of 0.026 mg/kg/day for SO₂.

E. Risk Quotient (RQ)

The risk quotient or risk level (RQ) can be determined by comparing the respondent's intake value with the PM_{2.5} inhalation exposure value (RfC) of 0.01mg/kg/day to obtain the RQ value. If the result is RQ ≤ 1, the risk level is still relatively safe, but if the RQ value > 1, the risk level is unsafe and risk management is required. The calculation formula for risk level for inhalation and non-carcinogenic pathways is as follows:

$$RQ = \frac{I}{RfC}$$

Notes:

I (Intake) : Calculated Rate of Intake

RfC (reference concentration) : Reference Value of Risk

Agent in inhaled exposure (RfC

for PM_{2.5} is 0,01 mg/kg/day).

Based on the data obtained during data collection, intake values and risk characteristics (RQ) of 92 respondents from the villages of Fatufia, Bahomakmur and Labota were calculated and are shown in Table 5 below.

Table 5 Distribution of Risk Quotient (RQ) for SO₂, PM₁₀, and PM_{2.5} Exposure in the Villages of Fatufia, Bahomakmur, and Labota

Exposure	Risk Quotient	Frequency (n)	Percentage (%)
SO ₂	RQ ≤ 1	86	93,48
	RQ > 1	6*	6,52
PM ₁₀	RQ ≤ 1	87	94,57
	RQ > 1	5*	5,43
PM _{2.5}	RQ ≤ 1	87	94,57
	RQ > 1	5*	5,43

Source: Primary Data, 2024

Note:

*At Risk

Based on Table 5 on the distribution of Risk Level (RQ), out of 92 respondents, the risk level of SO₂ exposure of respondents who have an RQ value > 1 is 6 respondents with a percentage of 6.52%. The risk level of PM₁₀ and PM_{2.5} exposure of respondents who have an RQ value > 1 is 5 respondents with a percentage of 5.43%.

F. Risk Management

The following is the determination of safe limits for respondents at risk based on the following parameters:

a. SO₂

Table 6 Safe Limit of Concentration (C), Exposure Time (tE), Exposure Frequency (fE), and Exposure Duration (Dt) of SO₂

Responden No.	Value RQ	C safe (mg/m ³)	t _E safe (hour/day)	f _E safe (day/year)	Dt safe (year)
34	1,831	0,157605	13,11	199,40	6,56
52	1,767	0,163251	13,58	206,54	6,79
68	1,609	0,179277	14,91	226,82	8,08
69	1,432	0,201526	16,77	254,97	10,48
82	2,368	0,12181	10,13	154,11	5,07
85	1,883	0,1532	12,75	193,83	6,37

Source: Primary Data, 2024

Based on Table 6 on the safe limit of SO₂ exposure, respondent number 34 may only be exposed to SO₂ concentration of 0.157605 mg/m³ for 13.11 hours/day, 199.40 days/year and 6.56 years. Respondent number 52 may only be exposed to SO₂ concentration of 0.163251 mg/m³ for 13.58 hours/day, 206.54 days/year and 6.79 years. Respondent number 68 may only be exposed to SO₂ concentration of 0.179277 mg/m³ for 14.91 hours/day, 226.82 days/year and 8.08 years. Respondent number 69 may only be exposed to SO₂ concentration of 0.201526 mg/m³ for 16.77 hours/day, 254.97 days/year and 10.48 years. Respondent number 82 may only be exposed to SO₂ concentration of 0.12181 mg/m³ for 10.13 hours/day, 154.11 days/year and 5.07 years. Respondent number 85 may only be exposed to SO₂ concentration of 0.1532 mg/m³ for 12.75 hours/day, 193.83 days/year and 6.37 years.

b. PM₁₀

Table 7 Safe Limit for Concentration (C), Exposure Time (tE), Exposure Frequency (fE), and Exposure Duration (Dt) PM₁₀

Responden No.	Value RQ	C safe (mg/m ³)	t _E safe (hour/day)	f _E safe (day/year)	Dt safe (year)
71	1,281	0,084864	18,73	284,83	9,36
72	1,127	0,096534	21,30	324	11,54
79	1,318	0,082492	18,21	276,87	9,10
80	1,658	0,06559	14,48	220,14	7,24
92	1,002	0,108514	23,95	364,21	14,97

Source: Primary Data, 2024

Based on Table 7 on safe limits of PM₁₀ exposure, respondent #71 only experienced PM₁₀ concentration of 0.084864 for 18.73 hours per day, 284.83 days per year, with a potential exposure of 9.36 mg/m³. Respondent No. 72 could only be exposed to PM₁₀ concentration of 0.096534 mg/m³ for 21.30 hours per day, 324 days per year, and 11.54 years. Respondent No. 79 could only be exposed to PM₁₀ concentration of 0.082492 mg/m³ for 18.21 hours per day, 276.87 days per year, and 9.10 years. Respondent No. 80 is likely to be exposed to a PM₁₀ concentration of 0.06559 mg/m³ for 14.48 hours per day, 220.14 days per year, and 7.24 years. Respondent No. 92 is likely to be exposed to a PM₁₀ concentration of 0.108514 mg/m³ for 23.95 hours per day, 364.21 days per year, and 14.97 years.

c. PM_{2.5}**Table 8 Safe Limit for Concentration (C), Exposure Time (t_E), Exposure Frequency (f_E), and Exposure Duration (Dt) PM_{2.5}**

Responden No.	Value RQ	C safe (mg/m ³)	t _E safe (hour/day)	f _E safe (day/year)	Dt safe (year)
71	1,509	0,060617	15,90	241,81	7,95
72	1,327	0,068953	18,19	275,06	9,80
79	1,553	0,058923	15,56	235,05	7,73
80	1,953	0,04685	12,29	186,89	6,14
92	1,180	0,07751	20,33	309,19	12,71

Source: Primary Data, 2024

Based on Table 8 related to the safe limit of PM_{2.5} exposure, respondent number 71 may only be exposed to a PM_{2.5} concentration of 0.060617 mg/m³ for 15.90 hours/day, 241.81 days/year, and 7.95 years. Respondent number 72 may only be exposed to a PM_{2.5} concentration of 0.068953 mg/m³ for 18.19 hours/day, 275.06 days/year, and 9.80 years. Respondent number 79 may only be exposed to a PM_{2.5} concentration of 0.058923 mg/m³ for 15.56 hours/day, 235.05 days/year, and 7.73 years. Respondent number 80 may only be exposed to a PM_{2.5} concentration of 0.04685 mg/m³ for 12.29 hours/day, 186.89 days/year, and 6.14 years. Respondent number 92 may only be exposed to PM_{2.5} concentrations of 0.07751 mg/m³ for 20.33 hours/day, 309.19 days/year, and 12.71 years.

G. Intake and RQ Projection

In this study, the calculation of intake values and non-carcinogenic RQ is projected for up to 30 years. The 30-year projection is the average period for the non-carcinogenic effects of a pollutant in the ARKL method.

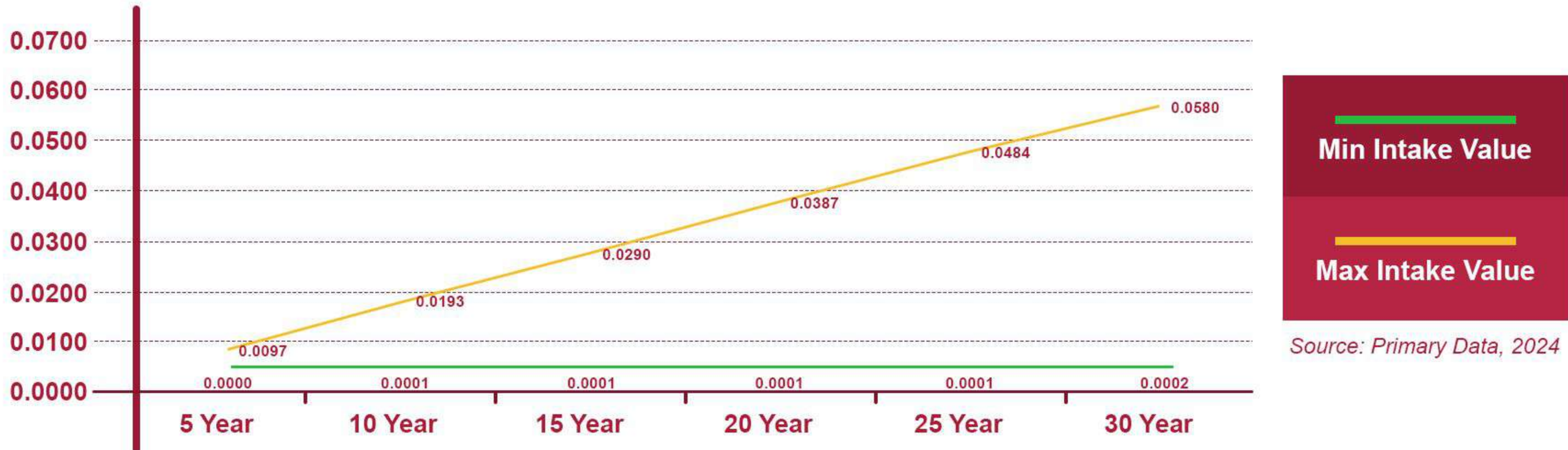
a. Intake Projection

Environmental health risk analysis methods use Reference Concentrations (RfC) to measure the toxicity of risk substances through inhalation. The RfC value for PM₁₀ is 0.014 mg/kg/day (WHO), for PM_{2.5} 0.01 mg/kg/day (IRIS), and for SO₂ 0.026 mg/kg/day (IRIS). Intakes above the RfC value may cause reactions in the form of respiratory diseases.

