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Ambient Air Quality Assessment in the Limestone Mining Area of Ponjong District, Gunung Kidul, Indonesia

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Abstract
Limestone, a non-metallic industrial mineral, is abundantly found across Indonesia. The extraction process involves overburden removal, limestone breaking using rock breakers, loading onto dump trucks with excavators, stockpiling, and subsequent processing. These activities can negatively impact the environment, particularly air quality. To evaluate the ambient air quality in the mining area, measurements were taken focusing on hazardous substances such as SO2, CO, NO2, O3, and Total Suspended Particles (TSP). This study aims to assess the ambient air quality within the limestone mining area. Results indicate that the ambient air quality in the mining area is relatively good, with no parameters exceeding established quality standards. Specifically, SO2 levels were 9.39 µg/m³, NO2 levels were 4.19 µg/m³, CO levels were 69.74 µg/m³, O3 levels were 24.90 µg/m³, and TSP levels were 133.26 µg/m³. For a more comprehensive assessment, it is recommended to conduct extended monitoring of these parameters to ensure the long-term air quality status for both the environment and the mine workers

1. Introduction

Mining commodities certainly make a big contribution in various fields, one of which is limestone. Limestone is one of the non-metallic industrial minerals with enormous potential spread throughout Indonesia [1]. The mining process was carried out in a mining company that has open pit mining system (quarry). The mining method applied is a side hill-type quarry. A side hill type quarry is a mining system that is applied to mine rocks or industrial mineral deposits that are located on hillsides or the deposits are in the shape of hills [2]. Mining begins by stripping the overburden, dismantling the limestone using a rock breaker, loading it in a dump truck using an excavator, stockpiling, and processing, so that this activity results in one of the negative impacts on the environment, namely decreasing air quality. Air quality is an air condition in an area that includes various physical, chemical, and biological parameters that affect human health, the environment, and the ecosystem as a whole. The types of primary air pollutants produced are generally gases, including CO, NOx, HC, SOx, and particles. Wind speed and direction greatly influence outdoor air pollution because strong, turbulent winds cause the concentration of pollutants to become dilute, while calm, weakly turbulent winds cause the concentration to become concentrated, and this wind speed can be an indication of the direction of distribution and fluctuations in the concentration of pollutants in the air [3]. To determine whether the ambient air quality is good or harmful to the environment, air quality measurements are carried out in the research area. Ambient air quality measurements are based on hazardous substances, such as SO_2, CO, NO_2, O_3, and TSP which add to air pollution [4]. Air quality is determined from the measured concentration of air pollution parameters that is higher or lower than the National Ambient Air Quality Standard value. Air quality standards are limits for measuring the presence of air pollutants contained in Ambien air [5]. Therefore, maintaining air quality is the most important thing to maintain the continuity of living things on Earth [6]. Good air quality, when viewed based on the amount of pollutant concentration according to the ambient value quality standard, is air with pollutant content below the set value of the ambient air quality standard, while bad air has a pollutant level that exceeds the ambient quality standard value limit set by the government. National Ambient Air Quality

Standards according to Republic of Indonesia Government Regulation Number 22 of 2021 concerning Implementation of Environmental Protection and Environmental Management [7].

Table 1. Ambient Air Quality Test Results in Mining Areas

No	Location	Parameter	Unit	Quality standards	Analysis results	Method	Information
1	The area of mining company S= 08°01'00.6" E=110°43'49.2"	NO_2	µg/m^3	200	4.19	19-7119.2-2005	Temperature= 31.4 °C
		SO_2	µg/m^3	150	9.39	SNI 7119-7:2017	Humidity=54.0 %
		CO	µg/m^3	10000	69.74	Spectrophotometry	Wind speed= 2.2 m/sec
		O_3	µg/m^3	150	24.90	SNI 19-7119.8-2005	Air pressure= 722.4 mmHg
		Particles (TSP)	µg/m^3	230	133.26	SNI 7119-3:2017	Wind direction = north Weather = sunny

Ambient air pollutants have a high potential to cause respiratory and hearing problems in humans. NO_2, SO_2, CO, and noise pollutants are several types of pollutants in the air, especially those produced from burning fossil fuels [8]. The impacts resulting from exposure to these pollutants include irritation of the respiratory tract and problems with the human hearing system. Long-term exposure to ambient air can cause respiratory diseases such as chronic bronchitis, swelling of the lungs, swelling of the eardrum, and can lead to death [9]. Side effects from exposure to NO_2 and SO_2 gas at low concentrations can cause symptoms of watery and sore eyes, while at high concentration levels, it can cause shortness of breath, throat irritation, and even death. Exposure to CO gas can have side effects in the form of eye irritation, throat irritation, and swelling of the mucous membranes, and can worsen conditions such as asthma, COPD (chronic obstructive pulmonary disease), and chronic bronchitis [10]. Limestone industry workers are often exposed to dust and gas, so it is recommended to check lung function every year, for those who are abnormal the period of repeat examination can be shortened [11]. Monitoring ambient air quality is part of air quality management to make air quality in the environment suitable for human health. Along with the increase in human activity in meeting daily needs, especially in the transportation sector, the burden of pollutants on the air environment is increasing. NO_2, SO_2, CO, and noise compounds are several types of pollutants in the air that result in decreased air quality in the ambient air environment [12]. Therefore, this research aims to determine the ambient air quality in the mining area.

2. Methodology

This type of qualitative research uses an observational method which is descriptive because it is carried out by describing a situation or object being studied objectively. The research design is cross sectional where exposures are collected at the same time or within a certain time. In this study, the ambient air quality measurement time was carried out for 1 hour with each parameter tested, namely NO_2, SO_2, CO, O_3, and particulate matter (TSP). The data used in this research is secondary data from the mining company. The parameters tested were NO_2 using SNI 19-7119.2-2005, SO_2 parameters using SNI 7119-7:2017, CO parameters using spectrophotometry, O_3 parameters using SNI 19-7119.8-2005, and for particle parameters (TSP) using SNI 7119 -3:2017. This sampling was carried out by the Yogyakarta Special Region Occupational Safety and Health Team.

Table 2. Results of Parameter Analysis of Quality Standards

Sampling Location	Parameter	Results µg/m^3	Quality standards µg/m^3	Information
Mining company area	NO_2	4.19	200	≤Quality standards
	SO_2	9.39	150	≤Quality standards
	CO	69.74	10000	≤Quality standards
	O_3	24.90	150	≤Quality standards

Sampling Location	Parameter	Results µg/m^3	Quality standards µg/m^3	Information
	Particles (TSP)	133.26	230	≤Quality standards

3. Results and Analysis

3.1 Ambient Air Quality Test Results NO_2, SO_2, CO, O_3, and TSP

The mining company engaged in limestone mining. Geographically the mining location is at coordinates 110°46' 08" E and 7°46'08"-7°50'58" S. Based on the shape and characteristics of the limestone layers and covering layers, the mining system applied is an open pit mining system. Mining activities carried out in general are land clearing, stripping topsoil, and excavating limestone. In the research area, apart from mining, limestone processing is also carried out, which has an impact on the environment, namely decreasing the quality of the ambient air. Based on the results of ambient air quality testing at the mining company, can be seen in Table 1. From the test results data in Table 1, it shows that for the NO_2 parameter, the results obtained were 4.19 µg/m^3 with the specified quality standard being 200 µg/m^3. For the SO_2 parameter, the result obtained was 9.39 with the quality standard set at 150 µg/m^3. For the CO parameter, the result obtained was 69.74 with the quality standard set at 10,000 µg/m^3. The analysis result obtained for O_3 was 24.90 with the quality standard set at 150 µg/m^3, while for particles (TSP) the result was 133.26 with the quality standard set at 230 µg/m^3. In Table 2. it can be explained that the results of the analysis of the parameters NO_2, SO_2, CO, O_3, and particulates (TSP) still carry the established quality standards. This can be known based on the National Ambient Air Quality Standards according to the Republic of Indonesia Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Environmental Management.

3.1 Analysis of Ambient Air Quality NO_2, SO_2, CO, O_3, and TSP

Limestone processing produces dust and pollutant gases such as SO_2, NO_2, CO, O_3, and particulates (TSP) which are in the work environment, causing workers to be exposed to dust and pollutant gases in different concentrations. Nitrogen dioxide gas (NO_2) is an ambient air pollutant along with the element nitrogen monoxide (NO) which is usually produced from human activities such as burning vehicle engine fuel, burning waste, burning coal, and industry. The characteristic of this gas is that it has a sharp odor and is brown in color, where the impact on health is mainly a decrease in lung function, causing shortness of breath, and even leading to death [13]. Based on Material Safety Data Sheet information, exposure to NO_2 gas can irritate mucus, sinuses, pharynx, irregular respiration, and even pulmonary edema [14]. The effect on this toxic gas depends on the dose and duration of exposure. The increasing number of motorized vehicles each year can have an impact on increasing NO_2 and will hurt human health [15].