1) *Particulate Matter*

a) *PM₁₀*

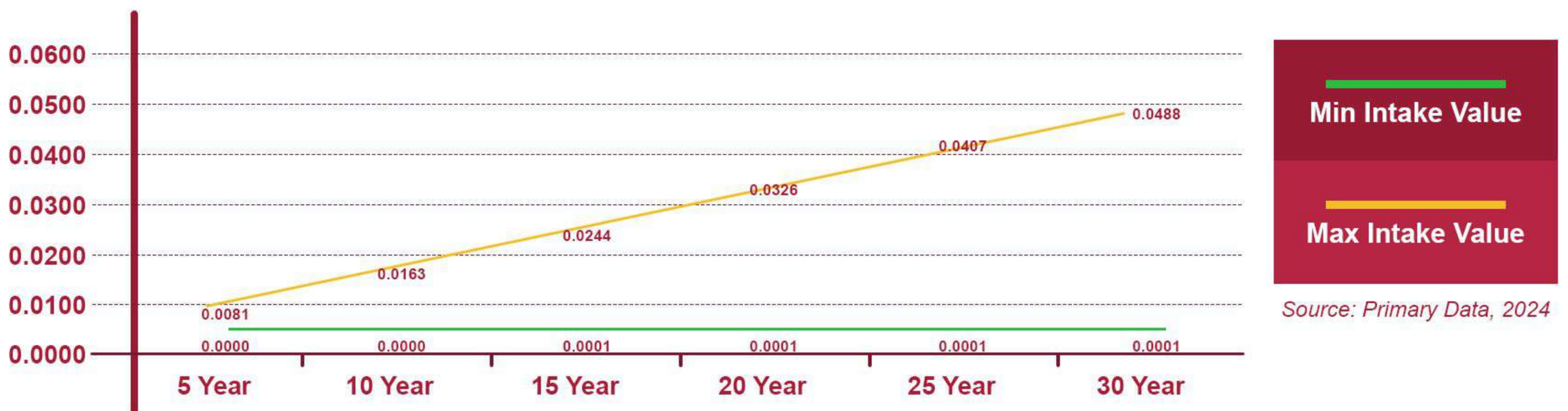
Figure 4 Intake Projection *PM₁₀* for 30 Years in the Villages of Fatufia, Bahomakmur, and Labota



The minimum intake of non-carcinogenic *PM₁₀* did not exceed the dose-response limit of 0.014 mg/kg/day for the next 30 years, but the maximum absorption exceeded the dose-response limit only after the 10-year exposure period.

b) *PM_{2.5}*

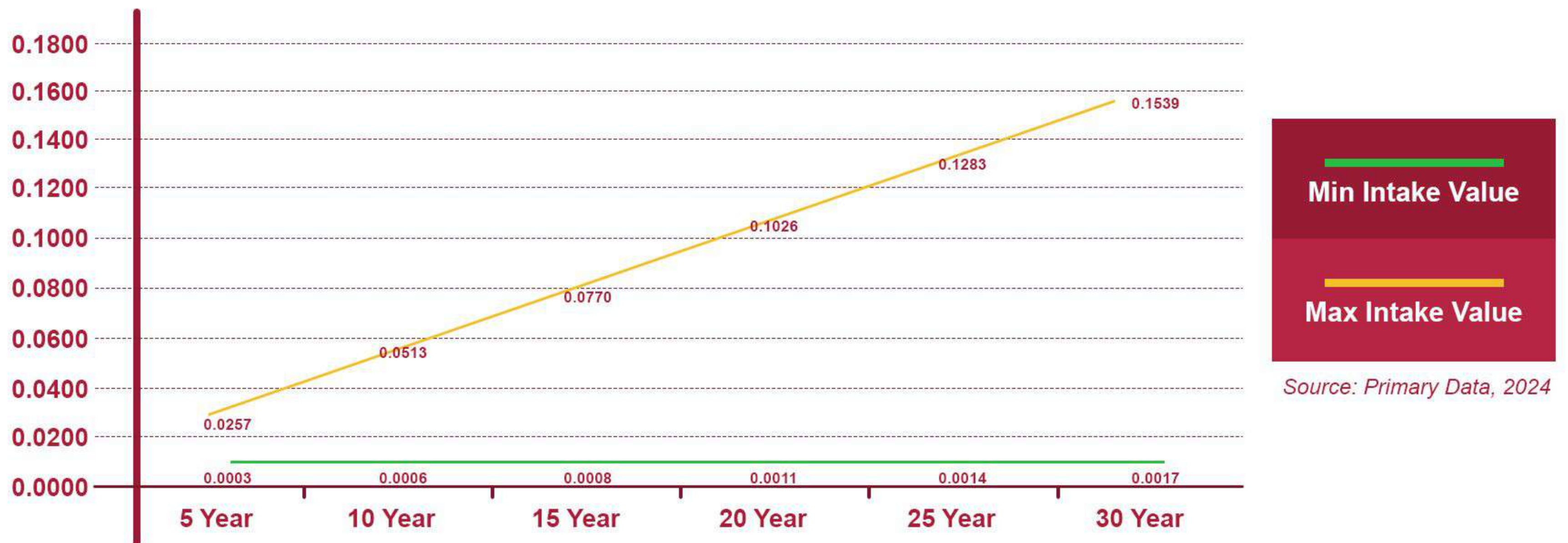
Figure 5 Intake Projection *PM_{2.5}* for 30 Years in the Villages of Fatufia, Bahomakmur, and Labota



It is known that the minimum non-carcinogenic intake of *PM_{2.5}* did not exceed the dose-response limit of 0.01 mg/kg/day over the next 30 years, but the maximum intake exceeded the dose-response value after 10 years of exposure.

2) Sulfur Dioksida (SO₂)

Figure 6 Intake Projection SO₂ for 30 Years in the Villages of Fatufia, Bahomakmur, and Labota



The minimum intake without carcinogenicity over the next 30 years is 0.0017, which is still below the SO₂ dose-response value of 0.026 mg/kg/day. The maximum predicted intake of carcinogens exceeds the dose-response limit at an intake of 0.0513 mg/kg/day over a 10-year exposure period.

b. Proyeksi RQ

1) Particulate Matter

a) PM₁₀

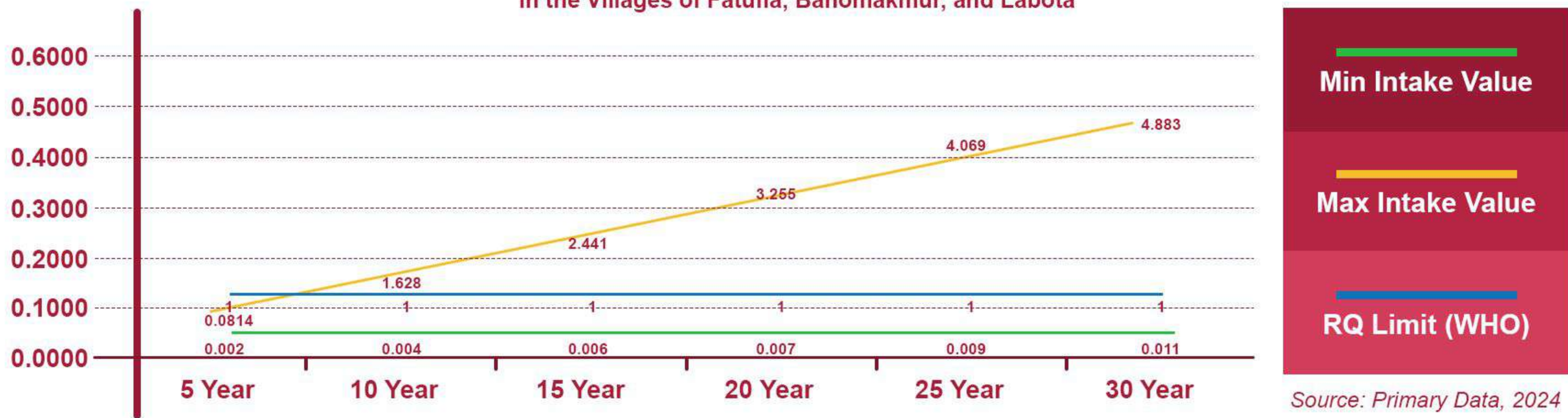
Figure 7 PM₁₀ RQ Projection for 30 Years in the Villages of Fatufia, Bahomakmur, and Labota



The prediction for the minimum RQ value indicates that there is no risk for the next 30 years. However, for the maximum RQ, there is a risk with an exposure period of 10 years and an RQ value of 1.382.

b) PM_{2.5}

Figure 8 PM_{2.5} RQ Projection for 30 Years in the Villages of Fatufia, Bahomakmur, and Labota



The prediction for the minimum RQ value indicates that there is no risk for the next 30 years. However, for the maximum RQ, there is a risk with an exposure period of 10 years and an RQ value of 1.628.

2) Sulfur Dioksida (SO₂)

Figure 9 SO₂ RQ Projection for 30 Years in the Villages of Fatufia, Bahomakmur, and Labota



The predicted RQ values (minimum) for SO₂ over the next 30 years show that the RQ is between 0.011 and 0.064, which is under the at-risk value (<1). Meanwhile, we know that the respondent with the highest RQ value is at risk for a 10-year exposure period of 1.974.

H. Respiratory Disorders

The distribution of respondents from Fatufia, Bahoumakmur, and Rabota villages based on respiratory disease diagnosis is shown in Table 9 below.

Table 9 Distribution of Respondents based on Respiratory Disorders in the Villages of Fatufia, Bahomakmur, and Labota

Respiratory Disorder Diagnose	Frequency (n)	Percentage (%)
Yes (Asthma)	1	1,1
No	91	98,9
Total	92	100

Source: Primary Data, 2023

Table 9 on the distribution of respiratory disease diagnoses reveals that 1 person was diagnosed with a respiratory disease, namely, asthma. The distribution of the respondents in this study based on disease symptoms can be seen in Table 10 below.

Table 10 Distribution of Respondents based on Disease Symptoms in the Villages of Fatufia, Bahomakmur, and Labota

Symptom	Yes	%	No	%	Total	
					Amount (N)	Percentage (%)
Cough	70	76,9	21	23,1	91	100
Sneeze	65	71,4	26	28,6	91	100
Cold	53	58,2	38	41,8	91	100
Headache	50	54,9	41	45,1	91	100
Sore throat	37	40,7	54	59,3	91	100
Eye irritation	34	37,4	57	62,6	91	100
Congested breathing	17	18,7	74	81,3	91	100
Skin Irritation	12	13,2	79	86,8	91	100

Source: Primary Data, 2024

Symptoms of respiratory disorders listed in Table 10 were collected from 91 respondents who did not suffer from respiratory diseases. Most respondents (70) had a cough (76.9%), while the least number of respondents (12) had symptoms of skin irritation (13.2%).

I. Qualitative Data

Based on the collection of qualitative data from various informants (stakeholders and community), the following information was obtained:

1. Mining Area

From the interviews, it became clear that mining activities require a fairly large area, which has an impact on the environment, including settlements. Below are excerpts from the interviews with the informants:

“... yes, previously the initial step was 3000 hectares for the mining area... then in 2022 there was also development and the results of our meeting yesterday also in 2024 there will be an additional area for the development of this industry...”

“...the mining is indeed far away. The area of the mining area is large. As for the office, the place used to be small, there were no large buildings like now, everything is now wow... if you look at the current situation, there are still many land acquisitions... yes, that means indirectly it will increase the area it has...”

2. Disposal of Mining Waste

The results of the interviews on the disposal and treatment process of mining waste revealed that some of the mining wastes were processed and used as raw materials for roads and brick mixes, others were used to fill excavated mountains, and others were disposed of randomly. The following are quotes from the informant interviews:

“...so, after the mining process, transportation, burning, then separation, there is a waste called slenk [sic] which now the company just dumps carelessly there, between the mountains, which the cliffs there, usually piled up, dumped there, then after being dumped, sometimes a factory is built on top of it... and according to information from the factory that is already operating here, the slenk [sic] no longer contains what is the content anymore...”

“...mmm, maybe some of it is processed, some of it, if I'm not mistaken, I don't know for sure, but from what I heard, some of it is mixed with concrete and then made into a road, and then some of it is for that, only a small part. Most of it is dumped...”

“...what I know is that there is a separate allocation, but (clears throat) ...there are indeed some naughty smelters like the one in Kindru, I can be frank...they are Kindru and Rissing. The allocation of waste disposal is still careless to the point that the impact on the river right there, behind my house, is polluted with coal waste... there are indeed processing efforts, there is a processor and I emphasize, it in the smelter and, what is it called ... a stimpul [sic], the stimpul [sic] functions to filter water before it enters the community's part of the river, like that. But those efforts are not really felt by the community and there are still much waste that come out of the company...”

“...the waste is like I said before, processed, the factory and processing are inside, um...”

“... if we talk about disposal, about the factory waste, the point is because we are outside, automatically, the information is lacking, yes, there are those things that are discussed, they make it into roads, landfills, what is the name of the factory waste again ... this can be used as a road, to make bricks, pressed bricks because it contains iron, there is sand and iron content... yes, if the scrap metal is recycled, anything that can be processed again, reprocessed. For the remaining factory waste, there is copper and iron content, it is usually used as a landfill, for example, to make roads across swamps, it is used as a landfill...”

“...it is not disposed of, the waste from mining excavation. I also worked in a mine, I used to work at BDM. The mining excavation waste is not disposed of anywhere, it is just dumped right there...”

3. Negative Impact of Mining Activities

The interviews regarding the impact of mining activities on local communities revealed that several informants felt uneasy about the mining activities because they caused air pollution, noise, and even various health problems. The following are quotes from the interviews with the informants:

“...one of the impacts, yes, it is naturally on the climate and weather pollution, right? It has an impact, it has a big impact, first of all, the problem is the pollution from the factory, right? The news was like at first, just because it's cloudy, because the weather is one of the triggers for air pollution, right? So, what else... Previously, if we said that in the second month it would start to rain, it would definitely rain in the sixth month, but with the presence of this factory, it has changed significantly, usually when it rains here, it doesn't rain on the lowlands. So now here it's the dry season, the rainy season is unpredictable, sometimes it only rains by grids (regions), In the past when it rained in Bahodopi, it rained all over. Now the rain ends there and it doesn't rain here. Near the mosque, it usually rains, that's the target, that was the impact of the factory...”

“...the negative impact of today, I see the one that is very prominent is the problem of... air pollution... Yes, that's for sure, that's for sure... then with the factory activities above is definitely the problem of the air; then of course of water, concerning environmental problems, of course... water, air... they are very prominent, because there have been many complaints from residents... related to the problem of clean water... so thank God, just a week ago (cough) we just finished handing over the assistance for the problem of clean water, natural water that can then be consumed by the community. So, thank God, to the management or from the company... Then the noise... there, when they are really ramping up, it's a production problem, like the noise, of course there's also an impact on the community...”

“...the smell there, like the smell of sulfur, sometimes it smells of sulfur, if the wind blows from there, sometimes it's like the smell of a cow dung shed, that smell, that's from the one that's far away and still not active, we don't know what will happen next... he eh, because we are on the periphery. It's still temporary work, but in terms of noise, maybe it's not like it was when we first heard it because maybe our ears are too used to hearing it anyway, so it's noise like we're used to every day (laughs), but we don't know what's going to happen in the future because what will it be like, what kind of factory, we don't

know, it's just that in my area, there was a flood there without rain... right, they made embankments, broke the embankments... Yes, on June 27, 2022, the incident was 930 families were affected, yes ma'am yes...”

“... actually, in this environment, there are many more negative things, some of which I think are air pollution... that... we also don't know where to run to, coughing and whatever... cause by the air like that...”

“...as for the economic impact it is big, yes, especially ... in terms of income, the community is big, the purchasing power of the community has increased, but (clears throat)..in activities in the periphery ... the surrounding areas especially the community is affected by air pollution (motorcycle horns) ... air pollution and environmental pollution, such as in rivers are leading to... the disasters of floods and so on...that has happened often, these floods... usually at the worst it was 2 times per year... yes a big flood, houses were even submerged, then we evacuated...”

“...Dust, ma'am, especially now, this area is a mining area so the environment is dusty, recently there are more and more mines beyond Bahomakmur, factories are starting, more and more factories or something ... the dust and air pollution, furthermore the majority of the community here is male, right ma'am, usually these adult males smoke, then it is also common to see them on the street going out here and there riding motorbikes. Some children wear masks, some do not. Especially, this is a mining area that is close to living quarters. here it is common for houses to have a lot of dust, ma'am, especially if it is rarely cleaned it is very dusty, if it is rarely cleaned it is dusty. My house in Bahomakmur is very dusty there is pollution here. Just the population here is very large, tens of thousands of employees here, so automatically the people who visit they have ARI symptoms such as coughs and flu, are so frequent...”

“... of course, being in contact with the environment in the processing of mining products must have an impact, especially that the distance between the factory and the residents' houses, there is no longer any between them, right, I mean, according to the rules there must be a distance, it is very wrong, it is a mistake, right. So, in terms of environmental management, of course where the environment is clean, there we live healthily, right, right, so we continue to try, for example in Fatufia Village, we only need to take steps to anticipate environmental pollution. However, no matter what the government's efforts are, if they are not supported by the awareness of our community, we may not be able to complete them, right...”

4. Positive Impacts of Mining Activities

The results of the informant interviews showed that there are positive impacts of mining activities, namely economic improvements felt by the local community and huge employment opportunities. The following are quotes from the informant interviews:

“...yes, it certainly increases because when there is an investment, our society will carry out its activities or make efforts that can get results. Then due to the presence of this institution, it will definitely bring people around, and everyone has needs, so the community will automatically try hard, with the presence of many people, they will buy a lot of products from the community here...”

“...the positive impact is to increase the community's economy and reduce unemployment...”

“...about the positive impact, perhaps, to the economy, the economy of the surrounding community, it seems that with this mine the community has additional income. There are boarding houses built (motorcycle sound) many employees live in their boarding houses (motorcycle sound), the boarding houses are fully occupied by employees (motorcycle sound). That becomes additional income for the community (motorcycle sound) and then, what? The economy increases (motorcycle sound) and so does the community's purchasing power (motorcycle sound).”

“...the positive impact is that, my dear. purchasing power is very high and that is a high income in terms of the economy, that is the impact...”

“... yes, to be honest there are positive and negative impacts, the positive one is that the population is growing here, it is dense, then we can see daily activities around here, the traffic is like that, it is dense...”

“... yes, that means the wheels of the economy turn, it has changed, there is a change, meaning, about the wheel, yes, the value of the community's buying and selling, yes... that's why I said in the past we couldn't buy cars, buy motorbikes, buy bicycles. Now with the presence of extraordinary companies in Bahodopi village, and around Bahodopi District mining area, yes, there are significant changes...”

“...about the economy, yes, about the positive impact, what was it, what is very significant was the economy, it's about infrastructure, the changes were severe, what used to be a smooth traffic now is totally congested ... so, the economic wheel turn was significant and there was a change ... for example the change in traffic infrastructure, it changed into and caused a problem of congestion. Maybe we have been here for 10 days, yes, more or less 10 days, we can see in the afternoon and dawn at 4 o'clock roads are already full with motorbikes ...”

5. Crime Rate

Interviews with informants revealed that crime rates in mining areas included theft, brawling, murder, adultery, and drug use. The following are quotes from the informants' interviews:

"...Yes, sometimes it's like this, right? Some friends, for example, from out of town, for example, the Toraja tribe sometimes speaks, maybe the way they speak is a bit loud, then they come here ... here in Bungku,, we are friendly or whatever, it's good, not loud, sometimes the way we talk. This disturbs the balance, how we have our usual way or habit, maybe we, how the Bungku people, usually greet by 'ba tabe", before we pass by someone. I see our Toraja friends usually don't use that, right? Sometimes if we don't understand each other, that's where misunderstandings arise, right..."

"...during the time I am here, yes, there were many criminal cases... such as theft, many motorbikes got stolen, theft, infidelity (laughs), it's like that, ma'am ..."

"...which may be because of the need to live, the person hasn't got a job, that's why (motorcycle sound) they do things like (motorcycle sound) like stealing whatever (motorcycle sound) (sound of other people talking) ... murder yeah, it happens very often here..."

"...yeah.... yeah, that's no longer a public secret, yeah it's not a secret anymore, but if there is a high economic turnover in a region we will get a higher level of ... social deviation, like theft, yeah, what's it called again ... sexual harassment against women, rape and theft even crystal meth and drugs...alcohol and other crimes like murder, there are also suicides (sound of children's toys)"

"... the only thing that really worries the public is motorcycle theft, what is it again, theft of cellphones in boarding houses, their targets are electronic devices. So, theft of motorcycles and electronic communication devices, their targets are boarding houses and houses of residents that are empty..."

6. Government/ Mining Company Policies

Results of the interviews with informants on government/company policies regarding mining activities: on the empowerment of local communities, prevention of environmental pollution through dust control devices, AMDAL documents, Corporate Social Responsibility (CSR), and replacement materials for roofs of houses corroded by carbon. At the same time, some believe that there are no policies that fully benefit local communities; some policies even harm them, such as the construction of conveyor belts on highways that cause traffic congestion. The following are quotes from the interviews with informants:

"... if we talk about policies, what does that mean, because all the rules have been designed by the PSDM industrial office, so the village is only limited to what ... talking with the community, there are documents needed from the village that companies can apply for, and companies also need village documents, good cooperation. Only if we talk about the policy, yes, the policy just mentioned ... suggests that the company must empower the community, both local workers and operators..."

“...Yes, although one example is air pollution, there are complaints from the community, after we checked, right, even though they have done dust control or whatever, we ensure they fix it again, that they have done it according to the commitments in the AMDAL before they operate the construction, then it must be repaired ... because it is usually like that sometimes... whenever there are problems like dust or whatever, it is usually like that, sometimes the community directly.. handles the problem ... And it is not wrong if the community acts like that, because it is also a commitment that the investors are ready if there are complaints from the community regarding the impact problem. And then they are the source of the problem, so automatically they have to be responsible...”