Table 3. Ambient Air Quality Standards

No	Parameter	Measurement Time	Quality standards µg/m3	Measurement System
1	Sulfur Dioxide (SO_2)	1 hour	150	Continuous active
				Active manually
		24 hours	75	Continuous active
		1 year	45	Continuous active
2	Carbon monoxide (CO)	1	10000	Continuous active
		8	4000	Continuous active
3	Nitrogen Dioxide (NO_2)	1 hour	200	Continuous active
				Active manually
		24 hours	65	Continuous active
		1 year	50	Continuous active
4	Photochemical oxidants (Ox) as Ozone (O_3)	1 hour	150	Continuous active
				Active manually
		8 hours	100	Continuous active
6	Dust particulates <100 µm (TSP)	24 hours	230	Active manually

No	Parameter	Measurement Time	Quality standards µg/m3	Measurement System
	Dust particulates <10 µm (PM10)	24 hours	75	Continuous active
				Active manually
		1 year	40	Continuous active
	Dust particulates <2.5 µm (PM25)	24 hours	55	Continuous active
				Active manually
		1 year	15	Continuous active
7	Lead (Pb)	24	2	Active manually

Sulfur dioxide (SO_2) is the largest air pollutant component. This gas has the characteristics of being colorless and having a sharp odor, when it reacts with water vapor in the air it will become H_2SO_4 or known as acid rain which can cause damage to materials, objects and plants [13]. The negative impact of these pollutants on humans is respiratory tract irritation and decreased lung function with symptoms of coughing, shortness of breath, and increasing asthma [16]. Based on Material Safety Data Sheet information, exposure to SO_2 gas can cause irritation of the eyes, nose, throat, sinuses, pulmonary edema, and even lead to death [14]. These two pollutant gases, both NO_2 and SO_2, have a negative impact, especially on the respiratory tract, because they enter through the inhalation process. Oxidants are compounds that have oxidizing properties, their effect on health is that they interfere with the respiratory process and can cause eye irritation. Apart from causing detrimental impacts on human health, ozone pollutants can cause economic losses due to materials (textiles, rubber, wood, metal, paint, etc.), decreased agricultural yields and damage to ecosystems such as reduced biodiversity. Particulates are solids or liquids in the air in the form of smoke, dust and vapor with very small diameters ranging from <1 micron-500 microns, which can remain in the atmosphere for a long time. Besides that, small particles in the air can be inhaled into the respiratory system and cause respiratory problems and lung damage. Carbon Monoxide gas is a type of gas that is colorless, odorless, tasteless and does not easily dissolve in water, poisonous and dangerous. This CO gas will interfere with the binding of oxygen to the blood because CO is more easily bound by the blood compared to oxygen and other gases. In cases of blood contaminated with carbon monoxide at levels of 70% to 80% it can cause death in people. Carbon monoxide in the environment can form naturally, but the main source is from human activities. Carbon monoxide comes from natural sources including from the ocean, metal oxidation in the atmosphere, mountains, forest fires and natural electrical storms. Sources of artificial CO include motorized vehicles, especially those that use gasoline as fuel. Based on estimates, the amount of CO from artificial sources is estimated to be close to 60 million tons per year. Half of this amount comes from motorized vehicles that use gasoline and a third comes from non-moving sources such as burning coal and oil from industry and burning domestic waste. Measurement of air temperature in this mining area with an average temperature of 31.4°C with humidity of 54.0%, wind speed of 2.2 m/sec, and air pressure of 722.4 mmHg where the weather at that time was sunny. According to research [16], the higher the air temperature will cause the air to become thinner and the pollutants will be lower. This lower pollutant condition will have more potential to cause respiratory problems because it is closer to the human respiratory tract. Ambient air quality measurements at the mining company were measured in the mining area. This measurement was carried out with the parameters NO_2, SO_2, CO, and O_3 for 1 hour, while for particles (TSP) it was measured for 24 hours. Ambient air is free air on the surface of the earth in the troposphere layer which is needed and influences the health of humans, living creatures, and other environmental elements. Measuring ambient air quality aims to determine the concentration of pollutants in the air. In general, the results of monitoring ambient air quality in the mining area of the mining company showed relatively good results. This is characterized by the absence of parameters that exceed the established quality standards (Table 3).

4. Conclusion

Based on the results of tests carried out at the Yogyakarta Special Region Occupational Safety and Health Center at the mining company area, it can be concluded that the results of monitoring ambient air quality in the mining area show relatively good results. This is characterized by the absence of parameters that exceed the established quality standards, where SO_2 results are 9.39 $\mu g/m^3$, NO_2

results are 4.19 μg/m^3, CO results are 69.74 μg/m^3, O_3 results are 24, 90 μg/m^3, and particle (TSP) results obtained were 133.26 μg/m^3. In this research, it is also necessary to measure ambient air quality based on SO_2, NO_2, CO, O_3, and particulate (TSP) parameters with a longer measurement time based on quality standards to see the status of the mining area to obtain good or dangerous ambient air quality results. for the environment and workers in the mine.

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