“... it's like this... we actually have three things, namely the company, the people and the government, if these three are not united, this cannot be done. Then for example the company cannot be established without a village government, it cannot be done. Then between the village head and the company, when the people are not being listened to, then there will be a demonstration. Yes, this is a thing, there are many such problems that we have dealt with, in other words, whatever the shortcomings of the village so far, activities, especially those that we have carried out for the village of Bahomakmur, the CSR funds that I use, the CSR funds with the provisions, we go along the steps, there are also impacts to the company, the steps such as that Bahomakmur village needs a fleet, a fleet to transport garbage, well, the Situmi funds that I use, even in 2023 I had to procure a debt because the CSR funds in the company was not enough for the price of the dam truck. It means we were also told to find a foster father, while to gain a foster father, if the presentation is not good enough, then they wouldn't want it. Finally, we were given the opportunity, saying that 'Village Head, the important thing is just to sign the provisions. We are giving another opportunity for CSR funds in 2024 to buy a fleet of garbage trucks here.' Well, that's the activities we are carrying out....”

“...as for the regulation itself, I have not really studied any policies issued directly by the district government or village government, but what I see and what we review directly is

that... the district government does not really care about the safety and health of the people in Labota. Why, we can see the canal (children's playing sounds) ... we have seen the canal (interviewer nods) ... then there are conveyor points that cross ... the provincial roads, that is permitted by the central government, to enter the district and village. And the permit cannot be obtained or cannot be made without permission from the government (car horn sound) ... and that reflects that the government is not pro-community, if it were pro-community, it would be easy to just regulate it with a certain mechanism, there is an environmental impact analysis and so on, it can be regulated. But that's not true...”

“...if it is on paper, we have yet to have a written rule, but this ... is not written, for example ... with the company's activities ... that caused not only flash floods, we have discussed that, what is called again (motorcycle sound) ... compensation ... still, those policies we make for example when ... the dry season comes, with strong winds, like earlier. There are also policies implemented by the company such as replacing roofs for residents...”

“...yes, even now we are in the process of ... building communication in terms of developing CSR funds. Now we are focusing on this ... because we have a plan to develop a tourist spot as per Company policy... CSR ... sometimes also if it takes a physical form, I ... don't know for sure because the [unclear voice] is handled directly by the company except for things like profit sharing funds...”

“...the development of ... the coal power plant that is so close to the construction of the conveyor crossing ... over the provincial road. This is a provincial road, you know... but as I said earlier, the provincial road should not be disturbed, that is one of the policies that indeed ignore the community. The community sure hope that it doesn't come to this, if the government really has the power, has the quality, has ... the tenacity to work, they have the capacity, they will be able to make Morowali a super power (children's toy sound) ... if there is a development policy that gives the extraordinary welfare to the people of Morowali, what I said can come true. And, it can be regulated by the rules they make, village rules or district

rules, but that it is not come to pass, not at all, there is neglect there ... not negligence but neglect. Yes, they just don't care, right..."

7. Government/Company Policies against Environmental Pollution

The results of the interviews with informants related to government/company policies on pollution in industrial areas, reporting mechanisms to the Environmental Office, waste management policies through CSR, and government policies involving AMDAL. However, some argue that AMDAL documents are contradictory to health and safety regulations. Below are quotes from the informants' interviews.

"...as for the provincial government, we are still waiting for information, right? Alhamdulillah, we have submitted reports to the Environmental Office from the beginning. The local government, they're like that, right? Since then, we have been waiting for the decision..."

"...oh yeah, about the waste, the government often hold, say, social service activities by the district government, usually led by the Forko Pincam [District Officials' Forum], right? Maybe it's the TNI [Indonesian Armed Forces]? The DANRAMIL [local military commander], the POLICE CHIEF and the CAMAT [District Head] often collaborate to create activities and also cooperate with organizers to clean up wastes. Sometimes what do they do? There are days, sir, days related to environmental problems, or every Friday, sometimes there are social service activities on days like that..."

"...yes, it does not comply with health and safety standards...we should...we should be pro-community in this case, yes ... (clears throat) ... yes, his position should be right, not for mediation, he should be pro-community and when a company asks for a permit like this, he should ask what is the company's contribution to the community and what is its impact, on the environment, their place of residence, on their health, are there any facilities provided. The local government, especially in Labota or in Morowali Regency, should be stronger to defend against ... company requests. So, why do they say ... 'We are in line. It's good for the government, it's also good for the company, because the requests cannot be denied.' Yes, I repeat that the impact on the economy, especially after the establishment of this company, is extraordinary for the community, who were just farmers or

fishermen before, now they own Pajero cars, have big houses, have boarding houses and so on..."

"...we from the village and the company PT IMIP, what the community conveyed to the village government is that we are proposing for mitigation by improving the channels, especially we do not want the water to spill over to Bahomakmur village area, because it's like this, the company has buildings up there and Bahomakmur is down here. No matter what, the water will still run downward. that's what we asked for earlier so that the water does not spill into Bahomakmur. It has indeed been implemented, many of the large pipes have been installed there for the company's area, but for the Bahomakmur area, such as the channels, so far, they have not been installed. Though for cleaning the ditches, it has been implemented..."

"...Yes. Sometimes the village head tells the company this and that ... that the water here is not suitable because there it's been contaminated..."

"...Usually, we write to the public relations team as the company's facilitator, to then connect ... connect between the community, the government and the company, regarding what the community's complaints, what that they feel down there. Then we follow up on that, but sometimes if it is urgent, without going through a proper written complaint, we directly meet the management at their office. We from the government meet the company face-to-face to then follow up on complaints or impacts (breathing) felt by the community, like that..."

"...naturally, pollution gives a negative impact, the village must act quickly, whether by reporting it to the company office, to

push for actions to overcome things with a potentially negative impact on the community, like that... what else? Yes, earlier in 2007 the company's IMIP mining permit was published, there was naturally what is called an AMDAL Environmental Impact Analysis involving villagers, both the government and the community. So, whenever there is a mine in one of the villages or one of the areas, naturally as I have mentioned earlier the impact on, what, traffic jams, and then there is the economic impact, well. Naturally when one talks about the AMDAL analysis, the village is automatically get involved..."

"...there is a cooperation with the company... for example, like on the waste disposal, right... wastes. That garbage truck is a CSR from the company, right? That is from the company, those garbage trucks. Six-wheelers..."

8. Community Involvement in Mining Activities

The results of the interviews conducted with informants regarding community consent and participation in the establishment of mines indicate that there are groups of supporters and opponents related to the establishment of mines, especially those communities whose settlements are located near industrial chimneys. Communities disturbed by mining activities demonstrated and complained about the intrusion of dust into their settlements. In addition, demonstrations were also held against the issuance of permits for the establishment of industrial companies, but there was no response from the government or the companies. Several communities were involved in the establishment of the industry through procedures carried out in accordance with the AMDAL document. The following are excerpts from the interviews with informants:

"...Yes... about the initial agreement ... the labor problem that local workers must be prioritized ..."

"...so, it's like this ... there must be pros and cons ... the cons are when the houses are too close to the factory area ... there would be no problem if the houses are far away. But the bigger pro is when it comes to opening up job opportunities..."

"... it does exist ... umm ... the procedure requires AMDAL, so before they actually build the factories, all of that ... goes through after AMDAL. Actually, the AMDAL office is in ... the province, in Palu ... Of course, there are pros and cons, but Alhamdulillah, if ... they are involved in the AMDAL process ... they would agree..."

"...Yes, no challenge was that hard, it's just that maybe they need a more detailed explanation of the purpose of this factory, that's the kind of question people usually ask. We, umm, accept it as normal, umm, most people don't understand, the fear this and that, right, fear the unknown"

"...Yes... If it's right to build here, building this or that."

It depends on the community, if the community says yes ... people can start building, like that... If it's from the village's point of view ...from this village here and the other 12 villages ... they must have ... in some form, in written, like that ... Yes, that was the intention of our elders ... In the form of a demonstration..."

"... the development goes on, it continues, like employee recruitment. We always set the rule, for example, okay, we register the domicile but prioritize local residents. Sometimes there would be a notification, we are given a privilege, residents of Bahomakmur can register based on this recommendation for this section, usually like that..."

"... we once had a conflict with a company that built in the village, because we were not the village head back then, there was this village head, well maybe as the village head, he was negligent... there was no permit but they were already building. After the construction was finished the community where we currently reside has been in legal trouble several times, but the verdict has not been issued. There is also such a case in Bahomakmur, PT. SA, it is called, Sentosa Abadi..."

“...oh, as I said before, there were indeed demonstration against companies and the government that grant permits, but we gained zero response, because all the hitherto movements are always...what is it called ... pushed out and buttoned up, until they are silent, until the voices are no more... (laughs)....”

“...still, because there are still frequent demonstrations, occasionally, (motorcycle noise) depending on whether (motorcycle noise), maybe there is another case (motorcycle noise), maybe the community gets disturbed by the dust or whatever, yeah they will march again...”

9. Monitoring and Evaluation Activities

Interviews with informants related to the monitoring and evaluation activities of relevant authorities revealed that both monitoring and evaluation are not carried out on a daily basis; but some authorities, such as the Mining Bureau, the Environment Bureau, and the Ministry, conduct in-situ visits on several occasions. The following are quotes from the interviews with informants:

“...about routinary, it's impossible, it's just that there would be a review every now and then... hmm, for example there's a complaint to us or from the residents, mining companies do this, whatever it is that they do ... that's actually our weakness, our government is passively waiting for replies from the province, right? Especially regarding work safety (horn sound) of course, certain agencies have the authority there, they have the obligation to monitor and supervise it. In the reality, it's not as we expected, but we still hope that our competent friends can do their jobs optimally (car sound) yes, especially regarding foreign workers...”

“...for instance, what hmmm from the relevant agencies, eh, the Mining Office, or whatever, often with, eh the Environmental Agency ... check out the impact, eh, of this mining on the community ... yeah, maybe go on location to check how it is, eh, what the impact is really like....”

“...As far as I know, there have been several visits by a Minister for the purpose of Anev, that is analysis and evaluation ... I forgot which ministry it was and they came to perform ... analysis and evaluation related to (sound of children buying snacks) ... the development in the area ... oh, it's quite often ... especially I once got an air pollution measurement of air quality standard, and it got a red zone rating (laughs)...at that time with ... the evaluation results, it was emphasized to minimize the impact of vehicle pollution especially from those bringing materials or ores...”

“...We did that but ... in my point of view, if you want it to be more effective, if you want it to be done more effectively, actually, try involving OPD [Regional Apparatus Body]. OPD is the technical regional apparatus regarding this matter. Actually, because, umm, we are a village government, there must be ... many limitations, only relying on analysis and visuals, right. Umm, that if we are talking about pollution like earlier, how can we study it, right? If we are talking about technical environmental matters, of course it would be good if the environmental service was present. About the infrastructure, there must be someone from the spatial planning engineering service or something, right? We are a village government, after all ... we are only limited to ... analysis, our village observations. Oh, this is unhealthy, this is not good, umm, when we talk about pollution, there should be someone from the related services such as the health service. They are necessary if we talk so that it would be comprehensive. We are just a village government. Because there are indeed many limitations, yes, maybe we lack equipment...”

“...Especially about the environmental impact, they would visit if, for example, there is a village that complains ... that in some areas ... that there are unwanted impacts in their area. Upon coordination with the regency, they visit the locations related to environmental issues. Secondly, about licensing. Thirdly, recruitment of workers. We talk about local versus non-local, and then about foreigners versus Indonesian, like that ...”

"...Usually, the Manpower Office visits... if the problem is with IMIP, sometimes they visit to check on the conditions inside the compounds, what the environmental conditions are really like..."

10. Sanctions on Industrial Offense

Findings from interviews conducted with informants in relation to sanctions imposed if an industry commits fraud or does not operate as per the SOPs. Sanctions are imposed in the form of warnings, cancellation of licenses, and compensation for victims of industrial accidents. Moreover, several sources stated that the whistleblowers have never heard of any sanctions against companies that violate regulations. Below are quotes from the interviews with informants:

"...there are no sanctions... eh, whether there are sanctions, I don't know so far ..."

"...yes, there are sanctions, it's clear because they have to be responsible... that's the regency's domain, firstly, it is an environmental issue, and then about licensing. Licensing, both for workers recruitment. Because that's what's wrong, about citizens or foreign workers. The Manpower Office has often conducted internal inspections, checks, whenever there's a report. For example, there was an NGO report that there aren't any ... maybe about the foreign workers, whether they have visas; if they have visas, how many years or months are they applicable for work. Perchance, they just use travel visas to get jobs. They should've already checked it... yeah, I can't explain it because it's the regency's domain to impose sanctions..."

"...If the sanction is in a definite form, no, meaning (clears throat) we will only be ... asking the company to be responsible when there is a big impact that, umm, affects the community due to their activities here... Yes, from ... the government, we invite the company management to, umm, find solutions to the problem. Of course it is the company's responsibility, umm, you see that it often happens. One example, earlier, umm, there was a flood, umm, many residents' houses were affected, that is the company's responsibility. After we conducted in-situ monitoring and evaluation that the source of the flood was indeed the company's activities, the source is from here..."

"...about sanctions ... the last we heard was about an explosion ... right ... the special incident on December 24, 2023 (clears throat) ...that was a special incident that has directly

caused ... a big impact on the company because we know that the occupational health and safety law of 1970 ... it refers to, umm, its provisions and implementations are problematic, umm, the penalties are so lenient and very cheap. Those who do not abide to or do not implement OSH in a work environment or in a company are only fined 100 thousand rupiahs. This was in 1970, right? The fine was only 100 thousand. There has been no revision of the law, but the government is trying so that sanctions do not stop there, but also there should be pressures such as damaged image, their image is damaged and they are given an extraordinary fine earlier. And it was emphasized that the victims or their families must receive compensation of 600 million/head. This thing happened after the fire and, umm, 24 hours in a day is not enough for all the teams in this company to find the victims' addresses. They visited the families immediately, gave compensation of 600 million. The plan was to make it go viral, but all of the sudden the incident became quiet and silently disappeared due to the compensation. That was indeed the company's efforts to maintain their image..."

"...if the sanction could be like a fine (motorcycle sound) or could be up to (motorcycle sound) having their permit revoked (motorcycle sound) if there are indeed any violations... oh, I don't know about that, it depends on the regulations from the uh, the severity of the violation as well... maybe in the regency, it depends on the agency that handles it"

"...never happened..."

11. Efforts of the Village/Regency Government

The findings from the interviews with the informants about village/district government initiatives before and after mining include tree planting and reforestation, and the use of CSR funds. However, some believe that the benefits are still minuscule. The following are quotes from the interviews with the informants:

"...the effort to replant or reclamation, right... that's clear, so each company, eh, has an obligation to do it after you dig it out, eh, you close it back up, then you replant it, that's the rule, that's clear..."

"...he, (motorcycle sound) at the most it would be tree planting, (motorcycle sound) planting trees, so the air can be filtered, then what else. This air pollution is addressed just like that..."

"...we submit complaints, but rather than waiting, we ordinary people take our own initiative. For example, what is a healthy house like? There should be ventilation... but we can't have ventilation here because when there is ventilation, the house will be unhealthy..."

"...The government's efforts before factory establishment and after... if we talk about the pre-establishment efforts, this is certainly not our village's authority, due to investment matter. In my view, our efforts are more after this, after this investment. We are the government, we certainly ... see who contributed more to the community, with the presence of companies investing in our area. Our efforts are on how our community can benefit from welfare ... with this investment. Apart from the problem of the impact, because we are talking about these two counterparts, the negative impacts come with the positive impacts. Those two, umm, cannot be separated..."

"...the efforts, yes...so the efforts of the company, uh...the government, with the establishment of the company ... one of the efforts (children's toy sound) is about policies...wait a second...so the efforts, if we scrutinize them, the government is not ready for the establishment of this company. Not ready at all, why, because they are not pro-community, not ready at all ... the local government here does not know about planning for the next ten to one hundred years, 10 years to 100 years; but the company already has a picture of the next ten, fifty to one hundred years, they already have a picture of what the

company will be like. The government is not ready for that because, why, they do not have the capacity and quality for that. that's why the government should actually be the controller here because they are the iron fist that controls the policy, controls the permits (clears throat) ... but their efforts are naught, crippled by all that glitters..."

"... yes, earlier, umm, utilizing CSR funds, CSR funds that are the company's obligation to channel funds related to community empowerment, both for infrastructure and empowerment, umm, for the community, related to small and medium business units..."

"... ahh... I don't know much about that, what is clear is that it is usually like that. The river is already polluted, yes, like that. About the management, I think it is difficult... difficult, because the company is that big, wow. Just look at the sea behind the house, it is no longer a sea, it's all muddy sand..."

12. Air Pollution Prevention

Interviews with informants on air pollution prevention revealed that the government has not taken any action against air pollution. However, industries have taken preventive measures like dust control, CSR funding, tree plantation, etc. Below are some quotes from the informants' interviews:

"... nothing at all ... so now the company has established a program, yes, this company, and I am included in the CSR membership, this CSR is corporate, umm, social reposting [sic]. So, about this CSR ... we are currently, umm, raising an environmental issue about the waste disposal in Bahodopi ... we can see from field observations that the Labota village environment is full of waste. The company have earlier, umm, we have been knocking on various door with several consultants that we called in to come up with plans about the Labota village or the Bahodopi area environment. The company has indeed made certain effort, umm, providing a fleet, providing personnel and funds for company-supported activities to raise this issue of cleaning the environment Earlier it's about cleaning efforts, now we are trying to, umm, what is it called, approaching all village heads in Bahodopi to hold regular talk about environmental issues whether it is about pollution, cleanliness and garbage disposal funded by the company's CSR..."

"...about prevention, there is no such effort from the village side... only from the company, I mean the community asked them ... because it has been managed behind the scenes by the company, then they installed like a high fence and then a wrapped a net around it, on top of the fence there is a water pipe. So, when there is coal unloading, the water sprays everything so the coal dust doesn't come out..."

"...if prevention is impossible, the village will be the one who does it. Although it is limited to a warning because when there is a company that pollutes, that means we can only to talk to them about it, umm, the problem is not the domain of the village because the village has not enough budget, not enough facilities. What can be done is that ... the village is only limited to reporting to the regency. The regency government is the one who gives a warning..."

"...At most, we only provide this information to the company based on public complaints, because so far, the problem management is only limited to prevention... Dust protection or whatever, about the air quality in the village, let alone procuring the equipment ourselves, as mentioned earlier. That is why we involve the related technical agencies, to discuss the matter. We, the village, have not been able to study the matter, I'm afraid... our demands will be excessive if we don't coordinate first with the related agencies to provide us with more accurate data on how the impacts arise, what kinds of solutions, what data we must take in the field..."

"...in our village of Bahomakmur, especially the youth organization, they start from reforestation... the youth organizations buy seedlings of woody plants, they plant them in places like schools, village halls ... we recommend that the community members plant something on the right and left sides of their homes. because frankly, if it's not like that, even in greenhouses, usually there's a lot of dust stuck to its glasses... the brown color smears all around. But if the plants are outside, it won't be a problem ... no other things have come up, there aren't any... there aren't any ... we even proposed a solution for the problem of black snot when one wakes up. No solution has been given..."

"...I think there might be one ... there is an impact but maybe not much, I mean compared to no effort at all..."

"...it means we have also done prevention but earlier (laughs) there was indeed an activity ... as the community complaints, they asked what kind of prevention we want, what steps for prevention, earlier someone told them to erect fences, like that (laughs)..."

13. Health Service Facilities

Interviews with health service facilities revealed that some informants felt that the company's clinics were still overcrowded and that there was a shortage of medical personnel, which sometimes led to lengthy queues. The informants said that the Community Health Center is quite adequate. The following are quotes from the informants' interviews:

"...the clinic hall here is rather narrow, so inevitably there are a lot of employees crowding the place. Long queues, that's the drawback. About the doctors and other facilities, they are well-equipped... yeah, uh, what I said earlier, maybe the hall is too small, because there are tens of thousands of employees inside the compound. Every day someone gets sick... there is a clinic outside the compound, another one inside. But the employees that work outside the compound want to get treatment, they can't get in..."

"...talking about service, my complaint is that it's not optimal... related to the facilities, then the room, umm, in terms of cleanliness it is lacking, they still need their up their performance so that the cleanliness of the facilities is really taken care of. That's one related to the room, the beds, all that..."

"...There is a clinic established by the company, it also serves the community around the mine. Umm, then for us in the village, as I said earlier, the village health post... For short-term, umm, treatments ..."

"...but even the IMIP clinic, wow, it's very below standard ... yes, it's very below standard, for example, if it's given a score from 5 to 10, umm... 0 to 10, I'll give it 0, umm, I'll just give it 3 (laughs) they just do a diagnosis and ask lots of questions, yeah, yeah ... pain here and there, then they just give out medicine, no further examination. Because the obstacle here is, why, the service is of such bad quality due to the lack of personnel. There are not enough doctors, there are not enough nurses, so the health services are not optimal, umm ... (sounds of children playing) ... yeah. lack of health workers. They really don't have enough health workers, imagine (sounds of children playing) ... Only a few dozen people, for example, at the IMIP

clinic that I know of, yes ... they have around 80 to 120 health workers, but they want to serve 78 thousand people in the IMIP area..."

"...in Bahomakmur there is a village health post. In the district level, there is a community health center. About the health service here, if you ask about the doctors, nurses, they are quite adequate and quite a lot. it's just maybe because there are so many people coming in... (interrupted because talking to someone else for 5 minutes) ... I think the health service here is good, it's just that the rooms, the equipment are still lacking because actually they are too few... actually for it standard it's good, okay, it's good, the rooms, just because there are so many people here, the population is dense, it's not enough. The capacity is inadequate... yes, the patients are divided, some are directly referred, collect a few of them then refer them to Bungku Hospital, like that. Clinics are also helpful, that's why people usually, for regular check-ups they usually prefer to go to pharmacies, naturally the service is good because we pay for it. Then we can say we have a lot of pharmacies here, more than 20, all of them have in-house doctors ..."

"...about the sub-health centers, they have been established to assist the health centers, especially about activities of elderly health posts, youth health posts, then toddler health posts, then also about natal and pregnancy. Here pregnant women are not allowed to give birth at home, they must be taken to the health center or the sub-health center. We also asked how many pregnant women in Bahomakmur, usually we get the answer, 'Oh, this many, sir, pregnant women, this many who are about to give birth.' Thus, we can keep it in control. We also provide one ambulance for the village..."

"... if you go to a clinic, not really. But in that clinic, usually mostly the people are employees who seek treatment there. Local residents usually go to the health center here... that's not bad, I think, because usually when we come, the queue is already long, umm, no more queue number is available. That means there are a lot of patients in a clinic. There are even more patients here..."

"...that's the problem, I don't know about the number of visits for other diseases. But specifically, for ISPA, they have more visits. I got a lot of visits to IMIP to check for ISPA, ISPA only. I don't know about other diseases. Because if I summarize it from visits to IMIP, Health Centers and practicing doctors, the most visits are to check for ISPA..."

"...oh, it's still lacking ... I mean the facilities... but the norm that applies is that, sometimes, umm, urgent cases, for example accidents, then there is, umm, an emergency, they definitely not brought to the health center, they go straight to the hospital. Then for bleeding, for example, we immediately refer them to the hospital..."

14. Availability of Medicines

The results of the interviews on the availability of medicines. Availability at the clinic is usually determined by the contract partner. However, in larger clinics, the range of available drugs may be more extensive. Below are quotes from the informant interviews:

"... Adequate... it is after all a clinic. One of the contractors that ... the contractor provides all the health supplies, that's one of the contractors..."

"... yes, it depends on how big the pharmacy is, eh, what? There are a lot of medicines in stock, yes... yes, especially the generic ones, umm, the over-the-counters medicines that are consumed a lot, like paracetamol... it's rare ... if we seek rare medicine, we go to pharmacies. The large one usually. Except for small pharmacies ... there might not have them in stock ... as for the stock of medicine, it's usually rare that there aren't available. Only maybe the price is a bit higher here than in other areas ..."

"...actually, if it's about medicines, we here, if you go to the health center, the medicines available are same old, same old... paracetamol, amoxicillin, like that I don't know what kind of medicine is effective. Because often when I go to the health center, I'm given the same medicines all over again ..."

"...the availability of medicines is sufficient and adequate, the midwife will also convey to the village government what is lacking, later we will make a budget or prepare funds, like that, it's a fast lane for health and education here. Those put on a fast lane because they are a priority..."

"...about the stalls, it seems that the availability is not, well... it's lacking. Nevertheless... I mean, I can always get what need there... but not all is available, it's not ... maybe there are certain medicines that can't be sold there at all..."

"...Well, it's adequate... It's like the clinic. Some that are available in the clinic aren't available here ... Sometimes they aren't available here if, for example, they run out of stock, then... then we must go to the clinic after all..."

"...Alhamdulillah for now ... yes, because usually, umm, the village midwives are also coordinating, umm, for our observations so far. Yes, of course, it would be more appropriate if village midwives were involved to explain this. Personally, I am still lacking... Like is said earlier, because there are still many complaints from the community, we only do as much as we can. So, whenever there are Development Planning Deliberation, we suggest, umm, we do more of this, related to health service issues. Because in the village we have many limitations, including budget issues (motorcycle noise), we maximize that..."

15. Access to Health Services

From the interviews with the informants regarding access to medical services, it seems that the medical facilities are easily accessible. However, from the observations, it was found that although the facilities are close to the settlements, the damaged roads are muddy, and full of holes and dust, causing traffic jams during rush hours, making it difficult to reach the health services. The following quotes are

"...He eh, the biggest obstacle is, umm, during rush hours there will be a traffic jam. We can try avoiding the traffic jam by going earlier, but there are certain times when employees go home from work. In my opinion, something has been tried, umm, following up on our proposal. Yes, Alhamdulillah, maybe in the near future, there will be a discussion on the matter of national roads or trans Sulawesi roads. The result of earlier Development Planning Deliberation, for the Bahodopi District area, because, umm, this road is no longer adequate. If it's like a plane, it is overloaded with passengers. Umm, the capacity of the road and the users, it's no longer, umm, balanced. Meaning that there are more users compared to the available road capacity, maybe it just needs widening or installing (breathing), drainage channels. Also, these residents who do business along this road, they can move or they may realize that what they are using is partly, umm, government facilities ... That means that it is still easy to access ..."

"...it's starting to get better except for the alleys. The main road is okay, it's just because of the density of vehicles, the traffic jam, they choose their time to visit..."

"...the road is not all paved, maybe people want to ride on paved roads, even though there is a closer road but it's not paved. About the distance, it's at most 1.5 kilometers..."

"...it's easy to go from here to the health center, it's only a few minutes. Even then, the road is paved so it's easy to reach. As is the case of the clinic, there are pharmacies along almost every road, there are several more pharmacies, every several meters there is another one ..."

"...for our people here, eh, it's easy..."

"...the road access is difficult, yes, the access is difficult if it is congested, muddy, full of potholes, right... umm, that's the problem here ... (salesperson's voice) ...it will be difficult if the road access is lacking (pause) umm, so about ... bismillah ... access to health facilities is ... difficult ... it is categorized as difficult ... and we checked in-situ the inadequate access ... why I said inadequate, because the road is used beyond its standard. The company vehicles also use those roads so it is easily damaged. This provincial road is used for public transportation with a maximum tonnage of only 10 wheelers. But then this company ... the company also uses this public facility beyond its capacity, umm, of public facilities... so, umm, there is a progress in the government's efforts and the company's efforts. The government's own efforts, umm, from the Public Works, especially for Morowali Regency, there are efforts to always maintain and strengthen road conditions (motorcycle sound) ... as well as the condition ... (voice motor) of the bridges and their maintenance. They are always repaired. About the efforts of, umm, the company ... the company is always holding back and they have a boundary and limitations. They have a boundary from the point, umm, in front of PT IMIP office to the point in front of the Makarti village alley ... that's it ... they always make improvements such as casting concrete roads, filling potholes. No drainage though ... the drainage is mostly made by the government..."

3. Discussion

A. Particulate Matter (PM₁₀ dan PM_{2.5})

PM₁₀ is a dangerous pollutant with a size of less than 10 µm which can enter the body through the human respiratory system. If the concentration of PM₁₀ exceeds the quality standard set in Attachment VII of PP RI Number 22 of 2021 by 75 µm, it will pose a health risk. The health risks include respiratory disorders, such as acute respiratory infection (ARI/ISPA).

PM_{2.5} is a hazardous pollutant that can lead to various diseases if inhaled. It measures only 2.5 µm in size, making it easy to enter the airways and alveoli. Human activities, such as mining, can generate PM_{2.5}. When PM_{2.5} concentrations surpass quality standards, they can negatively impact human health and cause respiratory diseases like acute respiratory infections. Even if PM_{2.5} concentrations do not exceed the quality standards, it does not guarantee permanent safety. With the rise in air pollution sources, including growing industries contributing to increased PM_{2.5} concentrations, this situation can change and escalate beyond the quality standards.

There are several factors that affect indoor or outdoor PM_{2.5} concentrations, including manufacturing activities, material handling processes, rooms with poorly maintained air conditioning systems, poor air circulation, and exposure to cigarette smoke that increases air pollution, which is in line with the studies conducted (Laila, 2023).

Other influencing factors may be meteorological in nature, with outdoor temperature measurements averaging 33.32°C and indoors 33°C and outdoor humidity measurements averaging 51% and 60%. When temperatures are low and humidity is high, PM_{2.5} concentrations are low. On the other hand, when temperatures are high and humidity is low, PM_{2.5} concentrations are high. This is consistent with a study by Nuryanto and Melinda (2023), who found that the relationship between temperature and humidity is generally inversely proportional. That is, as temperatures decrease, PM_{2.5} concentrations tend to increase, and conversely, as temperatures increase, PM_{2.5} concentrations tend to go up. The same is true for humidity, where high humidity generally tends to decrease PM_{2.5} concentrations, and conversely, low humidity generally tends to increase PM_{2.5} concentrations.

B. Sulfur Dioxide (SO₂)

Sulfur dioxide (SO₂) is a type of sulfur oxide gas (SOX) produced during the roasting, smelting, and conversion of processed sulfide ore products. This gas is easily soluble in water and has an odor. Nickel mine waste may also contain harmful substances such as ammonia, cyanide, and sulfur dioxide. The presence of these substances not only increases the risk of environmental pollution but may also harm the health of people living near mining areas (Saputro, Sari, and Putri, 2024). The nickel mining sector has an emission of 8,392.61 tons/year. The sources of SO₂ emissions in nickel mining are generally from the ore processing plant (15%), transportation, limestone processing (9%), backup boilers (4%), and sulfuric acid plant emissions (72%) (Kramawijaya, 2017).

The presence of SOx contamination at a concentration of 0.5 parts per million (ppm) in the air can have adverse effects on animals, humans, and plants. SOx levels can lead to throat irritation at 5 ppm and cause respiratory irritation at levels ranging from 1 to 2 ppm (Asriwati, 2023). Exposure to SO₂ can result in various health issues such as ischemia-reperfusion, impaired cardiovascular function, myocardial injury, atherosclerosis, pulmonary hypertension, lung injury, and brain damage (Genchi et al., 2020).

C. Intake Value

Intake analysis was used to calculate the intake in mg/kg/day of respondents from Fatufia, Bahomakmur, and Labota villages. The formula for calculating the intake without carcinogenic effects was used to calculate the intake in this study. The highest non-carcinogenic intake by inhalation (breathing) was 0.0052799921 mg/kg/day and the lowest was 0.0000258175 mg/kg/day.

The higher the intake value, the higher the risk for the respondent. This is in line with the study conducted by Lestari et al. (2021). The higher the respondent's intake, the higher the chance of exposure to health problems.

The intake value is calculated by multiplying the PM_{2.5} concentration value by the inhalation intake rate, exposure time, exposure frequency, and exposure duration, then dividing by body weight and average period. The higher intake value is affected by these factors.

D. Risk Quotient (RQ)

The risk quotient measures the level of risk of individuals being exposed to PM_{2.5} while working in Fatufia, Bahomakmur, and Labota Villages. It is divided into two: $RQ \leq 1$ and $RQ > 1$. With $RQ \leq 1$, the exposure is still considered safe or not yet risky. If $RQ > 1$, there is a non-carcinogenic health risk that should be avoided to ensure the health of the individuals and the surrounding environment. The RQ value is calculated by comparing the respondent's intake value with the default RfC value, which is set at 0.01 mg/kg/day.

Among the respondents, 58 people were observed with $RQ \leq 1$, which corresponds to a percentage of 100%. The risk of exposure to $PM_{2.5}$ is still in the safe range for the respondents or has not yet caused any health risks. In order not to cause health problems for the respondents, it is necessary to avoid the risk of exposure to $PM_{2.5}$. One person out of 92 respondents has a respiratory disease, i.e. asthma, and most of the respondents show symptoms of respiratory diseases, 31 (54.4%) have symptoms of coughing, 29 (50.9%) have symptoms of sneezing, 26 (45.6%) have symptoms of cold, 12 (21.1%) have shortness of breath, 31 (54.4%) have a sore throat, 36 (63.2%) have a headache, 33 (57.9%) have eye irritation, and 25 (43.9%) have skin irritation. The respondent with the highest RQ value, 0.527999, still belongs to the safe category since his $RQ \leq 1$.

E. Risk Management

Risk management aims to keep individuals safe from health issues when they are at risk of exposure to harmful agents. Several risk management methods can be employed, such as reducing exposure concentration, exposure time, and exposure frequency, as well as limiting the duration of exposure to levels that are safe for individuals. Additionally, adopting healthy behaviors and consuming nutritious food can contribute to risk management. In ARKL, there are two characteristics: $RQ \leq 1$ indicates safety or no risk, while $RQ > 1$ indicates the presence of risk, necessitating risk management measures.

The study's calculations show that people in Fatufia, Bahomakmur, and Labota Villages are not currently at risk of health problems due to $PM_{2.5}$ exposure. The RQ value obtained is ≤ 1 , which is considered safe. This aligns with a study by Sembiring (2020) on health risks for street vendors. The study indicates that the average RQ for $PM_{2.5}$ concentration ranges from 0.377 to 1.250, with an average of 0.603. The RQ values at both the minimum and average concentrations are below 1 ($RQ \leq 1$), indicating that the risk for street vendors at the Asemka Morning Market, West Jakarta, is still considered safe (Sembiring, 2020).

$PM_{2.5}$ can cause respiratory symptoms such as coughing, runny nose, shortness of breath, headache, sore throat, eye irritation, and skin irritation. Among respondents without pre-existing respiratory disorders, the following percentages experienced these symptoms: 54.4% encountered coughing, 49.1% experienced sneezing, 45.6% had a runny nose, 78.9% suffered from shortness of breath, 63.2% had a sore throat, 43.9% experienced headaches, 57.9% reported eye irritation, and 75.4% had skin irritation.

Respondents who experience symptoms of respiratory disorders may be affected by unhealthy behaviors and environments. Smoking is a known cause of diseases such as lung cancer, coronary heart disease, stroke, and other health issues. Among the 92 respondents, 47 people (81%) are often exposed to cigarette smoke, while only 7 people (12.1%) are not exposed to cigarette smoke. Among the 33 respondents who reported a habit of smoking, the highest frequency, 16 people (48.5%), reported smoking 7-12 cigarettes per day. This behavior could potentially lead to the respiratory disorder symptoms experienced by the respondents.

Exposure time and frequency risk management can be accomplished using personal protective equipment (PPE) such as N95 standard masks. Out of the 92 respondents, 15 people (25.9%) occasionally use PPE, whereas 38 people (65.5%) use PPE regularly. Among the respondents, 17 people (29.3%) used medical masks, while 32 people (55.2%) used cloth masks during work.

Consumption patterns and behaviors such as physical activity, milk consumption, and vitamin C consumption also play an important role in human health. Physical activity is categorized into three levels: light, moderate, and heavy.

Heavy physical activity is any activity sustained for at least 10 minutes until pulse and breathing increase more than usual, such as jogging, cycling, exercising, fetching water, climbing, sprinting, cutting wood, felling trees, etc. Moderate physical activity occurs when moderate physical activity (sweeping, mopping, etc.) is performed for at least 5 days with a minimum activity time of 150 minutes per week. Anything less than the above description counts as light activity. Other ways to get active include walking, cycling, rollerblading, active recreation, and play – they are possible for all skill levels and are fun for everyone (WHO, 2020).

UHT milk is reconstituted or recombined milk from fresh milk that is sterilized at a temperature of 135°C with an F0 value for 3 minutes and then packaged aseptically. UHT (Ultra High Temperature) milk is produced using a heating process that exceeds the pasteurization process, typically involving a combination of time and temperature to create a sterile commercial product. Milk is rich in essential nutrients such as phosphorus, calcium, vitamin A, vitamin B, and riboflavin (Putra and Jumino, 2021). A study on milk consumption habits found that out of 92 respondents, 33 people (56.9%) frequently consume milk, while 11 people (19%) do not.

Vitamin C plays a vital role in modulating the immune system. It acts as a potent antioxidant by donating electrons, which helps protect important biomolecules such as proteins, lipids, carbohydrates, and nucleic acids from damage caused by oxidants generated during normal cell metabolism or exposure to toxins and pollutants (Yanuartono, et al., 2021). This study found that out of 92 respondents, 81% regularly consume vitamin C, while only 12.1% do not.

F. Qualitative Discussion

1. Land Use and Its Impact on Society

The mining industry activities in Bahodopi District require large land areas. Development continues to be carried out by related parties, with PT. IMIP continuing land acquisition in the Labota, Keurea, and Bahodopi areas. The PT. IMIP area covers around 3,000 hectares, which will be expanded to 6,000 (PT. Indonesia Morowali Industrial Park et al., 2021). Nickel mining activities often involve seizing land owned by and managed by the community, notwithstanding previous landowner agreements. The increasing use of land over time can have complex environmental impacts, leading to erosion of native vegetation in the Bahodopi area. According to one informant, deforestation has led to floods and landslides during the rainy season due to the absence of natural absorption and soil retention. These large mining activities have impacts on several conditions.

- a. The impacts of mining activities are not only social but also affect the economic situation of the inhabitants of mining areas.
- b. Because mining operations require large areas of land, they often lead to the loss of productive resources such as land and natural resources, which results in local communities being unable to produce their own goods and needs. Furthermore, disruptions to consumption and production systems mean that people become increasingly dependent on external goods and services, which affects their economic situation.
- c. Distribution activities have also been disrupted by the increasing influx of goods and services from outside the community (Frawansa and Anggrani, 2023).

2. Waste Management and Dumping

Nickel mining produces waste called slag. According to the Decree of the Minister of Environment and Forestry of the Republic of Indonesia concerning environmental permits for B3 (hazardous and toxic) waste management activities, Nickel slag is categorized as a type of B3 waste, which is waste or residue from Nickel processing that was initially in liquid form. Nickel slag is utilized as a component in concrete and asphalt mixtures. In general, Nickel slag can be used as a construction material and as an asphalt hardener. If Nickel slag is utilized optimally, it can help alleviate the problem of increasing accumulation of Nickel slag waste (Tanjung et al., 2022).

One source reported that the slag generated from mining was simply discarded without any further treatment. Mining waste typically has low organic content and soil moisture, making it easy to compress. If organic materials in mining waste are not managed properly, they can contaminate the environment. Furthermore, other iron materials and used tires from mining activities are also disposed of and piled up. Both slag and other iron materials can lead to environmental pollution and affect public health. If exposed to acid rainwater, the accumulated slag can produce leachate containing heavy metals, polluting surface water bodies and groundwater. A source highlighted that direct exposure to water from the region's mountains led to skin problems. It's important to note that one of the consequences of water pollution from heavy metals is skin issues. Research by Ressa et al. (2024), explains that slag from processing nickel ore, when used as piled material, can have long-term effects like skin cancer if it contaminates water bodies.

3. Impact of Mining Activities on Climate Change

Climate elements include air temperature, humidity, and sunlight intensity. One source mentioned that after the establishment of the company, the weather in the area often changed. Fossil fuels can lead to increased production of greenhouse gases in the Earth's atmosphere. An increase in these gases can lead to higher heat retention in the atmosphere, affecting the Earth's climate conditions. Climate change is characterized by rising average temperatures, changes in rainfall patterns, and increasing sea levels (Susilawati et al., 2021). The Nickel Industry can contribute to increased greenhouse gas emissions. Greenhouse gases include various pollutants such as sulfur dioxide (SO₂), carbon dioxide (CO₂), methane (CH₄), nitric oxide (N₂O), hydrofluorocarbons (HFCs), and chlorofluorocarbons (CFCs). One of the impacts of greenhouse gas emissions is increased rainfall in tropical climate areas (Raswin, 2015).

The Nickel industry produces SO₂ emissions that cause an unpleasant odor and disrupt the surrounding community. Human senses can detect the presence of SO₂ gas in the air at concentrations ranging from 0.3 to 1 ppm, causing throat irritation at 5 ppm (Fardiaz, 1992). Additionally, dust from the mining process poses health risks, leading to diseases such as Silicosis, Asthma, and Lung Cancer (Mei Ananda Natali & Probowati, 2021). Observations also indicate that the proximity of residential areas to the smelting location may have serious health impacts on the local community.

4. Mining Industry's Positive Impact

The Nickel mining industry has significant positive impacts, contributing to economic growth and improving the social welfare of the local community. The industry fosters community involvement through employment opportunities and the creation of various businesses in the area. Overall, the mining industry has a positive effect on generating foreign exchange and providing employment. The establishment of the Morowali industrial area has led to increased income, job prospects, and business opportunities for the local community. According to the 2019 P4K-Untad study, 76% of the Bahodopi community's monthly income is above IDR 3 million, with 43% reporting an income above IDR 5 million (Lampe, 2021).

The native workforce employed by all companies in the PT. IMIP area until March 2020 totaled 1,065 people. This number accounts for 13.95% of the population in Bahodopi District in 2019, which was 7,634 people (PT. Indonesia Morowali Industrial Park, 2021). There are abundant business

opportunities for Bahodopi residents in the informal sector, such as boarding houses, food stalls, laundries, kiosks, coffee shops, cafes, and various other services required by employees. Local residents are also involved as contractors and suppliers of company needs by engaging Village-Owned Enterprises (BUMDES) (Lampe, 2021).

The mining industry provides health insurance to its employees in the form of free BPJS. This is part of the state's effort to ensure that workers have access to health insurance through the BPJS program. However, mandating companies to register with BPJS could impact other businesses in the same industry, such as the health insurance financing. It is important for the government to introduce innovative policies that do not unfairly disadvantage other institutions. The responsibility of the state is to protect all business activities, not to be competitors or give preference to certain institutions, but to allow them to act objectively and fairly in all business activities (Luhukay, 2021).

The Environmental Office is a regional agency responsible for implementing preventive measures and addressing violations in the environmental sector. Additionally, the Environmental Office (DLH) is tasked with administering sanctions to those who cause environmental damage (Rosyadi and Wulandari, 2021).

5. Crime Rate

Many sources have indicated that the mining industry has contributed to an increase in the crime rate. This high crime rate can be attributed to economic disparities, such as differences in per capita income between cities and regencies (Sari et al., 2022). Various forms of crime, including murder, robbery, rape, gambling, and drug trafficking, are prevalent in the area. The influx of diverse immigrant communities, each with its own characteristics and interests, has also contributed to social conflict due to differences in culture, ethnicity, nation, race, language, and religion. The high population density has further exacerbated the situation, providing ample opportunities for perpetrators and victims of crime to come into contact (Audey and Ariusni, 2019).

6. Society's Consent and Forms of Participation

When examining the development of the mining sector, particularly in Bahodopi District, it's evident that the establishment of a mining industry company has sparked both support and opposition from the local community. Those who oppose it are typically from the communities in proximity to the company and are directly impacted by mining activities, in the forms of 1) dust pollution, 2) water pollution, 3) land degradation, and 4) air pollution. One approach to involve the local community in the industry and mining in Bahodopi District is to engage the surrounding community as workers. The individuals involved are evaluated based on their qualifications, abilities, and skills. However, it's important to acknowledge that many foreign workers are also involved. According to one source, the majority of the company's workers are foreign, with only 20% being local residents. Additionally, the low employment rate of local workers is attributed to the quality of available human resources.

According to the research conducted by BB (2019), mining activities have been found to significantly increase community income, especially for local residents. This increase in income has led to more job opportunities, thus reducing unemployment. Additionally, mining activities have led to the development of public facilities and the growth of community micro-enterprises. Prior to the company's establishment, a majority of local people relied on jobs in the plantation, forestry, and fisheries sectors. However, with the introduction of the company, many individuals transitioned to new professions as entrepreneurs and workers.

The company allocates one million rupiahs per family as a social responsibility fund (CSR) to the local community each year. Corporate Social Responsibility (CSR) is a commitment of a Limited Liability Company (PT) to contribute to sustainable economic development, improving the quality of life and the environment for the community. The budget amount complies with LLC Law and PP (Government Regulation) No. 47 of 2012. Each region has regulations on the allocation of CSR funds, which must not exceed 4%. In addition to providing economic benefits to the community, mining industry activities contribute to the country by increasing state revenue from royalties and taxes. The IMIP Industrial Estate generates \$187 million in foreign exchange from exports and pays Rp 306.874 billion in taxes and royalties to the state. These figures increase annually, and in 2022, the investment value was \$20.927 billion, with export foreign exchange reaching \$15.030 billion and tax and royalty deposits to the state totaling USD 20.927 billion (PT. Indonesia Morowali Industrial Park, 2021).

7. Governmental Monitoring and Evaluation

The government's implementation of monitoring and evaluation is not conducted regularly, but only on an ad-hoc basis. Reviews are only carried out when there are reports from the community. The government needs to enhance the capacity for monitoring and supervision of Nickel mining activities. An efficient monitoring system can help identify potential environmental impacts and ensure company compliance with regulations. Monitoring and evaluation are generally carried out by related agencies such as the Mining Office and the Environmental Office. Meanwhile, the Village government must first coordinate with the Regency. According to information from one of the Village Officials, there has never been a case related to pollution that has reached the central government, the highest government hierarchy.

8. Sanction against the Company

.Companies that do not comply with standard operating procedures (SOPs) will face administrative sanctions such as written warnings, revocation of business permits, and fines. Various violations committed by companies are related to activities causing air pollution, work accidents, and breaches of business licensing regulations. Recently, a work accident occurred in one company, which resulted in the company compensating the victim's family in order to protect its reputation. In terms of environmental protection, according to Law Number 11 of 2020 concerning Job Creation, the government stipulates that individuals who, by negligence, conduct production activities that lead to exceeding ambient air quality standards, water quality standards, seawater quality standards, or other environmental damage criteria not in line with Business Licensing, will be subject to administrative sanctions (Nasir & Triadi, 2024).

9. Government Efforts Before and After the Establishment of the Mining Industry

After mining activities, efforts are made in the form of tree planting, reclamation, and utilizing CSR funds provided by the company. The CSR funds are channeled into community empowerment, environmental management, and infrastructure. The reclamation stage aims to organize the land so that it can function again. It is the responsibility of mining business units to properly manage post-mining land, which can include reclamation and replanting to restore greenery to the exposed land. However, most reclamation areas are currently composed of pioneer species rather than local endemic species, which can lead to the loss of the area's authenticity. Regarding the soil, post-mining Nickel land has low fertility due to the open nature of mining, resulting in the loss of the top layer of soil (Ardiyansyah, Wasis, and Hilwan, 2019). The CSR funds provided by the company are used by the Village government to fulfill the needs of the Village. For example, in Bahomakmur Village, CSR funds are used to improve waste management efforts, such as acquiring garbage collection fleets.

The government is responsible for addressing community complaints about environmental pollution. The village government will coordinate with the company to take action. For instance, when the community raised concerns about coal dust pollution, the government urged the company to use a wind fence to spray water and control

the pollution. This action is in line with Government Regulation of the Republic of Indonesia Number 41 of 1999 regarding Air Pollution Control, specifically Article 21. According to this article, businesses must adhere to air quality standards set by the Government, prevent and address air pollution, and inform the public about controlling air pollution.

The government also has a policy regarding the replacement of people's roofs due to corrosion caused by air pollutants. Atmospheric corrosion occurs when metal materials degrade and deteriorate due to interaction with the atmosphere and is worsened by the presence of pollutants such as gases or salts in the air. Industrial exhaust gases, like SO₂, have a significant impact on the rate of corrosion. SO₂ becomes sulfuric acid (H₂SO₄) when oxidized in wet particles or water droplets (Supardi, 2015). This policy indirectly indicates that the air quality in the Bahodopi Industrial area is not very good. Steel corrodes when its surface is in direct contact with air or a corrosive environment. The humidity level of the surrounding air influences the corrosion on the surface of steel. Air pollution containing SO₂, especially in urban and industrial areas, poses a threat to construction materials around it. Corrosion occurs due to acidic rainwater, leading to the dissolution of metal from catchment areas, pipes, and storage tanks (Yushananta, 2021).

10. Air Pollution Prevention Efforts by Village, District, Regency, and Provincial Governments

Pollution prevention focuses on how to avoid and minimize waste through reducing waste sources or recycling on-site. Reducing waste sources can be achieved in different ways, both related to the process and the product. This includes product modification by changing the form and composition of the product's raw materials; input substitution to reduce the use of raw materials and additional materials that cause pollution, as well as the use of process aids (e.g., lubricants and coolants); and technology and management modifications to reduce or eliminate waste and emissions. Technically, the government does not directly intervene in pollution prevention. The government only cooperates with industry in providing policies to control the course of industrial activities.

The local government's role in mining activities in Morowali Regency is closely linked to the policies and regulations that govern the mining industry. These policies are based on the concept of sustainable and environmentally friendly mining practices. The implementation of mining areas is expected to bring several benefits, including improving community welfare, implementing community empowerment programs or Corporate Social Responsibility (CSR) initiatives, conducting technical, economic, and environmental feasibility studies (AMDAL Studies), reclamation and environmental management, creating more job opportunities, and increasing regional income.

Although some farmers are neutral towards mining in the Bahodopi District area, farmers' reactions to mine management policies and activities are perceived as mostly negative. Farmers interpret the impacts of mining as follows: 1) mining creates new jobs for farmers, 2) mining damages farmland and the environment, 3) mining brings high sale value (economic value) to farmland, 4) mining is a blessing (economic aspect) because their lives are better now. However, most farmers are not aware (don't know, don't understand) of the long-term impacts of the mine (Demmalino, Ibrahim, and Karim, 2018).

11. Health Care Facilities

According to Government Regulation of the Republic of Indonesia Number 47 of 2016 concerning Health Service Facilities, Health Service Facilities are tools and/or places used to organize health service efforts, including promotive, preventive, curative, and rehabilitative services. These services are carried out by the central government, local government, and/or the community. In Bahodopi Village in 2022, there are 4 polyclinics, 1 inpatient health center, and 27 pharmacies. The majority of the workers choose to seek treatment at the clinic while the community uses the Health Center. However, due to the large number of patients who need to be treated every day, patient care is not optimal. The community admits that further examination related to the diagnosis from health workers at the clinic is lacking. In addition, health service facilities in the Industrial area, especially in clinics and health centers, are still inadequate, particularly in terms of infrastructure and the number of health workers. This is not proportional to the number of patients treated. The availability of facilities, resources, and quality of service can affect the level of patient satisfaction in seeking treatment (Hadi, Ibrahim, and Nurhasanah, 2020). One informant reported that the frequently complained disease at the clinic was ARI.

12. Availability of Medicines

Medicine plays a crucial role in healthcare facilities, as its availability is essential for promoting rational drug use by patients and building trust in the healthcare system. Large company clinics typically have a more comprehensive range of medicines, and many pharmacies have also been established. Meanwhile, health centers usually only offer generic drugs. Village midwives have also raised concerns with the village government about securing health funds. It's important to ensure a steady supply of medicine at all times to support efficient and effective operations, as this is key to the success of community health center management.

13. Accessibility of Health Care Facilities

Health access refers to the ability of the community to access health services. It is influenced by several factors such as gender, travel time, transportation costs, location of residence, public perception of health, quality of service, education, and income (Firda Maulany, Ragil, and Eva, 2021). Despite the availability of health service facilities in the area, accessing them faces several obstacles including poor accessibility and road capacity. Congestion often occurs at certain points and times due to the narrow road and high density of road users. The presence of a company

conveyor for transporting goods and mining materials to the jetty also contributes to this congestion. These challenges have a direct impact on the community in terms of time and cost when trying to reach health facilities. Furthermore, the condition of the main road, often damaged by the traffic of transport vehicles, further hinders accessibility to health service facilities.

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